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Studies on *Pseudopernospora cubensis* Causing Downy Mildew of Cucumber and *in-vivo* Assay for Management

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Abstract
Downy mildew, caused by the obligate oomycete *Pseudoperonospora cubensis*, is a highly destructive foliar disease limiting cucumber productivity globally and regionally. To assess the contemporary distribution and spatial severity of this disease in Southern Rajasthan, an extensive roving survey was conducted across 44 farmer fields in 17 tehsils across Udaipur, Chittorgarh, and Banswara districts during the Kharif season of 2024–25. Disease severity was quantified using the Percent Disease Index (PDI) based on a standard 0–5 rating scale. Symptomatological monitoring revealed typical angular, vein-limited chlorotic lesions on the adaxial leaf surfaces, corresponding to a dense grey-brown to black downy sporulation on the abaxial surfaces under high humidity. The survey revealed widespread prevalence with significant geographic variation in disease intensity. The highest structural district-mean PDI was recorded in Banswara (30.86%), followed by Udaipur (26.22%), while the lowest disease pressure was logged in Chittorgarh (25.20%). At the sub-district level, the highest disease severity was documented in Bagidora tehsil of Banswara (48.21% PDI within specific fields; tehsil mean 32.11%) and Kotra tehsil of Udaipur (mean 36.50% PDI). Conversely, the minimum localized infestation was recorded in Jhadol tehsil of Udaipur (12.32% PDI within a single site). The heightened disease clusters in Banswara and specific humid tracts of Udaipur correlate directly with dense microclimates, high relative humidity, and traditional monocropping setups. This study maps the regional hot-spots of P. cubensis in Rajasthan, providing crucial epidemiological baselines for designing localized Integrated Disease Management (IDM) models.

Keywords: Cucumis sativus, Downy mildew, *Pseudoperonospora cubensis*, Roving Survey, Percent Disease Index (PDI), Rajasthan

Introduction
Cucumber (Cucumis sativus L.), belonging to the family Cucurbitaceae, represents one of the oldest and most economically vital vegetable crops globally (Tatlioglu, 1992) [11]. Valued for its high hydration capacity, antioxidant wealth, and medicinal properties, cucumber serves as a fundamental source of vitamins and minerals (Javid *et al*., 2024) [3]. India is the second-largest global producer of vegetables, trailing only China (Mallick, 2022) [5]. However, the per capita availability of protective vegetables in India remains around 125–130g per day, falling significantly short of the recommended dietary allowance of 285g (Singh, 1991) [10]. This gap is primarily driven by low productivity per unit area, largely caused by a range of biotic stresses. Among the various biotic constraints, downy mildew caused by the biotrophic oomycete *Pseudoperonospora cubensis* (Berkeley & Curtis) Rostovzev stands out as a highly destructive foliar threat (Lebeda and Cohen, 2011) [4]. Historically recognized since 1868, this pathogen rapidly spreads via wind-borne sporangia, thriving in warm, high-humidity environments characterized by prolonged leaf wetness (Cohen *et al*., 2015) [1]. The infection typically appears as chlorotic, yellow angular lesions bounded by leaf veins on the upper surface, with grayish-purple sporulation underneath (Savory *et al*., 2010) [9]. Advanced infections lead to leaf desiccation, curling, and premature defoliation, which severely impairs photosynthetic capacity, stunts plant growth, and compromises fruit yield and marketability (Thomas, 1996) [12]. In Rajasthan, cucumber cultivation has steadily grown, reaching an estimated 3.686 thousand hectares in 2025. However, expanding cultivation has also increased vulnerability to epidemics of *P. cubensis*.

Because downy mildew severity is highly dependent on regional weather patterns, localized microclimates, and cultural practices, a systematic field assessment is essential. Therefore, this study was undertaken to survey, map, and evaluate the contemporary distribution and severity of cucumber downy mildew across the key production belts of Udaipur, Chittorgarh, and Banswara districts in Rajasthan, establishing a baseline for targeted disease management models.

Material and Methods

Survey Locations and Execution

An extensive roving field survey was conducted during the Kharif season of 2024–2025 across major cucumber-growing tracts within three southern districts of Rajasthan: Udaipur, Chittorgarh, and Banswara. A total of 44 operational farmer fields spread across 17 distinct tehsils were examined. The sample distribution comprised 16 fields across 6 tehsils in Udaipur, 13 fields across 6 tehsils in Chittorgarh, and 15 fields across 5 tehsils in Banswara.

Symptomatological Identification

Infected plants were monitored in-situ for diagnostic macroscopic symptoms. Leaves were evaluated for the presence of early chlorotic spots, angular boundaries confined by secondary veins, tissue necrosis, and the characteristic velvet-like grey-brown to black downy sporulation on lower leaf surfaces during early morning hours under high relative humidity.

Disease Quantification (Incidence and Severity)

At each survey site, fields were traversed in a zigzag pattern. Five micro-plots were selected at random, and five plants per micro-plot were evaluated. Disease incidence was calculated using the standard formula by Wheeler (1969) [14]:

$$\text{Disease Incidence (\%)} = \frac{No.of\ infected\ units}{\text{Total no.of units observed}} \times 100$$

Disease severity on the foliage was scored using the standard 0 to 5 visual rating scale described by Jamadar and Desai (1997) [2], categorized as follows:

Score	**Per cent disease severity**
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

$$\text{Percent Disease Index} = \frac{\text{Sum of all numerical ratings}}{\text{Total number of leaves observed} \times \text{Maximum disease grade}} \times 100$$

Data Analysis

The mean PDI values for individual tehsils and overall districts were aggregated and descriptive statistical comparisons were compiled using MS-Excel and basic analytical packages to interpret spatial variation against regional agro-climatic conditions.

Results and Discussion

Symptomatological Profile in Surveyed Zones

Field inspections across the surveyed zones confirmed that the disease expression was highly characteristic of *Pseudoperonospora cubensis*. Early symptoms appeared as pale green to bright yellow chlorotic spots on the adaxial surface of older leaves. Due to internal structural boundaries, these lesions became sharply defined, angular, and restricted by the leaf veins. During humid mornings, a prominent dark grey-brown downy fungal growth (sporangiophores and sporangia) was consistently observed on corresponding abaxial surfaces. In advanced stages of infection, adjacent lesions coalesced, causing leaves to curl, dry out, and defoliate prematurely. This severe defoliation led to sun-scalded, smaller fruits and stunted vines. This progression matches the diagnostic patterns established by Savory *et al*. (2010) [9].

Spatial Distribution and Severity of Downy Mildew

The extensive survey revealed that downy mildew is widespread across all three surveyed districts, though its intensity varies considerably by location (Table 1). The field-level PDI ranged from a minimum of 12.32% in Jhadol (Udaipur) to a maximum of 48.21% in Bagidora (Banswara). At the district level, the highest average disease pressure was recorded in Banswara (mean PDI of 30.86%), followed by Udaipur (mean PDI of 26.22%). The lowest overall disease index was observed in Chittorgarh (mean PDI of 25.20%).

Table 1: Spatial Distribution and Intensity of Cucumber Downy Mildew Across Southern Rajasthan

District	Tehsil	No. of Fields Observed	Field PDI Range (%)	Tehsil Mean PDI (%)	District Mean PDI (%)
Udaipur	Girwa	3	19.23 – 20.17	19.65	
	Gogunda	3	21.67 – 28.73	24.72	
	Jhalod	2	12.32 – 26.75	19.51	**26.22**
	Kherwara	4	15.25 – 31.25	23.56	
	Kotra	2	34.25 – 38.75	36.50	
	Malvi	2	25.25 – 41.50	33.36	
Chittorgarh	Chittorgarh	2	17.00 – 18.25	17.65	
	Rashmi	2	19.25 – 28.50	23.86	
	Gangrar	2	21.40 – 25.71	23.56	**25.20**
	Begun	2	22.55 – 26.85	24.70	
	Kapasan	2	28.40 – 32.60	30.50	
	Dungla	3	24.80 – 35.50	30.93	

Banswara	Bagidora	4	22.43 – 48.21	32.11	
	Banswara	4	22.24 – 32.25	27.59	
	Garhi	2	22.50 – 30.75	26.63	**30.86**
	Ghatol	2	31.23 – 40.20	35.72	
	Kushalgarh	3	28.28 – 36.62	32.45	
C.V		12.02			
SEm±		2.23			
CD		NS			

Within Banswara, Ghatol tehsil recorded the highest mean severity (35.72% PDI), followed closely by Kushalgarh (32.45% PDI) and Bagidora (32.11% PDI). In Udaipur district, Kotra (36.50% PDI) and Mavli (33.36% PDI) emerged as major disease hot-spots. In Chittorgarh district, Dungla and Kapasan exhibited high disease levels, with mean PDIs of 30.93% and 30.50%, respectively. Conversely, Chittorgarh tehsil maintained the lowest sub-regional footprint at 17.65% PDI.

Discussion of Epidemiological Factors

The high disease severity observed across Banswara (30.86% mean PDI) and parts of Udaipur can be attributed to favorable environmental conditions and local farming practices. The Kharif cropping season in Banswara is characterized by frequent intermittent rainfall, prolonged leaf wetness, and high relative humidity. These factors create an ideal microclimate for the germination, sporulation, and secondary spread of *P. cubensis* sporangia, as noted by Wallace *et al.* (2020) [13]. Variations in disease index across different tehsils also point to the influence of agronomic practices (Narayanasamy, 2013) [7]. High plant density, narrow row spacing, and excessive nitrogen application create a dense canopy that traps moisture and limits airflow, accelerating infection. Additionally, continuous monocropping of susceptible cucumber hybrids increases the local spore load, leading to high disease indices like the 48.21% PDI found in Bagidora. Conversely, lower disease indices in areas like Chittorgarh (17.65% PDI) are likely due to wider plant spacing, better aeration, lower relative humidity, and proactive management by local farmers. These findings align with those of Negi *et al.* (2023) and Mirzwa-Mróz *et al.* (2024) [8-6], confirming that *P. cubensis* infestations are closely tied to regional weather variations and field management practices.

Conclusion

This baseline survey confirms that downy mildew, caused by *Pseudoperonospora cubensis*, is widely distributed and poses a significant threat to cucumber crops across Southern Rajasthan. Banswara district, along with specific humid tracts in Kotra and Mavli tehsils of Udaipur, are identified as major disease hot-spots due to favorable weather conditions and high crop density. The significant variation in Percent Disease Index (PDI) across the 44 surveyed fields highlights the urgent need for regional forecasting models. To protect cucumber yields, future management strategies should focus on these high-risk zones, combining disease-resistant cultivars with optimized plant spacing, improved field sanitation, and timely, weather-based fungicide applications.

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