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Research Paper

A comprehensive study of the status and strategic management of downy mildew of onion (*Allium cepa* L.) in Kashmir Valley

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ABSTRACT

Onion, one of the most important commercial vegetable crops is affected by the most destructive disease known as Downy mildew. It is the most serious and devastating disease of the onion seed crop in the temperate zones of Jammu and Kashmir, limiting the quality and quantity of both bulb and seed. The disease occurs year after year in epiphytotic form taking lion's share of the produce. Therefore, detailed investigations were undertaken with the objectives to record disease incidence and severity in different districts of Kashmir valley and also devise suitable management strategies with chemicals and botanicals. Survey the year 2020, revealed that the disease was prevalent in Kashmir valley ranging from 30.90 to 37.65 per cent. The highest disease incidence was recorded in district Budgam (35.09%) and minimum in district Srinagar (23.73%). The severity ranged from 13.12 to 15.2 per cent, maximum in district Budgam (14.88%) and minimum in district Srinagar (9.99%). The pathogen was identified on the basis of morphological features as *Peronospora destructor* (Berk.) Casp. Ex Berk. Sporangiophores were dichotomously branched with size varying from 122-820 × 7-18 µm and pyriform/ fusiform sporangia measuring 53.6-62.8 µm in length and 24.8-25.0µm in width. Efficacy study of different fungicides and botanicals revealed that amongst the fungicides two formulations Metalaxyl 4% + Mancozeb (64%) 68n WG, followed by Metiram 55% + Pyraclostrobin 5% 60 WG (74.04%) were most efficacious, while of the tested botanicals, extract of *Allium sativum* (Garlic) proved to be the most efficient with disease control of 44.39 per cent followed by *Rheum emodi* (Rhubarb) (41.14%).

Key words: Botanicals, downy mildew, fungicides, management, *peronospora destructor*

The name onion is derived from a Latin word, unio, signifying "one huge pearl", and Chinese call it the "gem among vegetable" (Anonymous, 2015). Onion (*Allium cepa* L.) is a bulbous, monocotyledonous, herbaceous plant bearing linear hollow fleshy cylindrical green leaves and umbels of small white flowers, which mature into three celled capsular fruits containing small black seeds. Onion is an economic crop which is not just used for domestic consumption but also is one of the highest foreign exchange earners among the agricultural products. The major onion growing countries are China, India, USA, Iran and Russian federation (Anonymous, 2016). Onion is grown worldwide over an area of 2, 43,591 hectares, with a total production of 51, 34,362 million tonnes (Anonymous, 2017. India ranks first in acreage and second in production, next to China (Mahajan *et al.,* 2018). The total area under onion in India is 12.70 lakh hectares with an annual production of 215.63 lakh

tonnes (Anonymous, 2017a). In Jammu and Kashmir state, onion is cultivated commercially on an area of 2.85 thousand hectares with a total production of 65.27 thousand tonnes (Anonymous, 2017a) In spite of favorable environmental conditions for onion cultivation, the production of crop is affected by various insect pests, nutritional disorders and diseases. Among a number of production constraints, the frequent and widespread occurrence of certain dreaded diseases such as downy mildew, Purple blotch, Stemphyllium blight, are noteworthy (Sharma and Sharma, 2002). Under ideal disease conditions these diseases cause severe damage to the crop and result in huge annual losses. Among these, Downy mildew is the most serious and devastating disease of onion in the temperate zones of J&K and has been reported for the first time in India from Kashmir valley in 1975 (Mir, 1976), limiting the quality and quantity of both bulb and seed. Since then, the disease has been occurring year after year in epiphytotic form taking lion's share of the produce. Due to the significant role onions play in the agricultural economy and food security of the region, a study was undertaken to assess the status of downy mildew disease across various districts of the Kashmir Valley and to develop effective management strategies. This research involves evaluating the disease's prevalence and impact, as well as testing different chemical and botanical treatments to control its spread. By identifying effective solutions, the study aims to safeguard onion crops, thereby supporting local farmers and contributing to the region's agricultural stability and food security.

MATERIAL AND METHODS

The investigation was undertaken during the year 2020 in the laboratory and experimental field of Division of Plant Pathology, Faculty of Agriculture, SKUAST- Kashmir, Wadura. Field survey of commercially important vegetable growing belts in the districts of Srinagar (Central Kashmir), Budgam (Central Kashmir) and Baramulla (North Kashmir) was carried out during autumn (November) and spring (April) of 2019-2020. In Budgam district, the locations surveyed included Narkara, Bogam, and Chadoora. In Baramulla district, the surveyed locations were Nathipora, Arampora, and Wadura. For Srinagar district, the locations included Mujgund, Noorbagh, and Tengpora. The disease incidence and intensity were assessed using a 1-9 scale as proposed by Mohibullah (1991).

Disease incidence was calculated as per the formula:

$$\text{Disease incidence (\%)} = \frac{\text{No. of diseased plants}}{\text{Total No. of plants examined}} \times 100$$

For determining the severity of downy mildew, forty plants from each field were randomly selected and five such observations per field were recorded. Grading of the disease was done as per the modified 1-9 scale of Mohibullah (1991) where:

Disease intensity scale by Mohibullah (1991)

Grade	Description
1	No Symptoms
2	Only few leaves affected
3	Less than half of plants affected
4	Most of the plants affected, attack is restricted to 1 leaf/ plant
5	All plant affected, attack is restricted to 1-2 leaf/ plant
6	3-4 leaves of each plant affected, crop looks fairly green
7	All leaves affected. Crop gives blighted appearance
8	All leaves severely affected. Greenness restricted to central shoot only
9	Foliage completely blighted

The disease intensity was calculated using the formula:

$$\text{Disease intensity (\%)} = \frac{\text{Sum of all numerical ratings}}{\text{Total No. of ratings} \times \text{Maximum grade value}} \times 100$$

Symptomatology: Symptoms were recorded on tagged onion plants under natural epiphytotic conditions. Diseased plants displaying symptoms were collected and brought to the laboratory. Infected leaves with characteristic symptoms were thoroughly examined under a microscope to detect the presence of sporangia, mycelia, and sporangiophores. Morphological characteristics, including hyphal septation, sporangiophore branching, and the size and shape of sporangia of the downy mildew pathogen, were recorded as per the guidelines suggested by Murphy and McKay (1926).

Pathogenicity test: For the pathogenicity test, sporangia were collected from the surfaces of infected leaves of field-raised plants using a camel-hair brush and suspended in sterilized distilled water for subsequent experiments. To confirm the pathogenicity of Peronospora destructor, the spray and drop inoculation method was employed on forty-five-day-old plants (Chen and Wang, 2005). The leaf surfaces to be inoculated were initially sterilized with 2% sodium hypochlorite for 15 seconds and then wiped with a cotton pad soaked in distilled water (Abd-Elrazik and Lorbeer, 1980). The spore suspension was then sprayed and dropped onto healthy onion leaves. Following inoculation, the plants were placed in a greenhouse, with a suitable control maintained. The incubation period was calculated using the formula i = ts – ti.

Management: The management of the disease was approached using various chemicals and botanicals. The preparation of the plant extracts involved several steps: First, the selected plants were dried both at room temperature and in an oven at 70°C for 4-6 hours. Once dried, the plants were ground into a fine powder. This powdered plant material was then mixed with distilled water and placed in a shaker incubator at 75°C and 500 rpm for 6 days. Following the incubation, the mixture was filtered through Whatman filter paper no. 1. The filtrate was then evaporated in an oven at 60°C until all the solvent had been removed.

The resulting residue was dissolved in sterilized distilled water to create a stock solution, from which a concentration of 2000 ppm of the extract was prepared (Kumar and Singh, 2017). A field trial was conducted during the Rabi season of 2019-20 at the Faculty of Agriculture, SKUAST-K, Wadura. The experiment was arranged in a Randomized Complete Block Design (RCBD), with each treatment replicated three times and a control included. The field was divided into raised beds, each measuring 1m × 1m, with spacing of 20 cm × 15 cm. Fungicides were sprayed at their recommended concentrations immediately after the first disease symptoms appeared, with a total of three sprays applied at fortnightly intervals. Observations on disease severity were recorded at 7-day intervals. In the control plots, seeds were treated with sterile water only. Data from these experiments was subjected to statistical analysis using standard procedures as outlined by Gomez and Gomez (1984) and Panse and Sukhatme (2000).

RESULTS AND DISCUSSION

Survey for the disease status: With a view to find out the status of downy mildew of onion in Kashmir valley, the survey was carried out in three districts *viz.,* Srinagar, Budgam and Baramulla during autumn 2019 and spring 2020 (Fig.1). Highest disease incidence (41.34%) was recorded at Qaisarmulla (district Budgam) and the lowest (14.27%) at Batamalloo (district Srinagar). Amongst the districts, highest disease incidence was recorded in district Budgam (35.09%) followed by district Baramulla (33.89%) while as the district Srinagar exhibited the least disease incidence (21.43%).

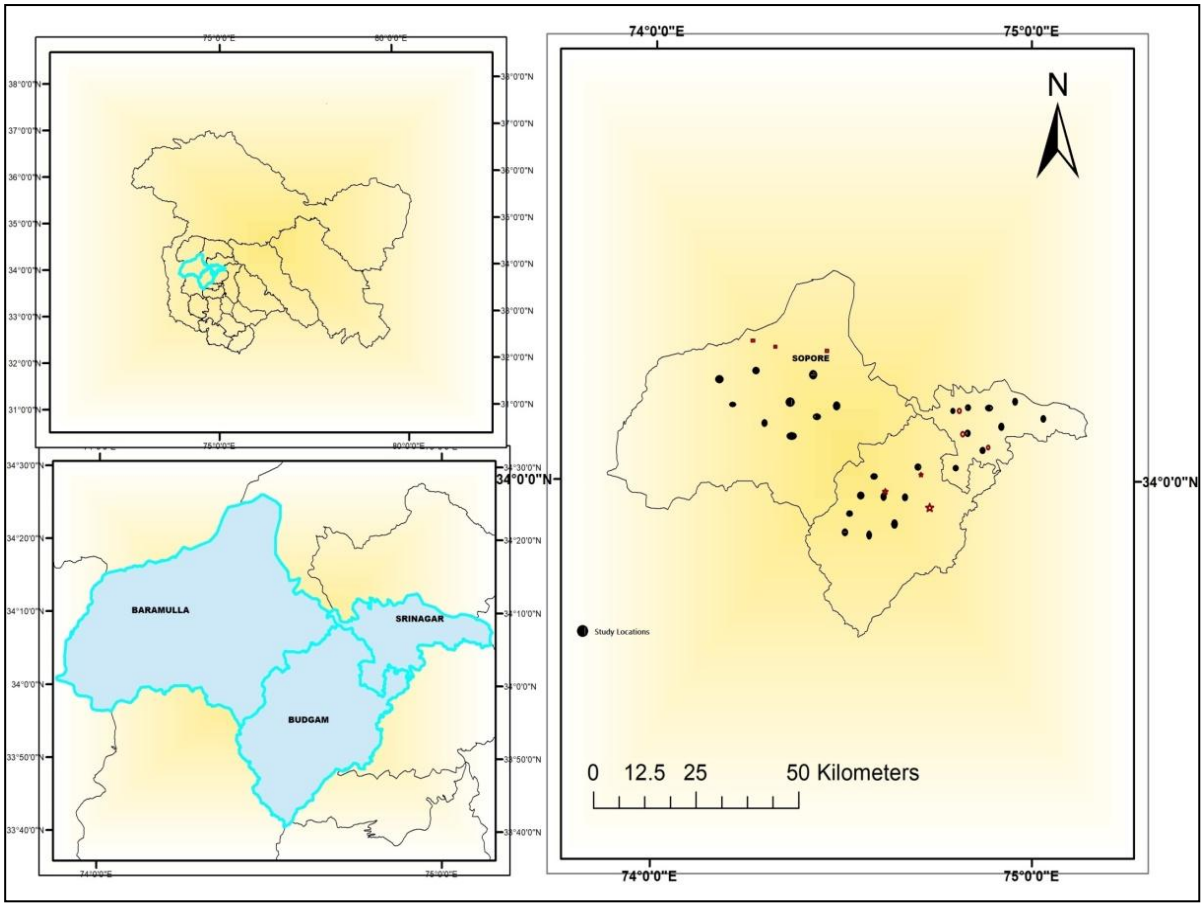


Fig. 1: Locations surveyed for recording status of downy mildew disease of survey map of selected location of Kashmir Valley for disease status

The data on disease incidence is presented in Table 1 and Figure 2. Additionally, disease incidence was observed at different locations, with intensity levels ranging from 6.20% to 18.32%. Highest disease intensity (18.32%) was recorded at Qaisarmulla (district Budgam) and the lowest (6.20%) was recorded at Batamalo (district Srinagar).

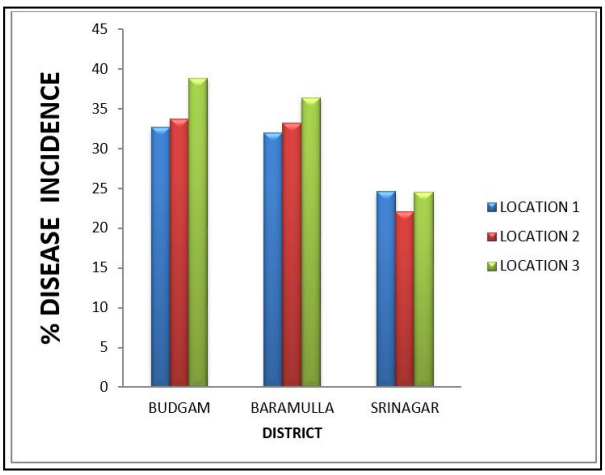


Fig 2: Incidence of Downy mildew of onion (*Peronospora destructor*) in Kashmir valley during the year 2019-20

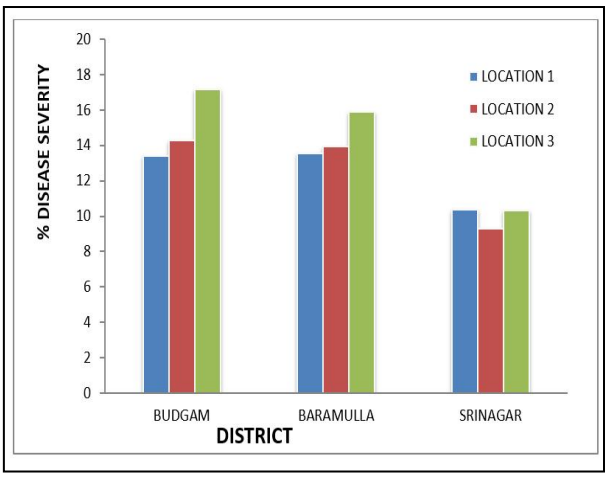


Fig 3: Severity of Downy mildew of onion (*Peronospora destructor*) in Kashmir valley during the year 2019-20

Table 1: Incidence of downy mildew of onion (*Allium cepa*) in different districts of Kashmir during the year 2019-2020

District	Location	Site	Disease incidence (%)*	95% C.I**
Budgam	Narkara	Ompora	38.79	
		Sebdan	29.00	
		Narkara	30.33	
	Bogam	Batpora	31.93	
		Nowbugh	33.33	
		Bogam	35.78	
	Chadoora	Badipora	37.30	
		Dawlatpora	38.00	
		Qaisarmulla	41.34	
		Sub mean	**35.09**	**29.00-41.34**
Baramulla	Nathipora	Wahipora	32.00	
		Yunsuu	32.73	
		Nathipora	31.33	
	Arampora	Arampora	30.63	
		Chinkipora	30.67	
		Takyabal	38.40	
	Wadura	Payeen	39.98	
		Balaa	35.19	
		Malagunipora	34.00	
		Sub mean	**33.89**	**30.63-39.98**
Srinagar	Mujgund	Mujgund	24.63	
		Maloora	25.27	
		Panznoar	24.00	
	Noorbagh	Qamarwari	27.69	
		Noorbagh	21.96	
		Pallipora	16.51	
	Tengpora	Batamalo	14.27	
		Tengpora	16.30	
		Danderkah	22.30	
		Sub mean	**21.43**	**14.26-27.97**
		Overall mean	**30.14**	

The data pertained to the disease incidence is presented in Table 2, Fig 3. Statistical analysis of the surveyed data revealed that the limits for average disease intensity in districts fluctuated between 10.80 to 18.32 per cent for Budgam, 12.22 to 17.58 per cent for Baramulla and 6.2 to 15.92 per cent for Srinagar. During a survey, it was observed that farmers in the Budgam district cultivate onion crops in fields with inadequate drainage and closer plant spacing. Data indicated that both disease incidence and intensity were notably higher in areas where dew persisted for extended periods during the winter season. The severity of the disease has been reported to be extremely high, with incidences reaching up to 100 percent in various parts of the world (Palti, 1989; Bashi & Aylor, 1983; Kennedy, 1998). It has worldwide presence and is becoming more significant in temperate regions

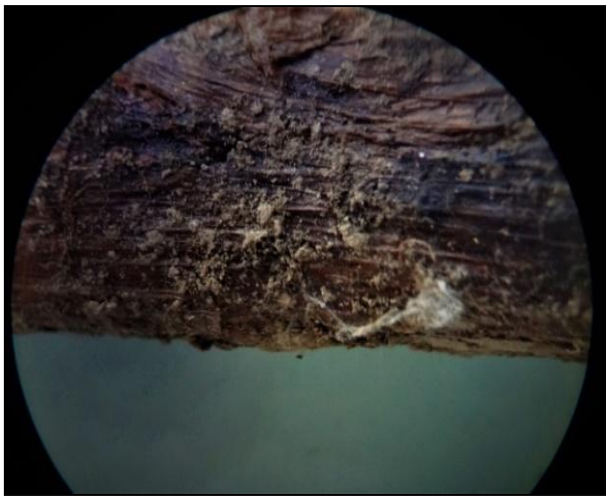
(Domingues and Tofoli, 2009). The spread of this pathogen is global (Agrios, 1995; Brewster, 2001) and greatly affects the crop yields by more than 60% (Surviliene *et al.,* 2008).

Symptomatology: The symptoms exhibited by downy mildew affected onions comprised of circular or elliptical lesions which looked like a mechanical injury with white sunken and roughened lesions. Such lesions were only seen on one side of the stalk of onion. The infected leaves were light green and the tip was seen to die back in the form of necrosis and curling.

Fig. 4 : Symptoms of downy mildew of onion on leaves (A,B, E, F) and Bulbs (C, D)

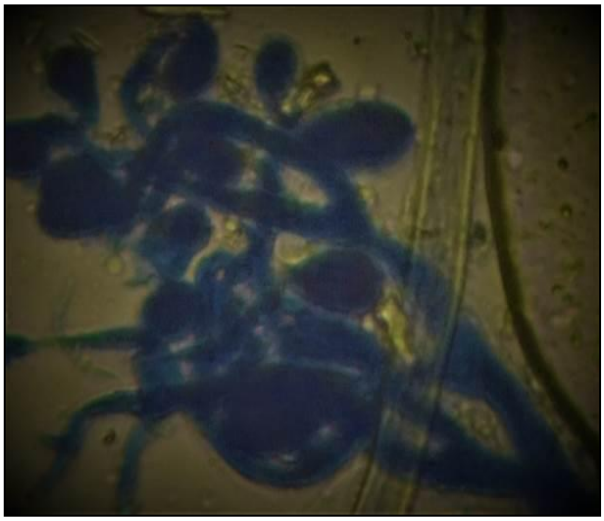
The lesions became necrotic accompanied by girdling and collapsing of that portion of leaf that contributed to hanging of leaf stalk from the point of necrosis. Similar kind of symptoms were reported by many workers (Maude, 1990; Schwartz and Mohan, 1995; Sharma *et al.,* 2002; Gonzalez *et al.,* 2010). Severe infection was seen on many onion bulbs which caused few bottleneck bulbs. The pathogen P. destructor affected the bulb development and reduced the yield thereby minimizing not only the yield but also the quality of the bulbs. Scholten *et al.* (2007) has also observed similar kind of symptoms on bulbs that caused reduction in quality and yield of the onion crop. Symptomatology of the diseased plant is shown in Fig. 4.

Pathogen identification: Downy mildew on onion leaves is characterized by circular or elliptical lesions that initially appear white, slightly sunken, and roughened (Fig.5). These lesions are primarily found on older leaves, typically on one side of the stalk. Over time, the lesions develop into grey downy masses and, following heavy rains, may turn purple. Prolonged infection leads to necrosis of the affected area. The downy growth consists of sporangia and sporangiophores with characteristic branching. Systemic infection occurs when plants are infected at a young stage, resulting in stunting, defoliation, and necrosis, which ultimately cause tissue death. Affected leaves appear light green with tip die-back, necrosis, and curling. Severe infestation leads to girdling and collapse of the leaf portion, causing the leaf stalk to hang from the point of necrosis. Downy mildew also affects bulb development, reducing yield as infected bulbs are smaller and less developed compared to healthy ones (Fig.5).

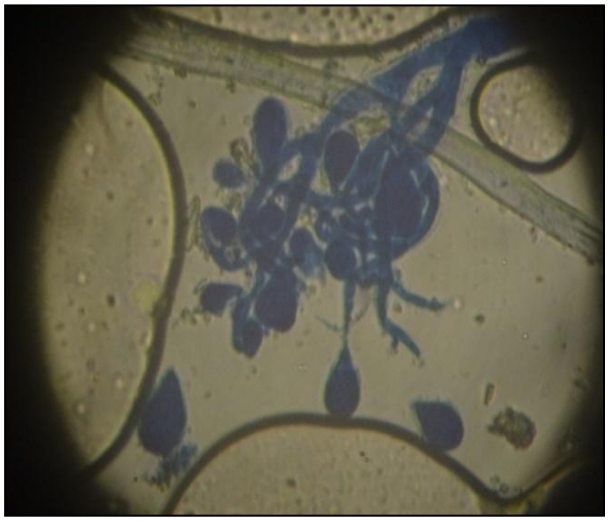


Mycelium

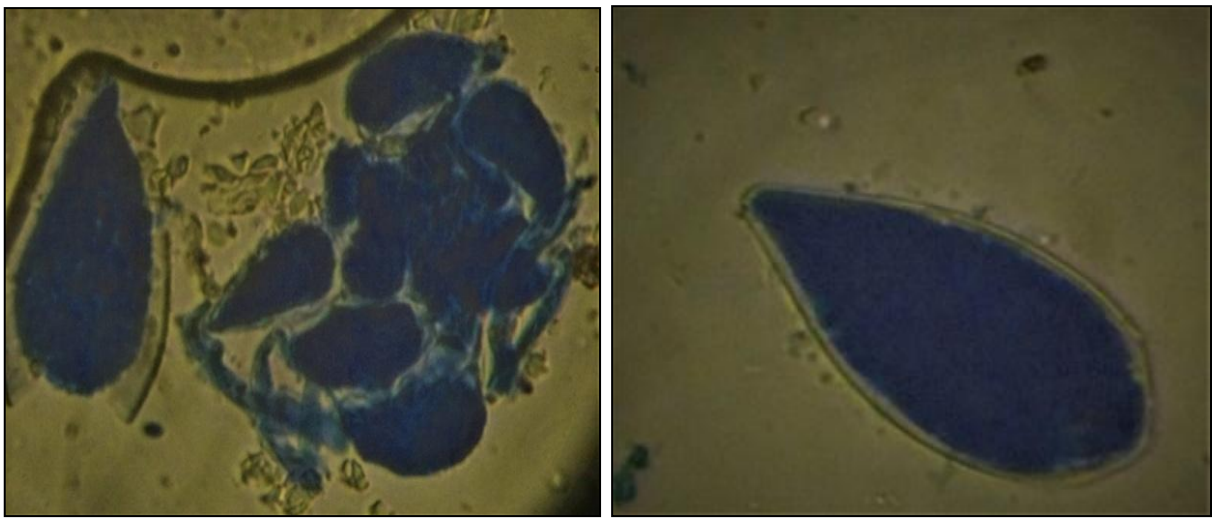
B. Mycelium



C. Sporangiophore



D. Sporangiophore



E. Sporangia F. Sporangia

Fig. 5: Morphological characteristics of *Peronospora destructor* causing downy mildew disease of onion

Systemically infected bulbs become soft, shriveled, and watery, with symptoms primarily visible in storage onions. Severe infection of the aerial parts of the plant can result in bottleneck bulbs. The quality and size of the bulbs are significantly compromised. Additionally, affected plant tissues are further colonized by other bacterial or fungal pathogens.

The microscopic examination of the fungus revealed that the size of sporangiophores varied greatly. (Fig. 5) The size varied from 122-820 × 7-18.0µm. The sporangiophores were dichotomously branched. The size of sporangia ranged from 53.56-62.8× 24.8-25.0 µm. The shape of the sporangia was pyriform to fusiform and the colour was hyaline. On the basis of explained morphological characters the pathogen was identified as Peronospora destructor (Berk.) Casp.ex Berk. The above findings were well supported by the work of Langston and Sumner (2000) and Goker *et al.* (2007).

Pathogenicity test: The typical symptoms of downy mildew were produced after 12 days of incubation. (Fig. 6). Such observation has also been reported by Develash and Sugha (1997b). The latency period until the development of new sporulation ranges from 9 to 16 days (Yarwood, 1943; Van Doorn, 1959; Maude, 1990; Schwartz and Mohan, 1995).

Table 2. Chemicals used for the management of downy mildew of onion (*Allium cepa*)

S. No.	Chemicals	Concentration
1.	Mancozeb 75WP	0.3%
2.	Cymoxanil 72WP	0.2%
3.	Kresoxim Methyl 40SC	0.04%
4.	Metiram (55%) + Pyraclostrobin (5%) 60 WG	0.1%
5.	Metalaxyl 75 WP	0.25%
6.	Zineb 80 WP	0.2%
7.	Copper Oxychloride 50WP	0.25%
8.	Metalaxyl (4%) + Mancozeb (64%) 68WG	0.2%
	Control (Untreated)	

Management of disease using botanicals and chemicals: During the management studies of the disease by various chemicals and botanicals, it was observed that all the treatments restrained the disease incidence and intensity to a level significantly lower than that of the control and enhanced the yield appreciably in the experimental field. In order to study the effect of different fungicides on management of downy mildew disease, eight fungicides (mancozeb, cymoxanil, kresoxim methyl, metiram + pyraclostrobin, metalaxyl, zineb, copper oxychloride and metalaxyl+ mancozeb) were evaluated under field conditions against downy mildew amongst which metalaxyl 4%+ mancozeb 64% 68 WG @ 0.2% proved the most effective by showing the highest disease control (75.57%) followed by metiram 55% + pyraclostrobin 5% 60 WG @ 0.1% (74.04%), metalaxyl 75 WP @ 0.25% (73.01%), mancozeb 75 WP @ 0.3% (70.53%), zineb 80 WP @ 0.2% (70.38%), kresoxim methyl 44.3SC @ 0.04% (67.36%), cymoxanil 72 WP@ 0.2% (55.94%%) and copper oxychloride 50WP @ 0.25% with lowest disease control (45.68%).

Table 3. Botanicals used for the management of downy mildew of onion (*Allium cepa)*

S. No.	Botanicals	Part used	Concentration
1.	*Dioscorea*	Leaf	2000 ppm
2.	*Rheum Emodi*	Corm	2000 ppm
3.	*Allium sativum*	Clove	2000 ppm
4.	*Mentha piperita*	Leaf	2000 ppm

Among different botanicals tested for the management of downy mildew of onion, *Allium sativum* extract @ 2000 ppm proved to be best biocide with 44.39 per cent disease control followed by *Rheum emodi* @ 2000 ppm (41.14%), *Mentha piperita* @ 2000ppm (36.91%) and the least effective being *Dioscorea* spp. @ 2000 ppm (35.44%). (Table 4, Fig. 7).

Fig. 6. Pathogenicity test of *Peronospora destructor* on potted onion plants

Table 4:Field efficacy of fungicides for downy mildew of onion (*Allium cepa*)

S. No.	Treatments	Conc. (%)	Disease severity (%)	Disease control (%)	Comparison
1.	Mancozeb 75WP	0.3	8.27 (2.87)	70.53 (46.05)	AB
2.	Cymoxanil 72WP	0.2	12.39 (3.52)	55.94 (33.84)	C
3.	Kresoxim methyl 40SS	0.04	9.19 (3.03)	67.36 (43.04)	B
4.	Metiram (55%) + pyraclostrobin (5%) 60WG	0.1	7.30 (2.70)	74.04 (49.24)	AB
5.	Metalaxyl 72WP	0.25	7.56 (2.75)	73.01 (48.30)	AB
6.	Zineb 80WP	0.2	8.34 (2.89)	70.38 (34.60)	AB
7.	Copper oxychloride 50WP	0.25	15.22 (3.90)	45.68 (26.69)	D
8.	Metalaxl (4%)+ Mancozeb (64%)	0.2	6.86 (2.62)	75.57 (50.75)	A
9.	*Dioscorea spp*	2000ppm	8.01 (4.24)	35.44 (20.03)	E
10.	*Rheum emodi*	2000ppm	6.53 (4.06)	41.14 (23.68)	DE
11.	*Allium sativum*	2000ppm	15.49 (3.94)	44.39 (25.94)	D
12.	*Menthapiperita*	2000ppm	17.61 (4.20)	36.91 (21.05)	E
13.	Control	-	28.36 (5.32)	-	F
C.D. (p≤0.05)			0.207	0.542	

* ***Figures in parenthesis are arc sine transformed values***

In the present study Metalaxyl 4% + Mancozeb 64% proved highly effective in controlling the disease with 75.57 per cent. The fungicide was applied three times fortnightly at 0.2% concentration. The results are in agreement with the results of Raziq *et al*. (2008) who concluded that Metalaxyl 4% + Mancozeb 64% was effective when used @ 0.2% and applied three times fortnightly. The same results were also reported by Iqbal *et al*. (2009) and Nasir *et al*. (2015). Other fungicides next best in order were Metiram 55% + Pyraclostrobin 5% 60 WG Metalaxyl 72 WP, Mancozeb 75 WP and Zineb 80WP. Effectiveness of Metiram 55% + Pyraclostrobin 5% 60 WG in the present investigation are in agreement with Vijayaraghavan *et al*. (2017). The studies were done on the management of downy mildew disease of bitter gourd which showed that the pyraclostrobin was found best in controlling the downy mildew. Other workers have also reported the efficacy of ridomil and Mancozeb in controlling the downy mildews (Sharma *et al*., 2003; Chaudhary *et al*., 2009; Bhat *et al*., 2018). For the control of muskmelon downy mildews (*Pseudoperenospora cubensis*) eleven fungicides were tested and it was reported that Mancozeb 72 WP stood first showing minimum disease incidence of 3.16% (Anonymous, 2004). Robak and Adamicki (2007 reported the highest efficacy of Pyraclostrobin + Boscalid against downy mildew disease of onion. Mancozeb was reported to be the best fungicide by Mo *et al*. (2016) for control of downy mildew. Fungicides containing Mancozeb and other active ingredients such as benalaxyl, dimetomorf and metalaxyl were reported the most effective and resulted in more than 85 per cent control of onion downy mildew (Hoppe BioEco, 2004). To achieve effective control of downy mildew in onions, it is crucial to implement prophylactic sprays at the first sign of disease symptoms in the field. Fungicide-treated plots have yielded marketable onion bulbs, confirming that early defoliation due to downy mildew significantly reduces bulb size and leads to yield losses (Gilles *et al*., 2004; Gianessi and Reigner, 2005; Survillene *et al*., 2008). The highest yields in fungicide-treated plots are likely attributable to an increased number of leaves, greater plant height, and reduced disease severity, which collectively contribute to higher yields (Raziq *et al.,* 2008; Iqbal *et al.,* 2009).

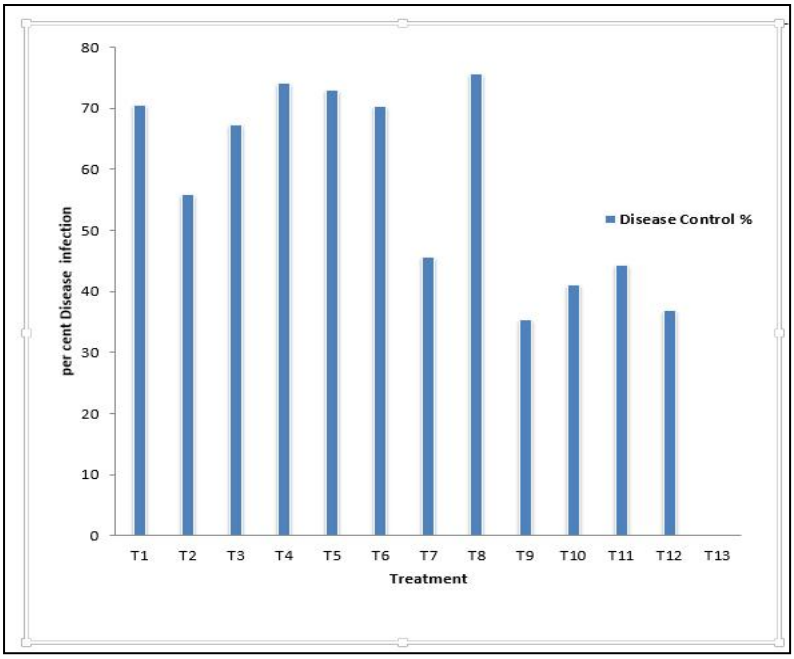


Fig 7: Effect of fungicides and botanicals on per cent disease infection

In present study, the botanical extracts used also proved to be very effective in managing the disease. *Allium sativum* (garlic) extract proved to be effective in controlling the disease with 44.39 per cent disease control. It was followed by *Rheum emodi*, *Mentha piperita* and *Dioscorea* spp. The studies on the efficacy of eco-friendly botanicals in the management of downy mildew disease of cucumber proved that the garlic extract can be used to manage downy mildew disease (Utobo *et al*., 2015). In vivo, plant extracts used in the spray inactivate the pathogen spores when they land on plant surface (Leksomboon *et al.,* 2001; Govindappa *et al.,* 2011). Botanical extracts have also been used for seed treatment to kill seed- borne pathogens (Begum and Lokesh, 2011). Yigal *et al*. (2006) and Rai *et al*. (2008) reported the significant control of downy mildew of cucumber by tested plant extracts.

CONCLUSION

Downy mildew of onion was prevalent in all the onion growing areas of Kashmir valley in moderate to severe form.. Disease appeared in the end of February and symptoms appeared first on leaves. The disease incitant was identified as Peronospora destructor. The protective sprays of the Ridomil Gold, Cabrio Top and Metalaxyl at 15 days interval on the onset of the disease proved most effective against the downy mildew disease. The botanical extract of garlic proved the most effective against the test pathogen.

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