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Impact of weather parameters on Downy mildew of Broccoli and its management through integrated approaches

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Downy mildew caused by *Hyaloperonospora parasitica* is a major disease of Broccoli (*Brassica oleracea* L.) in the world as well as in India. This fungus is common at low temperatures with high relative humidity, and survives well at an optimum cool temperature of 15-23^{0}C and relative humidity of 85% at leaf surface. Biological and fungicide application of *Trichoderma viride*, Tebuconazole, Copper oxychloride, Azoxystrobin, Carbendazim + Mancozeb, Neem oil, Metalaxyl + Mancozeb and Propiconazole were employed to study downy mildew disease control. Abiotic factors play a vital role for dissemination and propagation of pathogen propagules. Negative correlation was observed at both maximum and minimum relative humidity. The application of various treatments of fungicides, bioagents and botanicals showed a significant effect on disease severity, yield and head weight of broccoli. The current study was carried out at Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu during 2021-2022 and 2022-2023 seasons. The fungicide treatment of Metalaxyl+ Mancozeb combination showed disease severity of 12.40% and 18.3% during 2021-22 and 2022-23. Azoxystrobin with 20.30% and 16.6% during 2021-22 and 2022-23 in the cropping year 2022-2023. Similarly, application of chemical fungicide Azoxystrobin recorded highest yield of 84 and 76 q/ha during 2021-22 and 2022-23 during 2021-2022 and application of Metalaxyl+ Mancozeb showed 76.00 q/ha yield during cropping seasons 2022-2023. The application of Azoxystrobin resulted in increase in head weight of broccoli by 520 and 460 gm during the two seasons as compared to control and other treatments. The above study concludes that the application of chemical fungicides showed better results when compared with bioagents and botanicals.

Keywords : Biocontrol agents, broccoli, disease severity, downy mildew, fungicides, weather parameters, yield

INTRODUCTION

Vegetables play a prominent role in daily human diet, being important source of vitamins and minerals required for maintaining of good health. Broccoli (*Brassica oleracea* L.) is one of the most widely grown vegetable all over the world (Singh *et al*.2017). Resembling cauliflower but usually green in colour, introduced in India many years after cabbage and cauliflower, and gained popularity.It is also used as a vegetable in other countries, like Spain, Mexico, Italy, France and United States.

India stands at second position in broccoli production with an annual production of 674 tonnes from an area of 369 hectare (Patel, 2023). Besides being used as vegetable, the tender fresh leaves are served as salad and are extensively used in the preparation of pickles. It has very high calorific value due to its high content of protein, carbohydrates, fibres, calcium, iron, b-carotene, thiamine, riboflavin and ascorbic acid."Sulforaphane" a high level of cancer fighting chemical mobilizes the human body to combat cancer naturally and increase resistance to cancer (Gogoi *et al.* 2016).Conventional management practices and activities, like intensified monoculture in large areas, usage of genetically uniform plant varieties, and international trade of agricultural commodities, contributing largely to the widespread of plant disease epidemics and rapid pathogen evolution (Zhan *et al.* 2015). Like other

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Cruciferous crops, broccoli is also susceptible to infection by fungi (Alternaria leaf spot, anthracnose, blackleg or mildews), some viruses (mosaic virus)and bacteria (black rot, soft rots, bacterial leaf spots) (Pineda *et al*. 2022). Among the fungal pathogens, Downy mildew, caused by *Hyaloperonospora parasitica* is one of the most destructive diseases of cruciferous crops. Cool and damp weather conditions with high relative humidity and air movement favour sporulation and dissemination of spores result in infection by the pathogen. Primary disease symptoms include appearance of greyish white fluffy fungal growth on the underside of infected plant leaves during cool and moist weather. Lesions or Spots are initially yellow, then turn into brown in colour which appear on both sides of leaf where the fungal growth originally was observed (Fig.1). Later, infections will cause extensive necrotic regions on leaves, resulting in reduced photosynthesis. In broccoli, it may also spread systemically to stems and flowers, causing black streaks in in affected plant parts. The disease has worldwide distribution and has been reported on many economically important species in the Brassicaceae, including *Brassica oleracea* L. (broccoli, cabbage and other cole crops). Infection at the seedling stage is most destructive because cotyledons and young leaf tissues are highly vulnerable to attack and stunted or dead seedlings, greyish white fluffy growth that develops on underside of infected leaves. Small, angular lesions can also be seen on leaves and inflorescences. Fungicides Chlorothalonil and mancozeb are the main protectant fungicides for downy mildew on applications provide an effective way of controlling downy mildew. However, registered fungicides may be lost in the future due to concerns about their possible detrimental environmental effects. Use of resistant cultivars is one such alternative that would provide a long-term and practical solution for effective disease management (Wang *et al*. 2001). The present study aims at to study the effect of various weather parameters on disease development and to work out suitable management strategies against the disease.

MATERIALS AND METHODS

The experiment was carried out during rabi season of 2020-2022 at the University Research Farm of division of Plant Pathology, SKUAST-J, Chatha. The experiment on susceptible cultivar of Broccoli was sown and conducted to study the role of weather parameters in relation to disease occurrence and different chemicals were evaluated to observe their individual as well as combined effects on downy mildew disease in the field. Analysis was conducted to observe the effect of various meteorological parameters on disease incidence (DI).Disease severity was recorded by using the disease scale of 0 to 5 as described by Jamadar and Desai (1997) at weekly intervals. Per cent disease index (PDI) was calculated by using the following formula (Wheeler, 1969).

$$\text{Per cent disease index (PDI)} = \frac{\text{Sum of individual disease ratings}}{\text{Total no. of plants observed} \times \text{Maximum grade}} \times 100$$

Different weather parameters viz. maximum and minimum temperature (°C), maximum and minimum relative humidity (%) and rainfall (mm) were obtained from the obtained from Agro-meteorological Section, Chatha. Field experiments were laid out in randomized block design (RBD) with three replications for each treatment at research farm of division of Plant Pathology, SKUAST-J Chatha. The treatments included *Trichoderma viride* isolated from the soil and cultured under lab conditions and CFU count was obtained as $2x10^6$ CFU/ml and applied as 0.60 %, Fungicides application represented in Table 1. The disease severity was recorded by using the disease scale of 0 to 5 as described by Jamadar and Desai (1997) at fortnightly interval (Table 2).

RESULTS AND DISCUSSION

Each insect, pest or disease has a favourable period for its growth during which it flourishes well. similarly, *Hyaloperonospora parasitica* development and progression is influenced by different agrometeorological parameters. At a specific time, a particular weather parameter influences disease occurrence its development and spread. The microscopic observation of the pathogen is depicted in Fig.2.

The downy mildew incidence was observed from 01^{th} to 10^{th}standard meteorological week (SMW)

in both the cropping seasons, in which the weather parameters like maximum and minimum temperatures significantly influenced disease incidence. Maximum temperature in the range of 18-22! was most favourable for disease development but maximum progressed up to a temperature between a range of 23-29!. Minimum temperature in the range of 7-12! during 2021-2023 favoured disease development and progression positively correlated with maximum and minimum temperatures with correlation coefficient of 0.94 and 0.84 respectively. Maximum and minimum relative humidityin the range of 80-96 per cent and 40-50 per centwas most favourable for disease development andprogression negatively correlated with a correlation coefficient of -0.83 and -0.72. Rainfall is not favourable for development of disease. Maximum disease incidence was recorded during zero rainfall period (Fig.3).

Correlation coefficients between disease incidence and weather parameters

Correlation coefficients between disease incidence and different weather parameters *viz.* maximum and minimum temperatures, maximum and minimum relative humidity and rainfall were studied out and presented in Table 3. It was observed that the maximum and minimum temperature showed a significant positive correlation with disease incidence. While maximum and minimum relative humidity showed a significant negative correlation with disease incidence. Rainfall did not show any significant relationship with disease incidence. Similarly, results in respect to weather parameters and downy mildew disease severity were reported by Daunde *et al.* (2017) on downy mildew of cucumber caused by *P. cubensis* studied the rate of disease increase was dependent on weather factors.

Regression analysis between disease incidenceand epidemiological parameters

The regression analysis among different epidemiological parameters like maximum andminimum temperature, maximum and minimumrelative humidity, rainfall anddisease incidence was worked out. Best fitequation of regression was selected. From the obtained R^2 value it can beconcluded that most of weather parameterswere the major determinants of disease incidenceand the R^2 value explained the percent variabilityin disease incidence due to different meteorologicalparameters. The R^2 value was observed as 0.99 indicating that most ofthe meteorological parameters contributed significantly in the disease development and its progression (Table 4). Similar findings were obtained by Atri and Singh (2019) regression model exhibited a positive correlation of downy mildew incidence with maximum, minimum temperature and negative correlation with all other weather parameters. The value of coefficient of determination (R^2 = 0.981) indicated that all weather parameters contributed 98.1 per cent towards disease development.

Where, X_1 = Maximum temperature (!) ,X_2 = Minimum temperature (!)
X_3 = Maximum relative humidity (%) ,X_4 = Minimum relative humidity (%)
X_5 = Rainfall (mm) ,Y = Disease Incidence (%)

Management strategies against downy mildew disease

Different fungicides, botanicals and bioagents were evaluated during the two cropping seasons 2021-2023for management of downy mildew disease. Foliar application of application of metalaxyl +mancozeb 2 sprays @ 0.25% found most effective in reducing the disease with a meandisease severity of 12.40 percent in the year 2021-2022 and18.30 per cent in 2022-2023 followed by Azoxystrobin 20.30 and 16.60 during both the cropping seasons.Combinations of benalaxyl 8% and mancozeb 65% Wp in combating downy mildew of cucumber synergistic effect of downy mildew of cucumber (Saha *et al*. 2017), Carbendazim+Mancozeb with disease severity of @ 20.30, Propiconazole @ 29.30, Copper oxychloride @ 32.20 , Tebuconazole @ 35.0, *Trichoderma viride* @ 28.0 and Neem oil @ 52.30as compared to 56.70 per cent in control plots during 2021-2023 (Fig. 4 A).

Trichoderma viride application showed disease severity with 28.00and 37.20 in the two cropping years, yield was recorded as 70.0 and 64.0 q/ha

Table 1: Details of treatment applied

Treatment No.	Treatments	No. of sprays	Dose (%)
T1	*Trichoderma viride*	2	0.60
T2	*Tebuconazole*	2	0.10
T3	Copper oxychloride	2	0.30
T4	*Azoxystrobin*	2	0.10
T5	Carbendazim +Mancozeb	2	0.25
T6	Neem oil	2	0.40
T7	Metalaxyl+ Mancozeb	2	0.25
T8	Propiconazole	2	0.10
T9	Control		

Table 2: Disease rating scale for downy mildew

Grade	Description
0	No infection
1	0.1-10% leaf area covered with downy mildew growth
2	10.1-15% leaf area covered with downy mildew growth
3	15.1-25% leaf area covered with downy mildew growth
4	25.1-50% leaf area covered with downy mildew growth
5	More than 50% leaf area covered with downy mildew growth

Table3 : Correlation coefficients between the weather parameters and downy mildew

Sr. No.	Weather parameters	Downy mildew
1.	Maximum temperature	0.94^{**}
2.	Minimum temperature	0.84^{**}
3.	Maximum relative humidity (%)	-0.83^{**}
4.	Minimum relative humidity (%)	-0.72^{**}
5.	Rainfall (mm)	-0.49^{NS}

Table 4:.Linear regression of epidemiological factors with the disease index of downy mildew disease of Broccoli

Variety	Linear regression	Correlation coefficient (R)	Coefficient of determination (R^2)
All green	Y=23.744+3.905X1+0.544X2-1.184X3+0.442X4+0.806X5	0.997	0.994

Table 5 : Impact of different treatments on management of Downy mildew of Broccoli under field conditions during 2021-22 & 2022-2023

Treatment Details	Disease severity		Yield (q/ha)		Weight of head in (gm)	
	2021-2022	2022-2023	2021-2022	2022-2023	2021-2022	2022-2023
Trichoderma viride	28.000	37.200	70.000	64.000	360.000	341.833
Tebuconazole	35.000	42.800	76.000	68.000	380.000	340.000
Copper oxychloride	32.200	26.400	68.000	76.000	420.000	366.667
Azoxystrobin	20.300	16.600	84.000	76.000	520.000	460.000
Carbendazim+Mancozeb	20.300	25.100	78.000	74.000	350.000	316.000
Neem oil	52.300	44.200	69.000	73.000	280.000	309.000
Metalaxyl+ Mancozeb	12.400	18.300	68.000	77.000	450.000	390.000
Propiconazole	29.300	24.600	69.000	64.000	420.000	420.000
Control	56.700	60.400	48.000	45.000	250.000	240.000
C.D.	2.310	0.802	5.845	2.138	11.080	14.555
SE(m)	0.764	0.265	1.933	0.707	3.664	4.813

whereas weight of head was observed as 360 and 341.83 gm during the both cropping seasons Fig. 4 A. Sodama *et al*. (2011) reported that under field condition, downy mildew infection percentages were different based on foliar application and seed treatment. Seed treatment and foliar applicationswith biocontrol agents and their mixtures was more effective than individual treatment of seed treatment or spray during the two successive seasons. Combination of *T. viride* with *T. harzianum* or *B. subtilis* was the most effective in reducing downy mildew infection compared with the control.

During the year 2022-2023.Azoxystrobin showed least disease severity of 16.60 per cent and highest was reported in control with 60.40 per cent (Table 5). Similarly yield attributes for the following treatments were worked out during the year 2021-2023in which Azoxystrobin showed highest mean yield 84 q/ha, followed by Carbendazim + Mancozeb, Tebuconazole, *Trichoderma viride*, Propiconazole and Neem oil with 78.00, 76.00, 70.00, 69.00, 69.00 q/ha respectively. Metalaxyl +Mancozeb and Copper oxychloride showed a yield of 68.00 q/ha over control with 48.00 q/ha in the first cropping year 2021-2022 (Fig.4 B).

During 2022-2023 Metalxyl +Mancozeb, Azoxystrobin and Copper oxychlorideshowed highest yield of 77.00 q/ha, 76.00 q/ha and 76.00 q/ha respectively over control with 45.00 q/ha among all other treatments. Asalkar *et al*. (2023) reported Metalaxyl 4% + Mancozeb 64% WP, GI Chitosan @ 1 ml/lit and Potassium salt of active phosphorus @ 4 g/lit alternatively was observed the most effective against the pathogen *Pseudoperonospora cubensis* which causes downy mildew in bitter gourd, gave more yield than other treatments. The head weight of broccoli was also recorded after the application of given treatments from which we can conclude that application of Azoxystrobin had significantly helped to increase the mean head weight by 520 and 460 g during both the cropping seasons (Table 5).

The application of Metalxyl +Mancozeb combination also resulted in increasing the head weight of broccoli significantly with 450 gm and 390 gm in 2021-2022 and 2022-2023 respectively when compared with all other applied treatments over control (Fig.5).

CONCLUSION

In the present study, highly significant correlation coefficients (r) and coefficient of determinants (R^2) indicated that different weather parameters play a very significant role in Downy mildew disease developmentand its progression. The

Fig 1: Visual symptoms with white colour fluffy mycelium growth on leaves of broccoli

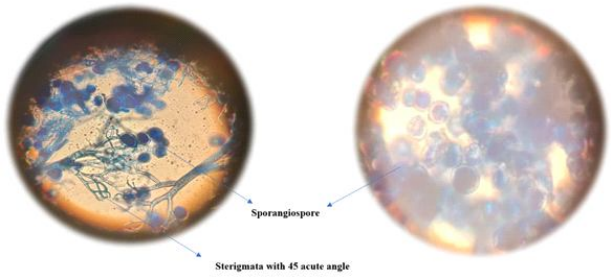
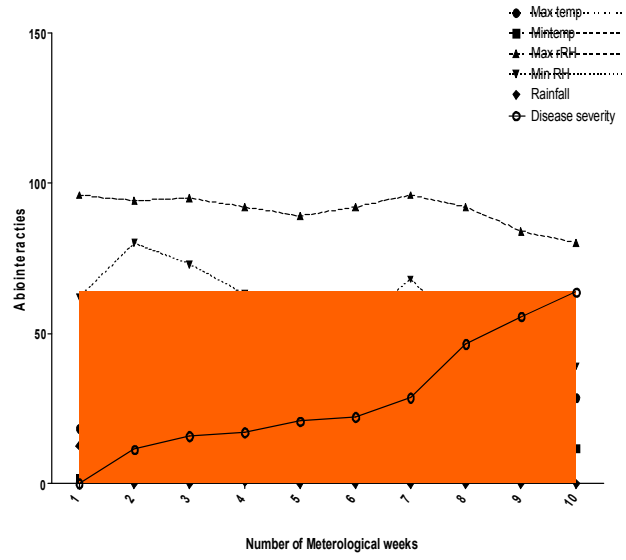


Fig.2: Microscopic view of the downy mildew (*Hyaloperonos-poraparasitica*) infecting broccoli

Fig. 3 : Effect of various weather parameters on Downy mildew disease development in Broccoli



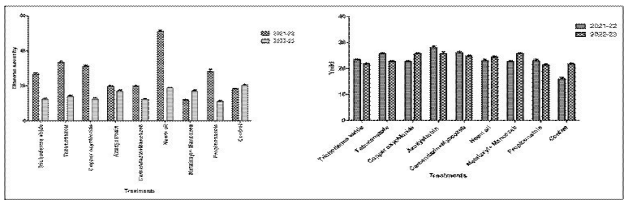


Fig. 4: Disease severity (**A**) and Yield (q/ha)(**B**) of broccoli after application of different treatments

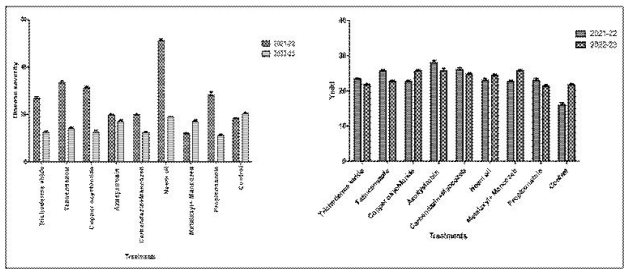


Fig. 5 : Weight of head in (gm) of broccoli when treated with different treatments

various weather parameters can be used to develop weather-based disease prediction models which can be very useful for early disease forecasting and issuing disease forewarning so that necessarycontrol measures can be taken to managedisease incidence.

The present study concludes that the application of combi products like Metalaxyl+Mancozeb, Azoxystrobin, Carbendazim + Mancozeb and Propiconazole showed better results in reducing disease severity when compared with all the other treatments of chemical fungicides, bioagents and botanicals. Similarly, the application of chemical fungicide Azoxystrobin showed highest per cent of increase of yield when compared with all the other applied treatments.

DECLARATION

Conflict of Interest. Authors declare no conflict of interest.

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