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Evaluation of Fungicides against Downy Mildew (*Peronospora destructor* Berk) of Onion (*Allium cepa*) in Bale Zone, South Eastern Ethiopia

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aims: To evaluate the efficacy of tested fungicides against downy mildew of onion and determine the appropriate interval of fungicides application.
Study Design: The experiment was laid out down in randomized complete block design with three replications for each treatments.
Place and Duration of Study: The experiment was carried out in farmers field of Aloshe village; Goba district of Bale zone in 2018/2019 during "Bona Season".
Methodology: Locally available onion variety and two tested fungicides (Mancozeb (Mancozeb 80 Wp) and Ridomil (Ridomil Gold MZ 68WG) were used. Locally available variety of onion was planted in a plot size of 3m x 2.4m with three replications. Each two fungicides were applied at interval of seven day, fourteen and twenty one day interval including unapplied fungicide plot as control.
Results: The result indicated that, both fungicides (Mancozeb and Ridomil) were effectively reduces the severity level of the disease. The higher plant height(42.5cm), bulb weigh (289g), total weight of the bulbs (114Qt/ha) and lower severity (8.35%) were recorded from weekly application of Ridomil, fourteen day application of Ridomil and weekly application interval of Mancozeb. The higher marginal rate of return of 2833.45% and 1999.07% were recorded from weekly and fourteen applications of Mancozeb and Ridomil respectively.
Conclusion: The minimum application frequency of three times of Ridomil in fourteen days and weekly interval application of Mancozeb were effective against downy mildew and profitable.

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Keywords: Downy mildew; Peronospora destructor; onion; fungicide; severity.

1. INTRODUCTION

Onion (*Allium cepa* L) is the most widely cultivated genus of *Allium* which consisting of more than 500 species grown in different parts of the world. Its production is increasing due to its income sources and expanding the irrigation facilities in the world. According to (FAO, 2019) about 22% of onion production in the world is covered by China followed by India and united state of America respectively. In Ethiopia, including Bale zone of accessible irrigation facility; it produced on a large scale as commercial crop which is significantly important in the national economy of the country. Hence, the crop is grown as cash crop by small farmers and commercial growers especially under irrigated condition. Onion plants are used in our daily life for their culinary and non culinary purposes.

However, both biotic and abiotic factors are the major constraints of onion production that leads to losses in both quality and quantity the crops. Among the biotic limiting factors, the disease of downy mildew of onion is the most important pathogenic agent and destructive in temperate as well as humid regions [1]. It is caused by the pathogen called *Peronospora destructor* which is economically important diseases where onions produced in the world [2]. The disease is favored by the presence of moisture in the form of free water from rain or dew on the leaf surface as well as the imbalance application of fertilizer and irrigations leads to the development of this pathogen [3]. In such situations the disease is easily and rapidly spreads for further infection. About 75% bulb losses were recorded due to severe infection of downy mildew [4,5].

Two major stages are involved as sources of inoculum. From infected bulb (primary stage) and Spores from infected leaf (secondary stage). Plants raised from infected bulbs are systemically exposed to infection from which they were remaining stunted, distorted and shriveled in storage. In other sides, the local lesion caused by air borne conidia contributes to secondary infection [6-8]. The lesion produced by conidia (oval to cylindrical shape) may be confused with initial lesions of purple blotch. Older leaves are attacked first and infection spreads to the sheath. Pathogen growth becomes clear on both upper and lower side of leaves under favorable conditions [3].

Different management tactics are used to reduce the sources of infection and spreads of the disease. Among the tactics, using of resistant variety, elimination of infected plants, heat treatment of bulbs and eradication of diseased volunteer plants are recommended for the management of downy mildew of onion [9]. However, the most effective means of controlling the downy mildew is the use of fungicides [9].

Fungicides are either inhibits germination, growth or multiplication of the pathogen [10]. Fungicides such as Antracol, Cuprisan 311-Super D, Dithane M-45, Nemispor, Penncozeb, Sandofan M, Ridomil MZ-71 and Tri- Miltox Forte) were tested against downy mildew of onion [9]. Highly significant control of the disease was obtained with Ridomil MZ-71 WP and Sandofan M followed by Nemispor. other author also Tahir et al. (1990) applied eight fungicides, i.e. Antracol 70 WP, Liromanzeb 80 WP, Daconil 75 WP, Ridomil MZ-72 WP, Duter-WP, Polyram Combi, Tri-Miltox Forte and Cupravit (Tahir et al.;1990). Among these, Antracol 70 WP was the most effective, followed by Ridomil MZ-72 WP. These fungicides increased bulb yield by 8-52% over the control.

Among the management practices adopted by different researchers and farmers, using fungicides is the most popular. In evaluating fungicides against downy mildew, many fungicides are registered for the control of downy mildew of flower and grape in Ethiopia. However, only one fungicide namely Matco (Metalaxayl 8% and Mancozeb 64%WP), is registered for the control of downy mildew of onion. Keeping this idea in mind, this study was aimed at testing of available fungicides against downy mildew of onion.

2. MATERIALS AND METHODS

The experiment was carried out in farmer's field of Aloshe village, Goba districts of Bale zone which located between 39^o 37' 30'' – 40^o 12' 00''E and 6^o 38' 0 '' – 7 ^{o} 4' 0 '' N, South East Ethiopia; during the main cropping season of "Bona season "in 2018/2019 which includes August to December (Yonas and Mashilla, 2012). The area is characterized by bimodal rainfall pattern. The long rainy season extends from March to April with high rain fall during June, July and August. The soil type of the studied area is vertisol types. The field selected due to its hot spot area for the downy mildew infection. Locally available variety of onion and uniform sized bulbs was planted (planting materials). Planting was done on August 15, 2018/2019.

During the onset of the disease, the two fungicides; Mancozeb 80 Wp and Ridomil Gold MZ 68WG were sprayed on experimental plot at the rate of 2.5kg/ha in three different sprays schedules viz., every 7, 14 and 21 days interval starting from the first appearance of the symptom of the disease. Unsprayed plots were included for comparison. There were a total of seven fungicides spray treatments including check plots. Each plot consisted of eight rows of 3m length with a distance of 0.3m and 0.1m between rows and plants, respectively. The treatments were arranged in a randomized block design (RCBD) with three replications. The plots were fertilized with Urea and DAP at the rate of 200kg and 150kg per hectare, respectively.

2.1 Data Collected

Disease severity (%): - was estimated in percentage of the leaf surface covered with lesions. Average severity of the 24 plants per plot was used for statistical analysis.

Plant height (cm):- average height of 16 plants of each plot measured from ground.

Bulb weight (g):- average weight of 16 bulbs from each plot after curing.

Total Yield (t/ha):- yield estimated from the middle six rows (60 plants) of each plot after curing and transformed to tones per hectare. Data on disease severity were recorded after the first appearance of downy mildew symptoms and after each spray, following 1-9 rating scale of [9] presented in Table 1. Area under disease progress curve (AUDPC) was calculated by using the formula of (Shanner and Finney, 1977), to determine the disease progression.

AUDPC= $\sum_{i=1}^{n} 0.5(xi + xi - 1)(ti + ti - 1)$ Shanner and Finney [11] whereas; xi = Present disease severity, xi-1 = Previous disease severity and ti+ti-1 = Time difference between two consecutive disease severities.

All the collected data were fed to computer, cleaned and subjected to GENSTAT 15th edition statistical software.

2.2 Cost-Benefit Analysis

The partial budget analysis was used to analyze the cost of production and benefit of each treatment. In this experiment the sum cost of fungicide, water, and sprayer rent, labor for spraying, water supply and cleaning equipments were considered as total variable cost. Marginal rate of return (MRR) was computed by considering the total variable cost incurred in each treatment. The yield and economic data were collected to compare the efficacy of fungicide application for the management of downy mildew of onion. The MRR was used as major criteria which measures the effect of additional investment on net returns [12]. MRR was calculated as the following formula:

MRR = (DNI/DIC) * 100

Where: - MRR-marginal rate of return, DNI-difference in net income compared with control, DIC- difference in input cost compared with control.

The total income from each treatment was obtained as sale revenue (SR) from the product (yield of onion) and the marginal cost is computed as sum of all production costs that varied and marginal benefit(MB) is calculated as a difference of sale revenue and marginal cost.

3. RESULTS AND DISCUSSION

3.1 Onion Downy Mildew Severity

There was a significant difference of disease severity among the treatments (Table 2). The lowest disease severity value of 8.35% was recorded from a plot treated with Ridomil applied in the interval of seven (7) days followed by fourteen day Ridomil application (14.2%) and weekly application of Mancozeb (19.74%), while the highest level of diseases severity of 74.18% recorded from untreated plot. this result is in line with the works of (F. Raziq et al., 2008) and (Ullah et al*., 2020).* they found the reduced level of infection due to the application of fungicides. The other treatments, where Ridomil and Mancozeb fungicides applied at different intervals, also resulted in lower disease severity than unprotected plot.

3.2 Average Plant Height

Significant differences (P=0.05) were recorded among the different treatments (Table 2). The maximum mean plant height (42.5 cm) was recorded in the treatment with Ridomil applied in every seven days; whereas the minimum (18.2cm) was recorded from check plot.

3.3 Weight of the Bulbs

Data on the weight of onion bulbs revealed significant differences among the treatments (Table 2). Maximum weight of a bulbs (289g) was recorded when Ridomil was applied at weekly interval. The lowest weight (90g) of onion bulbs was recorded when no fungicide was sprayed.

3.4 Total Weight of the Bulbs (Total Yield)

The analyzed data of total weight of the bulbs indicates that, there is a significant difference among the treatments. The higher total weight of the bulbs was obtained from the treatment applied with Ridomil at weekly interval (114Qt/ha), followed by fourteen days application of Ridomil (96.625Qt/ha) and Mancozeb applied at the intervals seven days (84.43Qt/ha). The lower total yield was obtained from unsprayed plot (35.5t/ha).

Area under Disease Progress Curve (AUDPC): Fungicide treatments resulted in lower AUDPC than the unprotected check (Table 2). However, significant differences (P=0.05) were found among the fungicide treatments. The lowest (308days) AUDPC was recorded for plot treated with Ridomil (7R), while the highest (2159 days) AUDPC was recorded from control plot.

Table 1. Assessment key for downy mildew of onion (Mohibullah, 1992)

Key scale	Description	Disease severity (percent)
1	No symptoms	0
2	Only few leaves affected	1
3	Less than half of the plants affected	5
4	Most of the plants affected, attack is restricted to one leaf per plant	10
5	All plants affected, attack restricted to one or two Leaves	20
6	Three to four leaves of each plant affected, crop looks fairly green	50
7	All leaves affected, crop gives blighted appearance	75
8	All leaves severely affected, greenness restricted to central shoot only	90
9	Foliage completely blighted	100

Table 2. Effect of applied fungicides on disease and agronomic parameters

Treatments	Severity percent	Plant height (cm)	Bulb weight (g)	Yield (Qt/ha)	AUDPC (% -days)
7M	19.74ab	36.50c	232.9bc	84.43d	538a
14M	20.39b	30.5b	196.7.0b	52.45c	575a
21M	62.50d	22.05a	106.0a	41.00ab	1818bc
7R	8.35a	42.5c	289.0d	114.00f	308a
14R	14.20ab	38.5c	275.3cd	96.625e	400a
21R	48.68c	29.10b	125.3a	47.35bc	1413b
Ctrl	74.18e	18.20a	90.0a	35.5a	2159c
CV (%)	6.4	3.8	4.5	2.6	8.0
$LSD_{0.05}$	5.56	2.92	20.66	4.28	202.1

Where, 7M- mancozeb applied in every seven days, 14M- mancozeb applied in every fourteen days, 21M- mancozeb applied in every twenty one days, 7R-Ridomil applied in every seven days, 14R- Ridomil applied in every fourteen days, 21R- Ridomil applied in every twenty one days,
Ctrl – unsprayed plot or control plot

3.5 Correlation and Regression Analysis

Pearson Correlation Coefficients of the analyzed parameters indicates that plant height, weight of the bulbs and yield had highly negative correlation with disease severity with coefficient correlation of -0.95,-0.96 and -0.86 respectively (Fig. 1). the disease severity also, high and positively correlated with AUDPC with the coefficient value of 0.99.The values of AUDPC were highly and negatively correlated with plant height, weight of bulbs and yield with the coefficient values of -0.94, -0.95 and -0.85 respectively. This is due to the higher progress rate of the disease results in affecting the yield and yield related parameters of the crop.

To assess the relationship between severity indexes of downy mildew of onion and yield the simple linear regression was employed. This showed significant difference (P=0.001) between treatments. The estimated slope of the regression line obtained for severity index was -1.01. It indicates that for each unit increase in percent severity index of downy mildew, there was onion yield (total weight of the tuber) loss of 1.01 Qt/ha (Fig. 1A). Based on the calculated value of coefficient of determination (R2), the equations explained that about 35% of losses in yield were due to downy mildew severity of onion. Similarly, the estimated slope of the regression line obtained for AUDPC was -0.03. It implies that for each unit increase in AUDPC, there was onion yield (total weight of the tuber) loss of 0.03 Qt/ha (Fig. 1B).

As shown by Table 3, the disease parameters (severity and AUDPC) highly negatively correlated with parameters of weight of bulbs, plant height and yield. The increase in disease severity and area under disease progress curve (AUDPC) directly decrease the weight of bulbs, plant height and total yield of the onion crops. The severity and AUDPC are proportionally correlated each other. The higher the severity, the higher the disease progress obtained.

Downy mildew, which causes tremendous losses to onion, can be effectively controlled through the use of resistant varieties. However, in the absence of host resistance, fungicides can minimize the losses due to pests. Hence, one of the most common means of controlling plant pests in the field is the use of chemicals that are toxic to pathogens [10].

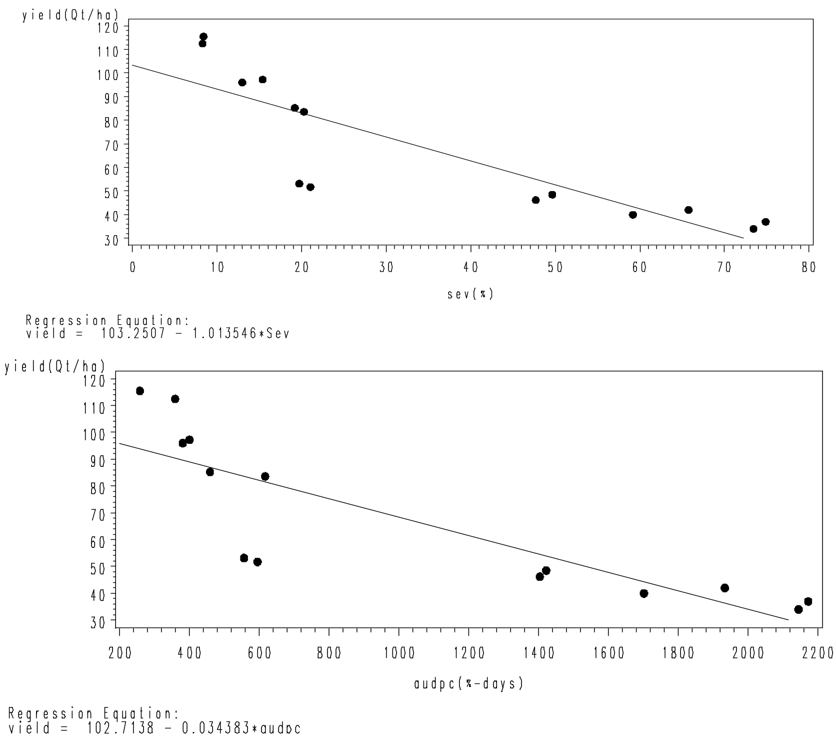

Fig. 1. Estimated relationship between losses in grain yield of onion and Severity index (A), and AUDPC (B)

Table 3. Pair wise Pearson correlation of disease parameters, yield and yield relates of onion

	Severity	Plant height	Weight of bulbs	Total yield	AUDPC
Severity	1				
Plant height	-0.95	1			
Weight of bulbs	-0.96	0.96	1		
Total yield	-0.86	0.94	0.95	1	
AUDPC	0.99	-0.94	-0.95	-0.85	1

Table 4. Total variable cost of fungicides and costs associated with it

Treatment	Fungicide rate kgha^{-1}	Cost (ETB)	sprayer rent	labor cost to spray	labor cost for water supply	Cleaning equipment	Total variable cost
Mancozeb at weekly interval	2.5	3750	225	90	60	45	4170
Mancozeb at 14 days interval	2.5	2500	100	60	40	30	2780
Mancozeb at 21 days interval	2.5	2500	100	60	40	30	2780
Ridomil at weekly interval	2.5	10500	225	90	60	45	10920
Ridomil at 14 days interval	2.5	7000	100	60	40	30	7280
Ridomil at 21 days interval	2.5	7000	100	60	40	30	7280
Unsprayed plot	0	0	0	0	0	0	0

ETB – Ethiopian Birr

Table 5. Cost benefit analysis of fungicides application interval against downy mildew of onion

Treatment	Fungicide used (kg/ha)	yield kgha^{-1}	SR(ETBha^{-1}	MC(ETBha^{-1})	MB(ETB ha^{-1}	MRR (%)
Unsprayed plot	0	3550	88750	0	88750	0.00
Ridomil at 21 days interval	5	4735	118375	7280	111095	306.94
Mancozeb at 21 days interval	5	4100	102500	2780	99720	394.6
Mancozeb at 14 days interval	5	5245	131125	2780	128345	1424.28
Ridomil at weekly interval	7.5	11400	285000	10920	274080	1697.16
Ridomil at 14 days interval	5	9662.5	241562.5	7280	234282.5	1999.07
Mancozeb at weekly interval	7.5	8443	211075	4170	206905	2833.45

SR- Sale revenue, MC-Marginal cost, MB- Marginal benefit, MRR-Marginal rate of return, ETB – Ethiopian birr

The application of fungicides significantly affected the yield by increasing weight of the bulbs. The highest yield was recorded in plot sprayed with weekly application of the two fungicides followed by fourteen days interval application of Ridomil. The maximum yield may be due to higher weight of the bulbs, maximum plant height and less disease severity, which contribute towards the final yield. This is confirmed with the work of F.Raziq et al (2008) and Tahir et al (1990) which they found maximum yield and less severity in plot treated with Ridomil. Other researchers also reported similar trends due to fungicides application (Mohammad Iqbal, 2009; J Abkhoo, 2012 ;). In treatment where no fungicide was applied, bulb yield was the lowest indicating that fungicide application helped in increasing bulb yield.

In the present study, two fungicides were evaluated at different interval of application to determine their effectiveness against downy mildew of onion. The results showed that, the two fungicides were effective in controlling the downy mildew of onion. However, their effectiveness is different as their application intervals are diverse. This is due to the type and mode of action of each fungicide against the host. The fungicide (Mancozeb) is more effective in weekly application interval and Ridomil is effective in both weekly and fourteen days interval application. These fungicides are known to stimulate defense reaction and the synthesis of phytoalexin which, in turn, suppressed the activities of *P. destructor*, and thereby reduced disease severity.

3.6 Cost-Benefit analysis

The partial budget analysis shows that the highest marginal benefit (274080 ETB ha-1) was obtained from a plot sprayed with Ridomil at weekly intervals and fourteen days interval application of Ridomil (234282.5ETBha-1) followed by weekly application of Mancozeb (206905ETBha-1).The lowest (88750 ETBha-1) obtained from unsprayed check (Table 3). From the economic profitability point of view, production of onion crops sprayed with Ridomil and Mancozeb three times at fourteen day intervals and weekly application, respectively is the most profitable option under small holder farmer's condition at the current onion market price.

4. CONCLUSION AND RECOMMENDATION

In the present study, the application of fungicides significantly suppressed the epidemic progress of downy mildew of onion. Among the treatments, the application of Ridomil and Mancozeb at weekly interval was effective in controlling downy mildew of onion followed by fourteen days interval spraying of Ridomil. However, the cost benefit analysis indicates that the application Mancozeb and Ridomil at weekly interval and fourteen days interval respectively, results in higher marginal rate of return (MRR). Therefore, based on biological data and cost benefit analysis, the minimum of three times application of Ridomil and Mancozeb at fourteen day and weekly application respectively is profitable and effective under small holder farmer's condition at the current market price.

In general, for better management of onion downy mildew the spray should be started on the appearance of the disease symptoms and the crop should be sprayed when the weather is clear, as in rainy season, the spray is not effective. Pests like thrips, should be controlled well in time because, these pests is providing sites for the entry of the fungal spores and propagating the disease. For the sustainable productivity, it is better to integrate with other method of management options. For further recommendations, the two fungicides should be tested at several locations.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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