

## Optimizing Onion Productivity in Balochistan: Fungicidal Control of *Fusarium* Basal Rot and Its Impact on Growth and Yield Parameters

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### ABSTRACT

The onion (*Allium cepa* L.) is one of the most important vegetable crops that is cultivated worldwide. It is one of the most important vegetable cash crops of Balochistan with an area of 35.8 thousand ha and a production of 681.5 thousand tonnes. It is attacked by many diseases, which affect the yield. Among onion diseases, the basal rot of onion is one of the most important diseases of onion caused by fungus (*Fusarium oxysporum* f. sp. *cepae*) that causes heavy losses of onion production and its quality worldwide. Keeping in view the economic importance of disease, the current study was carried out at the Directorate of Vegetable Seed Production, Agricultural Research Institute, Quetta, Balochistan. In the greenhouse experiment, plant growth attributes like plant height, number of leaves, leaf length, bulb size, bulb weight, root length, and root weight were significantly increased by all treatments. The Topsin-M was found most effective at all concentrations with the highest plant biomass production and biological yield, as with maximum plant height (72.30 cm), number of leaves (13.00), leaf length (62.23 cm), bulb size (5.45 dia), bulb weight (108.00 g), root length (18.26 cm), and root weight (1.45 g) at a concentration of 1% after 130 days, followed by Cabriotop, Score, and Antracol at 1% doses, respectively. While Mencozeb+ Metalxyl was least effective with plant height (45.63 cm), number of leaves (8.00), leaf length (35.90 cm), bulb size (3.81 dia), bulb weight (64.23 g), root length (8.18 cm), and root weight (0.36 g), at a level of 0.25% after 130 days over the control.

**Keywords:** Onion, Basal rot, *Fusarium oxysporum*, Fungicides, Plant growth attributes.

### INTRODUCTION

Onion (*Allium cepa* L.), locally known as Piaz, belongs to the family Alliaceae. It is one of the most important vegetable crops that is cultivated worldwide. Among vegetables, onion is often called the queen of kitchens because it is used in every kitchen around the world. It has great economic value

as one of the five most important fresh market vegetables worldwide [8].

It has high potential as a foreign exchange earner for many countries, like Pakistan. The world's total production of onion crops is 99.96 million tonnes. China is the world's leading onion-producing country, with the production of 24.96 million tonnes, followed by India with production of 22.81 million tonnes, USA 3.17 million tonnes, Egypt 3.08 million tonnes, and Turkey 2.2 million at ranks second, third, fourth, and fifth, respectively. Pakistan is at number six with the production of 2.05 million tonnes on cultivated areas of 146.1 thousand hectares, which's share globally is only 2.05 percent in terms of yield. Pakistan is very low as it stands at 23<sup>rd</sup> rank, which has 14.02 tonnes /ha as compared to the United States 60.53 tonnes /ha, and the Republic of Korea 73.21 tonnes /ha which is five times greater than Pakistan; however, there is a great potential in Pakistan to increase the production area as well as yield through proper production

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practices and best protection management strategies [8, 10].

In Pakistan, onion crops are grown on a total area of 148 thousand ha with a production of 2.07 million tonnes in year 2018-19. In the province of Punjab, onions are cultivated on an area of 45 thousand ha with a production of 425 thousand tonnes, while in Sindh, onions are cultivated on an area of 55 thousand ha with a production of 745 thousand tonnes. In Balochistan, onions are cultivated in an area of 35.8 thousand ha with a production of 681.5 thousand tonnes, and KPK is cultivated on an area of 119 thousand ha with a production of 223,957 thousand tonnes. In percentage points of view, Sindh produces a high percent nationwide with (35.88%), followed by Balochistan with (32.83%), Punjab with (20.49%), and KPK produces (10.78%), respectively, at second, third, and fourth [19, 24].

The onion (*Allium cepa*) is a vegetable bulb, and it is also called an annual crop. Advanced varieties typically attain heights of about 15 to 45 cm [31]. Onion is the first sown in the nursery and takes 45 to 60 days to transplant. Onion maturity needs 130 to 175 days to mature, but it generally depends on the climatic condition [33]. Onion is a good dietary food as it is rich with carbohydrates, protein, minerals like (phosphorus, calcium, sulfur, potassium, etc., vitamins (vitamin C, A, B<sub>6</sub>), and also a moderate amount of fiber, fat, and protein [4, 18]. It has many other medicinal uses, including anti-inflammatory, anti-cholesterol, anti-cancer, and antioxidant properties; it contains compounds for preventing cataracts, cardiovascular disease, and cancer owing to the presence of hypocholesterolemic, thrombolytic, and antioxidant effects and containing antimicrobial agents (bacteria, fungi) [31, 32].

*Fusarium oxysporum* f. sp. *cepae* causes basal rot of onion, which is one of the most important diseases of onion, causing heavy loss of onion production as it occurred worldwide. Moreover, *Fusarium oxysporum* also attacks other species of *Allium* family, like shallot, garlic, and leek. It is the most destructive in some countries, like USA, Japan, Netherland, causing severe yield losses [9, 11, 30]. The growth of fungus on medium becomes fluffy white colonies. *Fusarium* basal rot of onion caused huge losses in the field as well as in storage; almost 30-40% losses occurred in storage [5]. *Fusarium* basal rot caused 45% yield losses in the field and 12-30% losses in storage [26]. In view of the economic importance of the onion crops and the effect of basal rot disease on yield and quality, there is a need for investigation on effective management of this disease. There are many management techniques for control of plant diseases, e.g., biological control, cultural practices, growing

resistant cultivars, using botanicals, quarantine, and chemical application, etc. [1, 15, 17, 18, 25]. The above management techniques are applied for the control of *Fusarium* basal rot disease of onion, but the disease is still importantly present throughout the world, especially in developing countries like Pakistan. Chemical control is the easiest, quickest, and most effective method to control the *Fusarium* basal rot disease of onion. There is a need to evaluate and find out the best fungicides that may be suitable to control the fungus selectively and in our localities for the control of *Fusarium* basal rot onion disease. Therefore, the current study was carried out to find the effective fungicides on growth attributes against *F. oxysporum* f. sp. *cepae* for the control of basal rot disease in onion crops.

#### MATERIALS AND METHODS

The study was conducted at the Directorate of Vegetable Seed Production, Agricultural Research Institute (ARI), Quetta, Balochistan, during 2021. Evaluated different fungicides against *Fusarium* basal rot disease of onion under greenhouse conditions.

#### Collection of Diseased Samples

Diseased plant samples were observed and collected from the onion field and storage house of Vegetable Seed Production of Agricultural Research Institute, Quetta, and Hazar Ganji market of Quetta, Balochistan. Infected onion samples that were showing typical disease symptoms of *Fusarium* basal rot were examined and selected. These samples were brought to the laboratory of Plant Pathology, Directorate of Vegetable Seed production, ARI Quetta, for further studies.

#### Isolation of Target Pathogen

Some infected tissues were cut into small pieces and surface sterilized with 1% (NaClO) solution for two minutes and then rinsed three times in sterilized water. Then 3 to 5 measuring approximately 5 mm pieces were transferred with the help of sterilized forceps into petri dishes containing sterilized potato dextrose agar (PDA), incubated at 27±1°C, and observed for fungus growth for further identification and purification process. The entire process was done aseptically under controlled conditions. The fungal growth that appeared on the Petri plates was re-isolated, identified, and transferred to potato dextrose agar for further purification process. The pure culture of *Fusarium oxysporum* was multiplied and subcultured in test tubes during the study. In the identification process, fungus was observed under the microscope; thus, isolated fungus from onion tissues was identified based on morphological characters like certain mycelium shape, colony color, colony growth, and spore shape and size [4, 12].

**Table 1: Evaluation of different fungicides against *Fusarium* Basal rot of onion under greenhouse conditions**

Trade Name	Active Ingredients	Chemical Groups	Formulation	Mode of action
Score	Difenoconazole	Difenoconazole	25% EC	Systemic
Cabrio Top	Propineb	Benzimidazole	60% WP	Contact
Antracol	Pyraclostrobin 5% + Metiram 55%	Dithiocarbamate	70% WP	Contact
Topsin-M	Thiophanate-methyl	Thiophanate, Carbamate	70% WP	Systemic
Mencozeb+ Metalaxyle	Mencozeb 64% + Metalaxyle 8%	Phenylamide	72% WP	Contact

This study was carried out under greenhouse conditions to evaluate the efficacy of different fungicides as their names and formulations are mentioned in (Table 1) against the *F. xysporum* f. sp. *cepae*, through Complete Randomized Design (CRD) with three replicates. A spore suspension was made from the twelve-day-old pure culture of the target fungus; pure sterilized water was added to each plate, and then the fungus culture was scratched by using a spatula, and spore/conidial suspension was collected in a cleaned beaker and squeezed through double-layered muslin cloth, and spore concentration was adjusted to a volume of  $(1 \times 10^6)$  spore/ml with the help of a hemocytometer. Seedlings of the susceptible onion variety (Tarich meer) were taken, and seedlings were washed with cleaned water, and surface sterilization was done through 5% sodium hypochlorite, then rinsed properly to remove the residue of sodium hypochlorite. The onion seedling roots were inoculated by immersing them in spore suspension for fifteen minutes. After that, fungicides were applied by the seedling dip method, so the onion seedlings were dipped in required doses of fungicides for an hour. The seedlings inoculated with fungus without treatment of fungicides and un-inoculated without treatments were used as a control. Then seedlings were sown in earthen pots containing sterilized soil under the greenhouse. The plants were visited and observed regularly for symptoms and disease development. All agronomic practices were followed. After 130 days, when foliage growth was stopped and plants reached maturity. Growth parameters like plant height, number of leaves, leaf length, root length, root weight, bulb size, and bulb weight were recorded [2, 3, 6, 7, 26, 28].

#### **Plant Growth Attribute Parameters**

The efficacy of different fungicidal treatments was done on different onion growth parameters like plant height, number of leaves, leaf length, root length, root weight, bulb size, and bulb weight. The data was recorded after 130 days when plants reached maturity. Ten plants were randomly selected, marked, and then data was recorded [6].

#### **Plant Height**

The plant height was recorded in cm on 10 randomly selected plants at the stage of maturity, and the average was calculated.

#### **Number of Leaves**

The numbers of leaves per plant were counted from 10 randomly selected plants, and the average was found out.

#### **Leaf Length**

The leaf length was measured in cm on (randomly selected 5 leaves per plant) from randomly selected 10 plants per treatment and then calculated the average.

#### **Bulb Size**

The bulb sizes in diameter (cm) of ten randomly selected plants per treatment were measured by using a digital Vernier calliper, and average bulb diameter was calculated.

#### **Fresh Bulb Weight (g)**

The single fresh bulb weight of onion was measured on ten randomly selected plants by using an electric balance, and the average of fresh bulb weight was calculated.

#### **Root Length (cm)**

The root length was measured in centimeters on ten randomly selected plants per treatment, and the average of root length was calculated.

### Fresh Root Weight (g)

The fresh root weight of onion was measured on ten randomly selected plants by using an electric balance, and the average of fresh root weight was calculated.

### Statistical Analysis

CRD test was used in the lab and greenhouse. Data were analysed by the analysis of variance (ANOVA), and the significance of differences within treatments was separated by using a test at probability levels  $P < 0.05$  [29].

## RESULTS AND DISCUSSION

### Morphological Identification of the Pathogen

The FOC isolated from onion tissues was identified on the basis of morphological characters like mycelium shape, colony color, colony growth, and spore shape and size. The fungus was filamentous and characteristically produced chlamydospores, microconidia, and macroconidia. Under the microscope, the microconidia were found to be kidney-shaped, round, and oval and without septate as spherical and round, while the macroconidia were slender in shape, straight and slightly curved with medium length with 3 septate. The colony growth on the medium was found flat and scattered, white, fully, and like woolly cotton. The colony color was white, creamy, red violet, and purple, slightly pink. All above characteristics were similar to those results described

by Kalman *et al.*, 2020; Nelson *et al.*, 1994 and Okungbowa1 and Shittu, 2012 [12, 20, 22].

### Effects of Fungicides on Plant Growth Attributes in Greenhouse

In a greenhouse study, the efficacy of different fungicides at different doses was evaluated for the control of *Fusarium oxysporum* f.sp. *cepae* and their effects on plant growth attributes were observed.

### Effects of Fungicides on Onion Plant Height

The results showed that all fungicides at all test concentrations significantly increased the plant biomasses of onion plants over the control, but biomass production was increased with increasing concentration. Results showed that there was a significant difference statistically among fungicides and their doses in onion plant height. The Topsin-M was found most effective with maximum plant height, followed by Cabrio Top, Score, and Antracol, whereas Mencozeb+Metalxyl was found least effective as compared with other fungicides and provided good results when compared with control. The Topsin-M observed was the most effective fungicide, significantly increasing the plant height (72.30, 66.30, and 58.30cm), while Cabrio Top was observed to be the 2<sup>nd</sup> most most effective with plant height (67.36,



Figure 2: Microscopic confirmation of *Fusarium oxysporum* f.sp. *cepae*

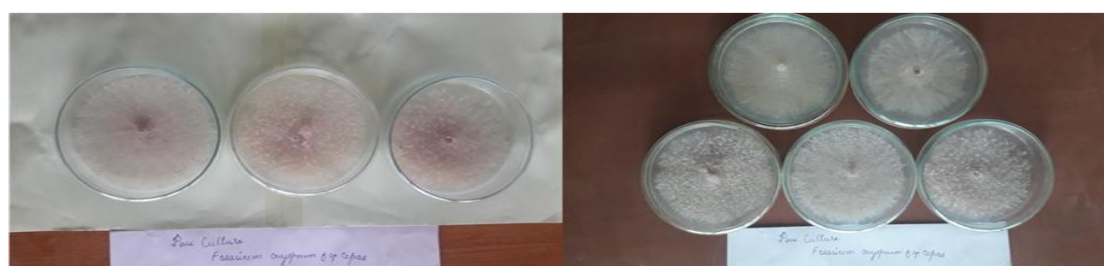


Figure 1: Pure culture of *Fusarium oxysporum* f.sp. *cepae*

**Table 2: Evaluation of different fungicides against *Fusarium oxysporum f.sp cepae* under greenhouse conditions and their effects on (Plant height cm)**

Fungicides	Concentrations (percentage %)			Means
	0.25%	0.50%	1%	
Antracol	49.03 j	57.13 g	60.33 e	55.49 d
Score	52.47 i	59.20 ef	64.06 c	58.57 c
Cabrio- Top	55.33 h	62.30 d	67.36 b	61.66 b
Topsin-M	58.30 fg	66.30 b	72.30 a	65.63 a
Mencozeb+Metalxyl	45.63 k	50.23 j	55.20 h	50.35 d
Control	26.10 l	26.10 l	26.10 l	26.10 f
Mean	47.81 c	53.54 b	57.55 a	

Alpha = 0.05, CV= 2.028

**Table 3: Effects of different fungicides on number of leaves under greenhouse conditions against (*Fusarium oxysporum f.sp cepae*)**

Fungicides	Concentrations (percentage %)			Means
	0.25%	0.50%	1%	
Antracol	8.33 fg	9.00 defg	10.00 cd	9.11 cd
Score	8.66 efg	9.66 de	11.00 bc	9.77 c
Cabrio- Top	9.33 def	11.00 bc	12.00 ab	10.77 b
Topsin-M	11.00 bc	11.66 b	13.00 a	11.88 a
Mencozeb+Metalxyl	8.00 g	8.66 efg	9.33 def	8.66 d
Control	4.66 h	4.66 h	4.66 h	4.66 e
Mean	8.33 c	9.111 b	10.000 a	

Alpha = 0.05, CV= 2.028

**Table 4: Evaluation of different fungicides against *Fusarium oxysporum* f.sp *cepae* under greenhouse conditions and their effects on (Leaf length cm)**

Fungicides	Concentrations (percentage %)			Means
	0.25%	0.50%	1%	
Antracol	39.16 i	46.36 fg	49.90 e	45.14 d
Score	42.30 h	48.83 e	53.46 c	48.20 c
Cabrio- Top	43.56 h	51.46 d	56.46 b	50.50 b
Topsin-M	47.16 f	55.53 b	62.23 a	54.97 a
Mencozeb+Metalxyl	35.90 j	40.13 i	45.46 f	40.50 d
Control	20.10 k	20.10 k	20.10 k	20.10 f
Mean	38.03 c	43.73 b	47.93 a	

Alpha = 0.05, CV= 2.028

**Table 5: Evaluation of different fungicides against *Fusarium oxysporum* f.sp *cepae* under greenhouse conditions and their effects on onion (Bulb size dia cm)**

Fungicides	Concentrations (percentage %)			Means
	0.25%	0.50%	1%	
Antracol	4.04 i	4.62 f	4.84 d	4.50 d
Score	4.19 hi	4.82 de	5.10 bc	4.70 c
Cabrio- Top	4.43 g	4.98 cd	5.21 b	4.87 b
Topsin-M	4.65 ef	5.26 b	5.45 a	5.12 a
Mencozeb+Metalxyl	3.81 j	4.33 gh	4.62 f	4.25 d
Control	1.80 k	1.80 k	1.80 k	1.80 f
Mean	3.82 c	4.30 b	4.50 a	

Alpha = 0.05, CV= 2.028

62.30, and 55.33 cm), followed by Score (64.06, 59.20, and 52.47 cm), Antracol (60.33, 57.13, and 49.03 cm), and Mencozeb+Metalxyl (55.20, 50.23, and 45.63 cm), at concentrations of (1%, 0.50%, and 0.25%), while Mencozeb+Metalxyl was found least effective with minimum plant height (45.63 cm) at a dose of (0.25%) over the control (26.100), while on

the contrary maximum plant height (72.30 cm) was obtained from Topsin-M at a concentration of (1%) over the control. In comparison with the control (26.10), all treatments significantly increased the plant height at all doses, but Topsin-M at a rate of 1% found best in (Table 2).

### Effects of Fungicides on Number of Leaves

The results showed that there was a significant difference statistically among all fungicides and their concentrations in the number of onion leaves. The Topsin-M was found to be the most effective fungicide on the maximum number of leaves, followed by Cabrio Top, Score, and Antracol, while Mencozeb+Metalxyl found to be the least effective as compared with other fungicides over the control. The Topsin-M found was the most effective fungicide, significantly increasing the numbers of leaves (11.00, 11.66, and 13.00) at concentrations (0.25%, 0.50%, and 1%), respectively, while Cabrio Top was found to be the 2<sup>nd</sup> most effective with the number of leaves (9.33, 11.00, and 12.00), followed by Score (8.66, 9.66, and 11.00), Antracol (8.33, 9.00, and 10.00), and Mencozeb+Metalxyl (8.00, 8.66, and 9.33) at their respective doses over the control (4.66) (Table 3).

The results of the current study indicated that Topsin-M was found to be the most effective fungicide with the maximum number of leaves (13.00) at a dose of 1%, while on the contrary, the minimum number of leaves (8.00) was obtained at a concentration of 0.25% over the control (4.66). In comparison with the control, all treatments significantly increased the number of leaves at all concentrations, but Topsin-M at the highest dose of 1% provided the best results. The results revealed that all treatments at all test concentrations significantly increased the leaf numbers of onion plants over the control; however, by increasing the concentrations, the numbers of leaves were also increased.

### Effects of Fungicides on Onion Leaf Length

Statistically, Topsin-M was found to be the most effective on maximum leaf length, followed by Cabrio Top, Score, Antracol, and Mencozeb+Metalxyl, respectively, over the control. The result indicated that Topsin-M was proved most effective among fungicides, having a significant effect on the plant leaf length with maximum (62.23, 55.53, and 47.16cm), leaf length at concentrations (1%, 0.50%, and 0.25%), respectively, while Cabrio Top was found at 2<sup>nd</sup> with leaf length (56.46, 51.46, and 43.56cm), followed by Score (53.46, 48.83, and 42.30 cm), Antracol (49.90, 46.36, and 39.16cm), and Mencozeb+Metalxyl (45.46, 46.36, and 39.16cm) at concentrations of (1%, 0.50%, and 0.25%) separately, over the control (20.10cm).

Mencozeb+Metalxyl recorded the minimum leaf length (35.90 cm) at the lowest concentration (0.25%), while on the other hand, the maximum leaf length (62.23cm) was observed from Topsin-M at the highest concentration (1%) over the control (20.10cm). In comparison with the control (20.10cm), all treatments significantly increased the plant leaf length at all test

doses, but Topsin-M at a rate of 1% provided the best result. The data expressed that fungicides had a significant effect on onion leaf length at all concentrations. The results revealed that all fungicides at all test concentrations significantly increased the plant biomasses of onion plants (leaf length) over the control, but leaf length was tremendously increased through increasing fungicide concentrations as shown in (Table 4).

### Effects of Fungicides on Onion Bulb Size

The Topsin-M was found most effective on bulb size, followed by Cabrio Top, Score, Antracol, and Mencozeb+Metalxyl correspondingly, when compared with the control. The Topsin-M found was the most effective fungicide, significantly increasing the onion bulb size (4.65, 5.26, and 5.45 dia cm) at concentrations of (0.25%, 0.50%, and 1%), respectively, whereas Cabrio Top stood at 2<sup>nd</sup> with bulb size (4.43, 4.98, and 5.21 dia cm) followed by Score (4.19, 4.82, and 5.10 dia cm), Antracol (4.04, 4.62, and 4.84 dia cm), and Mencozeb+Metalxyl (3.81, 4.33, and 4.62 dia cm) at their respective doses, which were statistically significant with each over the control (1.80 dia cm) in (Table 5). The results revealed that there was a significant difference statistically among all fungicides and their concentration on bulb size diameter.

The outcomes of the present study indicated that Topsin-M was found to be the most effective fungicide with maximum bulb size (5.46 dia cm) at a dose of (1%), while on the contrary, the minimum bulb size (3.81 dia cm) was recorded from Mencozeb+Metalxyl at a concentration of (0.25%) over the control (1.80 dia cm). In comparison with the control, all treatments significantly increased the bulb at all concentrations, but Topsin-M at the highest dose (1%) found to be the best by providing the best result. The outcomes of the study revealed that all test fungicides at all test concentrations significantly increased the bulb size of onion plants over the control; however, by comparing the doses, the higher doses were found to be greatly effective in encouraging the bulb size and plant biomass production, so it was observed that higher doses of fungicides have significant effects on *Fusarium* basal disease as compared to the moderate and lowest concentrations, resulting in increased plant biomass.

### Effects of Fungicides on Bulb Weight

Statistically, among all treatments, Topsin-M was found to be highly efficient by increasing the bulb weight, followed by Cabrio Top, Score, Antracol, and Mencozeb+Metalxyl, respectively, compared with the control. The results expressed that the minimum bulb weight was recorded in untreated control with (15.07g), whereas among fungicides,

Mencozeb+Metalxyl was found least effective with minimum bulb weight (64.23g) at its lowest concentration (0.25%) and (89.00g) at the highest dose (1%), when compared with others. Topsin-M was found most effective with maximum bulb weight (108.00g) at the highest concentration (1%) and (88.97g) at the lowest (0.25%) concentration. In comparison with the control (15.07g), all treatments significantly increased the bulb weight at all test concentrations, but Topsin-M at the highest dose was proved to be the best.

The result indicated that Topsin-M was proved most successful among fungicides, having a significant effect on the bulb weight with maximum (108.00, 104.90, and 88.97g) bulb diameter at concentrations (1%, 0.50%, and 0.25%), respectively, whereas Cabrio Top was found to be the 2<sup>nd</sup> with bulb weight (103.47, 99.13, and 81.07g), followed by Score (100.07, 96.10, and 74.33g), Antracol (95.17, 89.20, and 71.30g) and Mencozeb+Metalxyl (89.00, 85.17, and 64.23 g) at concentrations of (1%, 0.50% and 0.25%), respectively, over the control (15.07g) (Table 6).

It was observed that treatments had a significant effect on onion bulb weight at all concentrations. It was found that all fungicides at all test doses significantly increased the onion bulb weight over the control, but

bulb weight was tremendously increased through increasing fungicide concentrations, so it was found that there was a significant correlation between the concentrations of fungicides and plant biomass production.

**Effects of Fungicides on Onion Root Length** The data correlated with root length in (Table 7) showed that there was a significant difference statistically among all chemicals and their tested concentrations on root length. Statistically, the Topsin-M was observed to be the most effective with maximum root length, followed by Cabriotop, Score, Antracol, and Mencozeb+Metalxyl correspondingly, when compared with the control. The Topsin-M found was the most effective fungicide, significantly increasing the root size (12.56, 16.13, and 18.26cm) at concentrations (0.25%, 0.50%, and 1%), respectively, whereas Cabrio Top was the 2<sup>nd</sup> most effective fungicide with root length (10.61, 13.90, and 15.46), followed by Score (10.16, 12.56, and 15.20), Antracol (8.96, 11.30, and 12.63), and Mencozeb+Metalxyl 8.18, 10.11, and 11.86 cm) at their respective doses, which were statistically significant with each other over the control (2.68cm). The Topsin-M was found to be the most effective fungicide with a maximum (1.8033).

**Table 6: Evaluation of different fungicides against *Fusarium oxysporum* f.sp *cepae* under greenhouse conditions and their effects on onion (Bulb weight gram)**

Fungicides	Concentrations (percentage %)			Means
	0.25%	0.50%	1%	
Antracol	71.30 i	89.20 e	95.17 d	85.22 d
Score	74.33 h	96.10 d	100.07 c	90.17 c
Cabrio- Top	81.07 g	99.13 c	103.47 b	94.56 b
Topsin-M	88.97 e	104.90 b	108.00 a	100.62 a
Mencozeb+Metalxyl	64.23 j	85.17 f	89.00 e	79.47 d
Control	15.07 k	15.07 k	15.07 k	15.07 f
Mean	65.82 c	81.59 b	85.12 a	

Alpha = 0.05, CV= 2.028

**Table 7: Evaluation of different fungicides against *Fusarium oxysporum* f.sp *cepae* under greenhouse conditions and their effects on onion (Root length cm)**

Fungicides	Concentrations (percentage %)			Means
	0.25%	0.50%	1%	
Antracol	8.96 hi	11.30 efg	12.63 cd	10.96 c
Score	10.16 gh	12.56 de	15.20 b	12.64 b
Cabrio- Top	10.61 fg	13.90 c	15.46 b	13.32 b
Topsin-M	12.56 de	16.13 b	18.26 a	15.65 a
Mencozeb+Metalxyl	8.18 i	10.11 gh	11.86 def	10.05 d
Control	2.68 j	2.68 j	2.68 j	2.68 e
Mean	8.86 c	11.11 b	12.68 a	

Alpha = 0.05, CV= 2.028

**Table 8: Evaluation of different fungicides against *Fusarium oxysporum* f.sp *cepae* under greenhouse conditions and their effects on onion (Root weight g)**

Fungicides	Concentrations (percentage %)			Means
	0.25%	0.50%	1%	
Antracol	0.43 hi	0.58 fg	0.74 de	0.58 d
Score	0.51 gh	0.78 d	1.01 c	0.76 c
Cabrio- Top	0.56 fg	0.97 c	1.15 b	0.89 b
Topsin-M	0.75 de	1.24 b	1.45 a	1.14 a
Mencozeb+Metalxyl	0.36 i	0.53 fgh	0.65 ef	0.51 d
Control	0.13 j	0.13 j	0.13 j	0.13 e
Mean	0.46 c	0.70 b	0.85 a	

Alpha = 0.05, CV= 2.028

root length (18.26cm) at a dose of (1%), while the minimum root length was recorded in the control (2.68cm), by comparing the fungicidal treatments, the minimum root length (8.180cm) was recorded from Mencozeb+Metalxyl at a concentration of (0.25%). In comparison with the control, all treatments significantly increased the bulb at all concentrations, but Topsin-M at higher concentrations had great effects on root length by providing the best result as

shown in (Table 7). The outcomes of the study revealed that all test fungicides at all test concentrations significantly boosted the root length of onion plants over the control; however, by comparing the doses, the higher doses were found to be greatly effective in encouraging the root length.

#### **Effects of Fungicides on Roots Weight**

The results indicated that there was a statistically significant difference among treatments and all their

doses on the weight of onion roots. Among all treatments, statistically, Topsin-M was found to be highly efficient by increasing the root weight, followed by Cabrio Top, Score, Antracol, and Mencozeb+Metalxyl, correspondingly. The findings of this study revealed that minimum root weight was recorded in untreated control with (0.13g), whereas among fungicides, Mencozeb+Metalxyl was found least effective with minimum root weight (0.36g) and followed by Antracol with (0.43g) at the lowest concentration (0.25%), respectively, when compared with other treatments. Topsin-M was found most effective with maximum root weight (1.45g) and (1.24g) at (1%) and (0.50%) respectively. In comparison with the control (0.13g), all treatments significantly increased the root weight at all test concentrations.

The Topsin-M was found the most successful among fungicides having great effects on the onion root weights with maximum (1.45, 1.24, and 0.75g) root weight at concentrations (1%, 0.50%, and 0.25%), separately whereas Cabrio Top was found in the second position with root weight (1.15, 0.97, and 0.56g) followed by Score (1.01, 0.78, and 0.51g), Antracol (0.74, 0.58, and 0.43g) and Mencozeb+Metalxyl (0.65, 0.53, and 0.36 g) at doses of (1%, 0.50%, and 0.25%), respectively, over the control (0.13g) in (Table 8).

Treatments significantly affected onion root weight. All fungicides at all test concentrations significantly increased onion root weights over the control, but increasing test concentrations of fungicides significantly increased bulb weights (Table 8).

The results of this study are in conformity with previous findings of researchers Abbas *et al.*, 2014; Khafagi *et al.*, 2020; Khalequzzaman and Monjil, 2020; Maitlo *et al.*, 2014; Nizamani *et al.*, 2018; Poussio *et al.*, 2021; and Somu *et al.*, 2014, who demonstrated different fungicides against *Fusarium* wilt diseases and found Topsin-M and Cabrio Top to be effective fungicides against *Fusarium oxysporum f. sp. cepae* and other *Fusarium* wilt diseases of vegetables [1, 13, 14, 16, 21, 23, 27].

Similar findings of the current study were shown by Poussio *et al.* (2021) who conducted an experiment to test the efficacy of ten different fungicides *in vitro* and in greenhouse conditions against the *Fusarium* wilt disease. They found the Topsin-M to be the most effective fungicide with maximum shoot length (27.66cm) and shoot weight (2.2 cm) at the highest concentration, followed by Cabrio Top, Nativo, and carbendazim, whereas Antracol and Prevail were found to be less effective. The Topsin-M was also found effective with maximum root length and root weight, followed by Cabriotop and Carbendazim.

They revealed that fungicides were most effective at higher doses by promoting the plant biomass production as compared to moderate and lowest concentrations [23].

The results of this study are consistent with Raju *et al.* (2008) who reported different fungicides against *Fusarium* wilt; among them, Carbendazim and Topsin-M were found to be the most effective fungicides, with 100% inhibiting the fungus growth at higher doses followed by Thiram. On the other hand, Dithane Z-78 and Captan were observed as the least effective fungicides [24].

The outcomes of the present study are in line with Maitlo *et al.* (2014) who evaluated 14 different fungicides against *Fusarium* wilt disease *in vitro* and in greenhouse conditions. Among fourteen fungicides, they found Thiophanatemethyl, Carbendazim, Native, Score and Aliette, were effective fungicides; the remaining were the least effective among them. Metalaxyl + Mancozeb was included which had the least effective inhibition percent of 16.5% at 100 ppm and 63.12% at the highest 1000 ppm. Carbendazim was found to be the most effective fungicide, followed by Thiophanate-methyl, Nativo, and Score, but Carbendazim at higher doses of 100 and 1000 ppm caused high phytotoxicity with zero plant growth. Thiophanate-methyl was only found effective at all its concentrations without phytotoxicity. Thiophanate-methyl and Carbendazim were found to be the most effective with minimum disease development and maximum shoot length, shoot weight, root length, root weight, and yield, followed by Nativo and Score [16].

## CONCLUSION

In this study, the pathogen was isolated and identified on the basis of morphological characters. In greenhouse experiment the Topsin-M was found to be the most effective at all concentrations with highest plant biomass production in plant growth attributes as with maximum plant height (72.30 cm), number of leaves (13.00), leaf length (62.23 cm), bulb size (5.45 dia), bulb weight (108.00 g), root length (18.26 cm), root weight (1.45 g) at concentration of 1% after 130 days followed by Cabriotop, Score and Antracol (at 1% doses respectively while Mencozeb+ Metalxyl was least effective with minimum plant height (45.63cm), number of leaves (8.00), leaf length (35.90 cm), bulb size (3.81 dia), bulb weight (64.23 g), root length (8.180 cm), root weight (0.366 g), and disease severity on scale (5.66) at level of 0.25% over the control.

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