EVALUATION OF FUNGICIDES FOR CONTROLLING DOWNY MILDEW OF ONION UNDER FIELD CONDITIONS

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ABSTRACT

Efficacy of ten fungicides, viz Aliette, Antracol, Benlate, Cobox, Daconil, Derosal, Dithane, Polyram, Ridomil and Topsin-M, was tested at Tarnab Farm, Peshawar, in 2006 against a destructive disease of onion, downy mildew caused by *Peronospora destructor* Berk. Each of the fungicides was sprayed three times at an interval of 10 days following appearance of the disease symptoms. All the fungicides were found to be effective in controlling the disease. Ridomil was the most effective in reducing the disease severity and enhancing yield, followed by Topsin-M, Aliette and Antracol. Sprays with Ridomil also resulted in the least number of dead plants, greatest plant height, most abundant leaves per plant, and largest number and weight of medium, large and total bulbs. The use of these fungicides is recommended in an integrated control strategy, incorporating other methods such as resistant varieties and prudent cultural practices.

Keywords: Downy Mildew, *Peronospora destructor*, Fungicides, Chemical control.

INTRODUCTION

Downy mildew of onion, caused by the fungus *Peronospora destructor* Berk, is worldwide in occurrence and causes devastating economic losses to the crop (Cook, 1932; Viranyi, 1974). The pathogen attacks various kinds of onion, but is especially destructive to the common onion, i.e. *Allium cepa*. If leaf damage is severe, bulb development is markedly retarded and as a result, a large number of "bottle-necked" onion bulbs develop (Rondomanski, 1967).

Butler and Jones (1955) reported that the disease attacks the plants at all stages of growth and all parts of the plant may be invaded. The disease occurs in two stages: the primary stage (when infected bulb is planted) and the secondary stage (when a healthy plant at leaf stage becomes infected from spores produced by primary stage.

Plants raised from infected bulbs are infected systemically. These remain stunted, distorted and light green in colour. Under humid weather conditions, grayish violet downy growth of the fungus can be seen on the entire leaf surface. Systemically infected bulbs become soft and shrivelled in storage. Local infection is caused by air-borne conidia which produce oval to cylindrical spots. Lesions look violet to purple and may be confused with initial lesions of purple blotch. Older leaves are attacked first and infection spreads to the sheath. Affected leaves become pale green, fold over and collapse. When leaves are attacked in the middle, these droop from the point of infection. On seed stalks, circular or elongated lesions are produced and infected stalks break over from the weight of the seed umbel, thereby causing the seed to shrivel. The fungus also infects floral parts and may be carried with the seed. In dry weather, the fungal growth disappears and spots thin out, but the fungus may reappear when favorable conditions prevail again (Gupta and Paul, 2001).

The pathogen requires presence of moisture in the form of free water from rain or dew on the leaf surface for the rapid spread of the disease. For the initiation of infection, the pathogen requires cool temperature (less than 22˚C) and relative humidity greater than 95%. Cloudy days also favour the development of disease because 8 hours of light is lethal to sporangia (Gupta and Paul, 2001).

Measures to reduce sources of infection and prevent spread of disease are of great importance in controlling onion during mildew. Elimination of infected plants, heat treatment of bulbs and eradication of diseased volunteer plants are recommended for the control of the disease. However, currently the most effective means to control downy mildew is the use of fungicides. These fungicides either inhibit germination, growth or multiplication of the pathogen (Agrios, 1997). Mohibullah (1992) used several fungicides (Antracol, Cuprisan 311-Super D, Dithane M-45, Nemispor, Penncozeb, Sandofan M, Ridomil MZ-71 and Tri-Miltox Forte) against downy mildew of onion. Highly significant control of the disease was obtained with Ridomil MZ-71 WP and Sandofan M followed by Nemispor. 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. Among these, Antracol 70 WP was the most effective, followed by Ridomil MZ-72 WP. These

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fungicides increased bulb yield by 8-52% over the control. Testing of the available fungicides is essential for selecting the most effective and cost-effective ones. In the present study, several fungicides were evaluated under field conditions to find effective and economical fungicides for the control of this important disease.

MATERIALS AND METHODS

The experiment was conducted at Agricultural Research Institute, Tarnab, Peshawar, during 2006. Onion variety Swat-1 was planted in rows six m long and 25 cm apart. Different fungicides (Table I) were used along with an untreated check. Each treatment was applied to two adjacent rows in a randomized complete block design and replicated four times.

Raising of Nursery and Transplantation of Seedlings

Seed of the variety was sown in nursery beds prepared from well-manured soil. Fifty days after sowing, uniform and healthy seedlings were transplanted to the field. Farm yard manure, super phosphate and ammonium sulphate were applied at the time of land preparation at the recommended dose rate of twenty carts, 200 kg and 100 kg $acre^{-1}$ respectively. Urea was applied after the establishment of seedlings and 30 days after the transplantation, using a dose rate of 80 kg $acre^{-1}$. Irrigation and other cultural practices were done as usual.

Inoculum Collection and Inoculation

The inoculum of downy mildew was collected from the neighboring area and its identity confirmed by microscopic examination at Agricultural Research Institute, Tarnab, Peshawar. The infected leaves were crushed and a suspension was made with distilled water following the method of Gilles *et al*. 2004. The suspension was filtered through muslin cloth. The debris was held in the cloth and the fungal spores in the distilled water were sprayed on onion plants after adjusting spore concentration at 1×10^4 sporangia ml^{-1} with the help of a haemocytometer. The inoculation was done early in the morning when the prevailing temperature and relative humidity were conducive for infection.

Treatments

At the appearance of the disease symptoms, the scheduled spray programme was started at an interval of 10 days. The fungicides in Table I were sprayed on the crop.

Data Recording and Analysis

Data were taken on the following parameters: disease severity, plant height, number of leaves per plant, number and weight of small, medium and large size bulbs. Data on disease severity were recorded after the first appearance of downy mildew symptoms and after each spray, following 1-9 rating scale of Mohibullah (1992) presented in Table II. Area under disease progress curve (AUDPC) was calculated by using the formula of Shaner and Finney (1977) to determine the disease progression.

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

Whereas

x_i = Present disease severity

x_{i-1} = Previous disease severity

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

Yield data were recorded at the time of harvest of the crop. All the data were subjected to analysis of variance (ANOVA) and least significant difference (LSD) test to determine differences among the different treatments.

RESULTS AND DISCUSSION

Disease Severity

Significant differences in disease severity were observed among the different treatments (Table III). The lowest disease severity value of 13.13% was recorded in treatment with Ridomil, while the highest value of 68.75% was in the unprotected check. The other treatments, where different fungicides were sprayed, also resulted in lower disease severity than the unprotected check.

Area under Disease Progress Curve (AUDPC)

Fungicide treatments resulted in lower AUDPC than the unprotected check (Table III). However, significant differences ($P < 0.05$) were found among the fungicide treatments. The lowest (137.5) AUDPC was recorded for plants treated with Ridomil, while the highest (466.6) AUDPC was recorded for treatment Daconil. These treatments showed 81.24% and 36.36% lower AUDPC values, respectively, than the unprotected check.

Percentage of Infected Leaves

Significant differences ($P<0.05$) were recorded among the different treatments (Table IV). The minimum percentage (39.54%) of infected leaves was recorded in Ridomil treated plants, while the maximum percentage (82.58%) of infected leaves was recorded in the unprotected check.

Total Number of Leaves

Significant differences among different treatments were recorded (Table IV). The maximum number of total leaves (72) occurred on plants treated with

Ridomil or Aliette whereas the minimum number of total leaves (27) was observed in the unprotected check where no fungicide was applied.

Average Number of Dead Plants
Significant differences were found among the different treatments (Table IV). The lowest average number of dead plants (2.75) was observed in treatment Ridomil. The highest average number of dead plants (19.00) was recorded in treatment where no fungicide was applied.

Average Number of Living Plants
There were significant differences ($P<0.05$) among the different treatments (Table IV). Application of Topsin-M gave the maximum average number of living plants while the lowest average number of living plants was recorded in the unprotected check.

Average Plant Height
Significant differences ($P<0.05$) were recorded among the different treatments (Table V). The maximum mean plant height (28.79 cm) was recorded in the treatment with Ridomil, whereas the minimum (15.16 cm) was in the unprotected check.

Number of Small Bulbs (<3 cm Diameter)
Significant differences ($P<0.05$) were observed among the different treatments (Table V). The highest (11.75) number of small bulbs was in the treatment where Ridomil was applied while the unprotected check gave the lowest (2.00) number of small bulbs.

Weight of Small Bulbs
Data on the weight of small bulbs revealed significant differences among the treatments (Table V). Maximum weight of small bulbs (0.17 kg) was recorded in treatments Ridomil and Topsin-M. The lowest weight of small bulbs (0.05 kg) was recorded in the unprotected check.

Number of Medium Bulbs (3-5 cm)
Significant differences were found among the different treatments (Table V). The highest mean number of medium bulbs (63) was observed in the treatment where Ridomil was applied. This fungicide gave 101.60 % increase over the unprotected check where only 31.25 medium bulbs were registered.

Weight of Medium Bulbs
Application of Ridomil gave the maximum weight (2.50 kg) of medium size bulbs (Table V). The lowest weight (1.37 kg) was obtained in the unprotected check where no fungicide was sprayed.

Number of Large Bulbs (>5 cm)
Significant differences were registered among the different treatments (Table VI). The highest (31) number of large bulbs was recorded in the treatment Ridomil, while the lowest number (11.50) of large bulbs was recorded in the unprotected check.

Weight of Large Bulbs
Data on the weight of large bulbs showed significant differences among the treatments (Table VI). Maximum weight of the large bulbs (2.57 kg) was recorded in treatment Ridomil, whereas the lowest weight of large bulbs (1.02 kg) was recorded in the unprotected check.

Total Number of Bulbs
The application of Ridomil gave the maximum (105.8) number of bulbs (Table VI) which was 136.42% more than the lowest number of 44.75 bulbs obtained from the unprotected check where no fungicide was sprayed.

Total Weight of Bulbs
Data on the total weight of onion bulbs revealed significant differences among the treatments (Table VI). Maximum total weight of all onion bulbs (5.25 kg) was recorded when Ridomil was applied. The lowest weight (2.40 kg) of onion bulbs was recorded when no fungicide was sprayed.

Downy mildew, which causes tremendous losses to onion every year, can be effectively controlled through the use of resistant varieties. However, in the absence of resistant cultivars, fungicides can minimize the disease losses. One of the most common known means of controlling plant diseases in the field is through the use of chemical compounds that are toxic to the pathogens (Agrios, 1997).

In the present study, several fungicides were evaluated to determine their effectiveness against downy mildew. The results showed that Ridomil was the most effective, followed by Topsin-M, Aliette and Antracol. These chemicals either inhibit germination, growth and multiplication of the pathogen or are outright lethal to the pathogen (Agrios, 1997).

The results indicated that the treatment of plants with fungicides showed lower disease severity and higher yield than those where no such treatment was applied (untreated check). Consequently, yield loss in the treated plots was lesser than the untreated plots. It is assumed that the application of these chemical compounds reduced the incoming inoculum by killing the sporangia received regularly during the growing period of the crop. However, if the crop was

not sprayed with fungicides, the inoculum spread very quickly on the surface of the host plant and infected most of the foliage. Yield obtained from such plants was less on account of damage to most of the photosynthetic area.

In this study, the application of all the fungicides significantly reduced the disease severity and consequently increased yield in the fungicide treatments as compared to the unprotected check. However, the minimum disease severity was recorded in the treatment Ridomil (13.13 %) follwed by Topsin-M (20.00 %) and Aliette (22.50 %), while maximum disease severity (68.75 %) was observed in the untreated plot. Similar results were obtained by Teviodale *et al*. (1980) testing eleven fungicides. He found Ridomil as the most effective against *P. destructor,* on both bulb and seed crop of onion. Mohibullah (1992) reported that out of seven fungicides used, highly significant control of the disease was obtained with Ridomil and Sandofan M followed by Nemispor.

The application of fungicides significantly affected the yield by increasing number and size of onion bulbs. The highest yield was recorded in plot treated with Ridomil. This was followed by the plots treated with Topsin-M and Aliette. The maximum yield may be due to the more number of leaves, maximum plant height and less disease severity, which contribute towards the final yield. Tahir *et al.* (1990) concluded that Ridomil and Antracol increased bulb yield by 52 and 42 %, respectively. Other workers also reported similar trends due to fungicides application (Palti, 1989; Loss and Stenina, 1975; and Teviodale *et al.*, 1980). In treatment where no fungicide was applied, bulb yield was the lowest indicating that fungicide application helped in increasing bulb yield.

These fungicides are known to stimulate defense reactions and the synthesis of phytoalexin which, in turn, suppressed the activities of *P. destructor*, and thereby reduced disease severity. This led to increased plant height, development of more leaves and greater number of medium and large sized onion bulbs.

CONCLUSION AND RECOMMENDATIONS

The application of fungicides minimized the downy mildew attack and consequently increased yield. Application of fungicide Ridomil at the rate of 2.5 g/litre, followed by Topsin-M and Aliette, each at the rate of 2.5g/litre, were comparatively more effective than the other fungicides in reducing downy mildew severity and increasing yield. An interval of 10 days between the sprays was found to be effective in controlling the disease.

On the basis of this study, at least three sprays of fungicides Ridomil, Topsin-M, Aliette or Antracol should be made for the control of downy mildew in onion. These fungicides should be used as part of an integrated control strategy, incorporating resistant varieties and prudent cultural practices.

The spray should be started on the appearance of the disease symptoms, especially if weather conditions are conducive to the development of the disease. The crop should be sprayed when the weather is clear, as in rainy season, the spray is not effective.

To avoid the spread of the disease, pests like thrips should be controlled well in time, because these pests injure the plants, thus providing sites for the entry of the fungal spores and propagating the disease.

Table I. ***Fungicides and their doses used in the study***

S.No.	Fungicides	Dosage (g L^{-1})
1	Aliette (fosetyl-Al)	2.5
2	Antracol (propineb)	3
3	Benlate (benomyl)	2.5
4	Cobox (copper oxychloride)	4
5	Daconil (chlorothalonil)	2 ml
6	Derosal (carbendazim)	1
7	Dithane (mancozeb)	2.5
8	Polyram (metiram)	2.5
9	Ridomil (metalaxyl + mancozeb)	2.5
10	Topsin-M (thiophanate methyl)	2.5
11	Only distilled water (control)	

Table II. ***Assessment key for downy mildew of onion***

Scale	Description	% Intensity
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

Mohibullah, 1992

Table III. ***The effect of different fungicides on disease severity and area under disease progress curve (AUDPC) of downy mildew infected onion plants.***

Treatment	Mean disease severity (%)	Mean value of AUDPC
Aliette	22.50 fg	237.5 def
Antracol	27.50 ef	295.8 cde
Benlate	29.38 e	295.8 cde
Cobox	36.25 cd	379.2 bcd
Daconil	43.44 b	466.6 b
Derosal	38.75 bc	400 bc
Dithane	30.31 de	429.1 bc
Polyram	33.13 cde	362.5 bcde
Ridomil	13.13 h	137.5 f
Topsin-M	20.00 g	220.8 ef
Check	68.75 a	733.3 a
$LSD_{(0.05)}$	6.247	140.00
C.V. (%)	13.10	22.84

Figures in the same column followed by different letters are significantly different from one another at 5 % level of probability.

Table IV. ***The effect of different fungicides on the percentage of downy mildew infected and total leaves and mean number of dead and living onion plants per treatment.***

Treatment	% infected leaves	Mean number of total leaves	Mean number of dead plants	Mean number of living plants
Aliette	44.72 cd	72.00 a	5.50 de	16.75 cd
Antracol	54.17 c	61.00 bc	3.25 f	17.75 bc
Benlate	71.02 ab	51.75 cde	7.25 cd	20.00 abc
Cobox	69.22 b	48.75 de	7.50 cd	21.25 ab
Daconil	78.58 ab	58.75 bcd	9.00 c	19.50 abc
Derosal	77.04 ab	48.25 e	8.75 c	19.75 abc
Dithane	75.45 ab	55.25 bcde	12.50 b	21.00 ab
Polyram	73.10 ab	63.25 ab	8.75 c	19.50 abc
Ridomil	39.54 d	72.00 a	2.75 f	20.50 ab
Topsin-M	41.06 d	71.00 a	3.75 ef	22.75 a
Check	82.58 a	27.00 e	19.00 a	14.25 d
$LSD_{(0.05)}$	11.20	9.46	2.11	3.061
C.V. (%)	12.07	11.46	18.29	10.95

Figures in the same column followed by different letters are significantly different from one another at 5 % level of probability.

Table V. ***The effect of different fungicides on the average onion plant height and number and weight of small and medium size bulbs of onion plants.***

Treatment	Mean plant height (cm)	Mean number of small bulbs	Mean weight of small bulbs (kg)	Mean number of medium bulbs	Mean weight of medium bulbs (kg)
Aliette	24.01 bc	6.25 bcd	0.10 ab	51.00 b	1.92 bcd
Antracol	23.37 bc	7.50 abc	0.11 ab	53.75 ab	2.05 bcd
Benlate	21.48 c	6.00 bcd	0.10 ab	51.70 b	1.87 bcd
Cobox	21.02 c	5.75 bcd	0.10 ab	50.00 b	1.82 d
Daconil	21.64 c	7.00 bc	0.10 ab	55.00 ab	1.95 bcd
Derosal	20.53 c	6.25 bcd	0.10 ab	54.25 ab	2.02 bcd
Dithane	22.45 c	6.50 bcd	0.10 ab	61.00 ab	2.20 abc
Polyram	23.03 c	3.75 cd	0.05 b	52.00 b	1.85 cd
Ridomil	28.79 a	11.75 a	0.17 a	63.00 a	2.50 a
Topsin-M	26.90 ab	8.75 ab	0.17 a	59.50 ab	2.22 ab
Check	15.16 d	2.00 d	0.05 b	31.25 c	1.37 e
$LSD_{(0.05)}$	3.371	4.29	0.09	9.54	0.31
C.V. (%)	10.34	45.78	63.65	12.49	11.08

Figures in the same column followed by different letters are significantly different from one another at 5 % level of probability.

Table VI. ***The effect of different fungicides on the number and weight of large size and total onion bulbs per treatment.***

Treatment	Mean number of large bulbs	Mean weight of large bulbs (kg)	Mean total number of bulbs	Mean total weight of bulbs (kg)
Aliette	22.75 b	2.02 b	80.00 bcd	4.05 bc
Antracol	20.75 b	1.85 b	82 bc	4.01 bcd
Benlate	20.00 bc	1.72 b	77.50 bcd	3.70 bcde
Cobox	14.00 cde	1.05 c	69.75 d	2.95 f
Daconil	13.00 de	1.10 c	75.00 cd	3.15 ef
Derosal	17.75 bcde	1.45 bc	78.25 bcd	3.75 cde
Dithane	17 bcde	1.55 bc	84.50 bc	3.85 bcd
Polyram	19.00 bcd	1.52 bc	74.75 cd	3.42 def
Ridomil	31.00 a	2.57 a	105.8 a	5.25 a
Topsin-M	20.00 bc	1.82 b	88.25 b	4.22 b
Check	11.50 e	1.02 c	44.75 e	2.40 g
$LSD_{(0.05)}$	5.74	0.54	10.30	0.54
C.V. (%)	21.15	23.29	9.12	10.15

Figures in the same column followed by different letters are significantly different from one another at 5 % level of probability.

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