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Seasonal Incidence of Major Fungal Diseases in Bitter gourd, Cucumber and Muskmelon

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Abstract

The present study investigated the comparative disease incidence (DI %) of major fungal diseases affecting three important cucurbit crops, bitter gourd, cucumber, and muskmelon, across three distinct growing seasons, namely, *Kharif*, Rabi, and Summer. Six prevalent diseases, viz., Fusarium wilt, powdery mildew, downy mildew, Alternaria leaf blight, Cercospora leaf spot, and anthracnose, were assessed under natural epiphytotic conditions. The results revealed significant seasonal variation in disease incidence among the crops. During the *kharif* and rabi seasons, downy mildew was the most dominant disease, with the highest DI recorded in muskmelon (67.21%, 79.64%), followed by cucumber (59.36%, 76.79%), and bitter gourd (48.86%, 67.21%). In the summer season, powdery mildew and fusarium wilt emerged as the most severe diseases across all crops, with the highest DI in muskmelon (73.64%, 53.79%), cucumber (67.00%, 48.79%), and bitter gourd (46.50%, 32.36%). Whereas Anthracnose, Alternaria leaf blight and Cercospora leaf spot cause severe infection in *Kharif* but decline significantly during Rabi and summer. Overall, muskmelon and cucumber showed greater susceptibility to major fungal diseases than bitter gourd across seasons. The marked influence of seasonal environmental factors on disease development underscores the need for season- and crop-specific management strategies to enhance cucurbit productivity across diverse agroclimatic conditions.

***Key words*:** Bitter gourd, Disease incidence, Downy mildew, Powdery mildew, Fusarium wilt

Cucurbits constitute one of the largest and most diverse groups among vegetable crops, comprising 2 subfamilies, 8 tribes, approximately 118 genera, and 825 species worldwide [4], and exhibit wide adaptability from arid regions to the humid tropics. In India, cucurbits are cultivated over approximately 4.29 million hectares, with an average productivity of 10.52 t/ha, contributing around 5% to total vegetable production [9], and occupy a significant place in both commercial agriculture and kitchen gardening systems. Approximately 60 cucurbit species are cultivated in the country, of which nearly half are indigenous to the Indian subcontinent [9]. Important cultivated cucurbits include cucumber, bitter gourd, bottle gourd, ridge gourd, sponge gourd, pointed gourd, ash gourd, snake gourd, spine gourd, Ivy gourd, muskmelon, watermelon, snap melon, pumpkin etc.

Cucurbitaceous crops, specifically Bitter gourd (*Momordica charantia* L.), Cucumber (*Cucumis sativus* L.), and Muskmelon (*Cucumis melo* L.), are essential vegetable crops commonly cultivated across the different parts of India. These 3 crops were strategically selected for their diverse genetic backgrounds and distinct market utilities. Bitter gourd is primarily consumed as a cooked vegetable, cucumber is utilised for fresh salads and pickles, and muskmelon is valued as a dessert fruit. On a global scale, India occupies a dominant position in cucurbit production. India is the world's second-largest producer of cucumbers and muskmelons, following China, and holds the top position in the production of bitter gourd [2], [8]. During 2024-25, bitter gourd, cucumber, and muskmelon recorded total productions of 1931 MT, 2112 MT, and 1665 MT, respectively [8]. Despite their economic importance, the productivity of cucurbits is severely limited by various biotic stresses, with fungal diseases being the most destructive. Pathogens causing Fusarium Wilt, Powdery Mildew, Downy Mildew, Anthracnose, and various leaf spots are known to cause yield losses ranging from 20% to 80%, depending on the crop variety and environmental conditions. This study was designed as an intensive practical field investigation to systematically monitor and compare the incidence of major fungal diseases across three distinct agricultural seasons viz., *Kharif*, Rabi, and Summer. Unlike standard singular assessments, this work involved the continuous cultivation of these three host species to evaluate the shifting dynamics of fungal pathogenesis under varying environmental conditions. Maintaining these crops under natural epiphytotic conditions, without the use of fungicide sprays, enabled the recording of the baseline susceptibility of each host. The investigation focused on how seasonal transitions, from the high humidity of *Kharif* to the cool, dew-heavy Rabi and the arid, high-heat Summer, influence the prevalence of fungal pathogens. This comparative seasonal data is critical for understanding pathogen succession and provides a foundation for developing targeted, season-specific integrated

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disease management strategies for sustainable cucurbit production.

Vegetable cucurbits such as bitter gourd, cucumber, and muskmelon are widely cultivated in tropical and subtropical regions owing to their high nutritional, medicinal, and economic value. However, the productivity and quality of these crops are severely affected by several fungal diseases that occur under varying environmental conditions. Among these, powdery mildew, downy mildew, anthracnose, wilt, and damping-off are considered major constraints in cucurbit cultivation [16]. The incidence and severity of these diseases largely depend upon seasonal fluctuations in temperature, relative humidity, rainfall, and crop growth stage. Understanding the seasonal occurrence and progression of fungal diseases is essential for developing effective disease forecasting and integrated disease management strategies. Therefore, the present study was undertaken to investigate the seasonal incidence of major fungal diseases in bitter gourd, cucumber, and muskmelon under field conditions.

MATERIALS AND METHODS

Experimental site and agro-climatic condition

The field experiment was conducted during *Kharif*-2022 (June-September), Rabi-2022 (October-January) and Summer-2023 (February-May) at the Research field of Ellora Natural Seeds Pvt. Ltd., Chhatrapati Sambhajinagar, Maharashtra to assess the influence of varying environmental conditions on disease dynamics. This location is characterized by an arid to semi-arid climate, experiences a tropical climate with distinct hot summers (>40°C), a monsoon season, and mild winters.

Experimental design

The study evaluated a diverse germplasm comprising 20 selected genotypes of bitter gourd (*Momordica charantia* L.), cucumber (*Cucumis sativus* L.), and muskmelon (*Cucumis melo* L.). The experiment was laid out in Randomized Block Design (RBD) with seven independent replications under a mixed population to simulate natural field diversity. Crop spacing of 1.5 × 1.0 m, 1.0 × 0.5 m, and 1.5 × 0.5 m was maintained for bitter gourd, cucumber, and muskmelon, respectively. Standard agronomic practices, including trellis support, weeding, and fertigation, were followed uniformly across all seasons; however, no chemical or biological fungicides were applied throughout the duration of the study to allow natural fungal disease progression.

Disease monitoring and targeted diseases

Systematic disease observations were initiated at the onset of the reproductive phase and continued through the peak fruiting stages. The study focused on six major fungal diseases prevalent in cucurbitaceous systems viz., Fusarium wilt (FW), Powdery Mildew (PM), Downy Mildew (DM), Alternaria Leaf Blight (ALB), Cercospora Leaf Spot (CLS), and Anthracnose (ANT).

Disease incidence (DI)

Disease incidence was quantified as the percentage of the plant population exhibiting visible symptomatic infection. DI was calculated as the percentage of plants showing visible symptoms of the respective disease.

$$DI\ (\%) = \frac{\text{Number of infested or wilted vines}}{\text{Total number of vines in the plot}} \times 100$$

Disease rating scale

To ensure standardized quantification of symptoms, two distinct 0-5 numerical rating scales were employed based on the nature of the pathogen.

Foliar disease rating scale

For foliar diseases (PM, DM, ALB, CLS, and ANT), incidence was recorded using a standard 0-5 numerical rating scale suggested by [1], [15].

Table 1 Numerical rating scale for foliar fungal diseases

Grade	Percent disease incidence	Description of symptoms
0	0	No infection; leaves are healthy and green.
1	1-10	Trace infection; a few isolated small spots/patches.
2	11-25	Scattered spots/patches covering up to 10% of leaf area.
3	26-50	Spots/patches merging; 11–25% of leaf area covered.
4	51-75	Extensive infection; 26–50% of leaf area showing necrosis/mycelium.
5	75	Severe infection; >50% leaf area affected; defoliation or drying.

Table 2 Numerical rating scale for wilt diseases

Grade	Severity	Visual symptoms
0	Healthy	No symptoms; plant is fully turgid.
1	Very Slight	1–2 leaves at the base show drooping or slight yellowing.
2	Slight	Approximately 25% of the plant shows wilting or chlorosis.
3	Moderate	50% of the foliage is wilted; plant shows stunted growth.
4	Severe	75% or more of the plant is wilted; severe vascular browning.
5	Death	Complete collapse and death of the plant.

Vascular disease rating scale

For Fusarium Wilt (FW), a 0–5 wilting scale was employed. Since Fusarium is a vascular disease, the scale is based on the degree of systemic wilting rather than leaf area.

Statistical analysis

The data recorded for various disease parameters were subjected to statistical analysis to determine the significance of the results. The experiment was laid out in a Randomized Block Design (RBD) with three replications. The observed values for disease incidence, recorded as percentages, were first transformed using the arcsine (angular) transformation method prior to analysis to ensure the homogeneity of variance and normality of the data. The analysis of variance (ANOVA) was performed as per the procedure described by [10]. The Standard Error of Mean (SEm±) and Critical Difference (CD) at 5% ($P \leq 0.05$) were calculated to compare the means of different crop species and disease intensities across the seasons.

RESULTS AND DISCUSSION

The epidemiological survey of disease incidence (DI %) in bitter gourd, cucumber, and muskmelon across *Kharif*, Rabi, and summer seasons revealed pronounced seasonal variation in the occurrence and incidence of major fungal diseases. Cucurbits are highly responsive to environmental variability and are consequently prone to fungal diseases, the incidence and severity of which are influenced by various agro-climatic conditions [6]. The results clearly indicate that environmental conditions play a decisive role in determining disease dynamics in cucurbit crops.

Table 3 Comparative disease incidence (DI %) in bitter gourd, cucumber, and muskmelon during the *Kharif* Season

Crops	FW	PM	DM	ANT	ALB	CLS
Bitter gourd	15.86 (23.45)	15.79 (23.37)	48.86 (44.33)	21.36 (27.29)	10.79 (19.13)	8.64 (16.94)
Cucumber	20.64 (27.02)	21.93 (27.87)	59.36 (50.43)	28.64 (32.36)	14.07 (21.82)	9.79 (18.05)
Muskmelon	27.36 (31.53)	22.64 (28.41)	67.21 (55.10)	33.71 (35.43)	16.93 (24.25)	13.07 (20.99)
S.E.m±	0.30	0.67	1.51	0.98	0.97	1.04
CD at 5%	0.92	2.06	4.64	3.02	3.00	3.21

Values in parentheses represent Arcsine (Angular) transformed values
FW: Fusarium Wilt, PM: Powdery Mildew, DM: Downy Mildew, ANT: Anthracnose, ALB: Alternaria Leaf Blight, CLS: Cercospora Leaf Spot

During the Kharif season (Table 3), all six diseases were prominently observed, with downy mildew, and anthracnose emerged as the predominant fungal diseases in Kharif season [13]. Muskmelon recorded the highest incidence of downy mildew (67.21%), followed by cucumber (59.36%) and bitter gourd (48.86%) during the Kharif season. Similarly, anthracnose was another major disease observed, with the highest incidence in muskmelon (33.71%), followed by cucumber (28.64%) and bitter gourd (21.36%), indicating their susceptibility to Colletotrichum infection under high humidity and rainfall conditions [12]. In the later stages, powdery mildew incidence was also recorded, particularly higher in muskmelon (22.64%) and cucumber (21.93%) than bitter gourd (15.79%). Furthermore, fusarium wilt showed considerable incidence in muskmelon (27.36%), followed by cucumber (20.64%) and bitter gourd (15.86%). Other diseases, such as Alternaria leaf blight and Cercospora leaf spot, also followed a similar trend, indicating that muskmelon was the most susceptible crop during this season. The relatively higher humidity and rainfall during Kharif likely favoured the proliferation of foliar pathogens.

Table 4 Comparative disease incidence (DI %) in bitter gourd, cucumber, and muskmelon during the *Rabi* season

Crops	FW	PM	DM	ANT	ALB	CLS
Bitter gourd	13.36 (21.43)	24.07 (29.38)	67.21 (55.10)	2.43 (8.89)	8.64 (17.08)	6.36 (14.57)
Cucumber	15.21 (24.38)	34.50 (35.89)	76.79 (61.84)	3.07 (10.00)	10.07 (18.45)	7.93 (16.30)
Muskmelon	18.14 (25.91)	40.64 (39.61)	79.64 (63.39)	5.64 (13.70)	13.07 (21.18)	7.21 (15.57)
S.E.m±	0.72	0.81	1.89	0.41	0.47	0.39
CD at 5%	2.22	2.48	5.81	1.28	1.43	1.20

Values in parentheses represent Arcsine (Angular) transformed values
FW: Fusarium Wilt, PM: Powdery Mildew, DM: Downy Mildew, ANT: Anthracnose, ALB: Alternaria Leaf Blight, CLS: Cercospora Leaf Spot

In the Rabi season (Table 4), a shift in disease pattern was observed. Downy mildew remained the dominant disease, with very high incidence in muskmelon (79.64%) and cucumber (76.79%), while bitter gourd showed comparatively lower incidence (67.21%). Downy mildew severity exhibited a distinct temporal pattern from early October to early January, with a progressive increase from the fourth week of October, peaking in early November, followed by a gradual decline [7]. Disease development was favoured by conditions of fog, dew, and intermittent rainfall under moderate to warm temperatures. In contrast, higher temperatures (>35 °C) were unfavourable for disease progression; however, continued development was observed when accompanied by relatively cooler night temperatures (15–20 °C) [6]. In contrast, the incidence of powdery mildew increased notably during the Rabi season, particularly in muskmelon (40.64%), followed by cucumber (34.50%) and bitter gourd (24.07%). However, anthracnose incidence was drastically reduced across all crops (2.43–5.64%), indicating that the environmental conditions during Rabi were less conducive for its development. Similarly, fusarium wilt exhibited comparatively lower incidence in muskmelon (18.14%), cucumber (15.21%), and bitter gourd (13.36%) than in the *Kharif* season. Other diseases such as Alternaria leaf blight, and Cercospora leaf spot were recorded at moderate to low levels.

Table 5 Comparative disease incidence (DI %) in bitter gourd, cucumber, and muskmelon during the summer season

Crops	FW	PM	DM	ANT	ALB	CLS
Bitter gourd	32.36 (34.54)	46.50 (42.99)	17.79 (24.74)	8.64 (17.08)	11.36 (19.58)	2.86 (9.72)
Cucumber	48.79 (44.30)	67.00 (55.00)	23.14 (28.72)	10.79 (19.15)	8.07 (16.50)	3.71 (11.11)
Muskmelon	53.79 (47.33)	73.64 (59.51)	29.21 (32.58)	13.79 (21.75)	9.93 (18.31)	6.64 (14.91)
S.E.m±	2.04	1.33	1.58	0.52	0.50	0.21
CD at 5%	6.27	4.09	4.87	1.60	1.54	0.65

Values in parentheses represent Arcsine (Angular) transformed values
FW: Fusarium Wilt, PM: Powdery Mildew, DM: Downy Mildew, ANT: Anthracnose, ALB: Alternaria Leaf Blight, CLS: Cercospora Leaf Spot

During the Summer season (Table 5), the disease spectrum changed markedly. Powdery mildew and fusarium wilt emerged as the most severe diseases, especially in muskmelon (73.64% and 53.79%) and cucumber (67.00% and 48.79%), while bitter gourd recorded relatively lower incidence (46.50% and 32.36%). The world is facing 70-100% yield losses of cucumbers and muskmelon due to fusarium wilt [3], [14], whereas the cool and relatively dry conditions prevailing particularly during March to May are highly conducive for the development of powdery mildew [5], [11]. In contrast, downy mildew incidence was dropped across all crops (17.79-29.21%), likely due to unfavourable hot and dry conditions. Similarly, anthracnose, Alternaria leaf blight and Cercospora leaf spot remained at low levels. Overall, downy mildew (DM) had the highest mean incidence across all crops, followed by fusarium wilt (FW) and powdery mildew (PM). Muskmelon exhibited the greatest overall disease intensity, followed by cucumber, whereas bitter gourd showed comparatively lower susceptibility [20]. Other diseases (Alternaria Leaf Blight, Cercospora Leaf Spot and Anthracnose) recorded lower incidence across crops. The mean disease incidence hotspots are summarised in the heatmap (Fig 1).

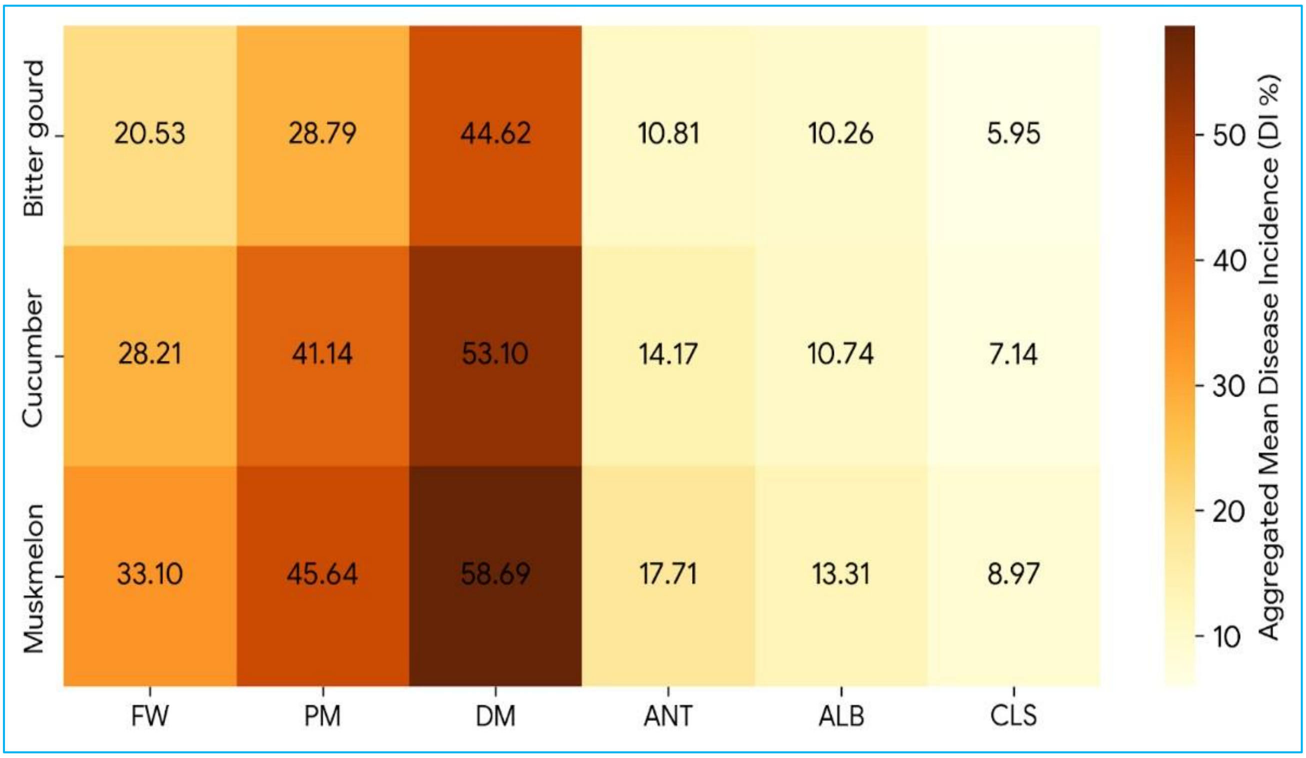

Fig 1 Heatmap: Comparative disease incidence (DI%) across all seasons (Pooled)

CONCLUSION

The present investigation clearly demonstrates that the incidence of major fungal diseases in cucurbit crops are governed by the interaction between seasonal micro-climates and host specificity. A distinct pattern of pathogen succession was observed across the *Kharif*, Rabi, and summer seasons. During the *Kharif* season, foliar diseases such as downy mildew and anthracnose predominated, with cucumber and muskmelon exhibiting higher susceptibility. In the Rabi season, downy mildew caused severe losses, particularly in muskmelon and cucumber. In contrast, the summer season showed a marked increase in powdery mildew, which resulted in substantial losses in muskmelon and cucumber, while Fusarium wilt became highly prevalent due to elevated temperature and moisture stress conditions. Among the crops studied, muskmelon consistently showed the highest susceptibility to most diseases, followed by cucumber, whereas bitter gourd exhibited relatively lower disease incidence. The statistically significant differences observed across crops and seasons highlight the role of environmental factors and host variability in disease development. Overall, the findings emphasize the importance of adopting season-specific and crop-specific disease management strategies, including the use of resistant varieties, cultural practices, and timely fungicidal interventions, to effectively reduce disease burden and enhance productivity in cucurbit cultivation. These findings provide a scientific basis for developing integrated disease forecasting and sustainable management programs tailored to specific cucurbit crops and prevailing seasonal conditions in order to ensure stable yield.

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