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During the 2024–25 crop growing season, a comprehensive field investigation was carried out to assess the prevalence of chilli leaf curl viral disease across the districts of Jammu, Udhampur and Samba. The study confirmed that the virus was widespread, being detected in all surveyed locations. Disease incidence rates showed significant variation, ranging from 14.94% to 30.88%, with an average of 22.35%. The highest level of infection was recorded in the Ferna area of Udhampur district, while the Sanoora locality in Samba district exhibited the lowest incidence. Alongside disease monitoring, the research evaluated the effectiveness of different management strategies, including both chemical and botanical interventions. Findings revealed that the combined application of imidacloprid with neem oil offered the most consistent and reliable control under field conditions, thereby highlighting a promising integrated management option for farmers in the region. Although constraints such as fluctuating vector populations and variable environmental conditions posed challenges in standardizing results across all locations, the study nevertheless made significant contributions by providing region-specific data on disease prevalence and demonstrating the potential of integrated chemical-botanical management practices.

Introduction

Chilli (*Capsicum annuum* L.) is a vital vegetable and spice crop widely cultivated in India for its economic and nutritional value [14, 9]. The fruit is a rich source of essential vitamins such as A, B and C, as well as carotene [8]. Capsaicinoid compounds found in the *Capsicum* genus not only provide its characteristic pungency but also exhibit antioxidant properties [1]. With 111 mg of vitamin C, 0.9 g of niacin, 0.19 g of thiamine and 0.19 mg of riboflavin per 100 g, chilli holds significant nutritional value and is highly beneficial in food [6]. Furthermore, bioactive compounds like fatty acids, volatile oils, capsaicinoids and carotenoids enhance its role in a healthy diet due to their anti-inflammatory and antioxidant effects [18]. The tropical regions of South America are regarded as the primary centre of origin for chilli, which was introduced to the Indo-Pak subcontinent by the Portuguese before 1585 [5]. Chilli is grown worldwide, covering an area of 1,832 thousand hectares and yielding 2,959 thousand tonnes annually [2]. India is the largest producer of chilli globally, with an annual production of 1,400 thousand tons, followed by China at 450 thousand tons and Mexico at 400 thousand tons [4]. However, its productivity is severely affected by different abiotic and biotic factors including plant viruses. Chilli leaf curl viral disease, caused by Begomovirus and transmitted by whiteflies (*Bemisia tabaci*), is one of the most destructive diseases that infect chilli plants [11]. The virus leads to leaf curling, stunted growth and significantly affect the

economic yield loss [17].

Materials and Methods

Field Survey

An extensive field survey was conducted during both the cropping seasons in 2024-25 across Jammu, Udhampur and Samba the three major chilli growing districts of the Jammu region. The primary objective was to evaluate the incidence of chilli leaf curl disease under open field conditions (Figure 1). Observations included the crop's growth stage, total number of plants examined, number of infected plants and the distinct symptoms appearing on different parts of the plant. The disease incidence was calculated by using the standard formula [10].

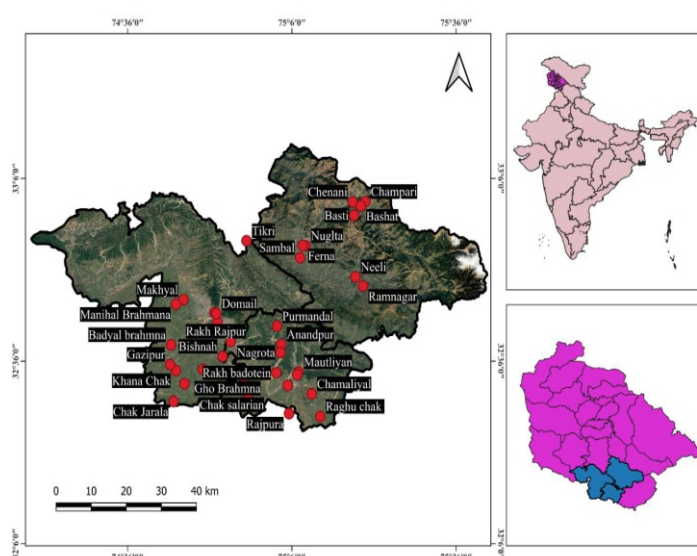


Figure 1: Different locations surveyed in Jammu, Udhampur and Samba districts of Jammu region during the study

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An field experiment was carried out to manage chilli leaf curl virus (ChiLCV) disease using selected insecticides and botanicals, applied either individually or in combination. Various insecticides like Imidacloprid, Cyantraniliprole, Fipronil, Profenofos and various botanicals like Azadirachtin, Chrysanthemum leaf extract, Garlic extract and Neem leaf extract were used for management study. The experiment was laid out at the Division of Plant Pathology, Research Farm, SKUAST-Jammu, during both cropping seasons of 2024-25. The experimental site was geographically located at 32°N latitude and 74°E longitude with an altitude of 426.7 meters above mean sea level. All the treatments were played with three replications in Randomized Block Design (RBD) with each plot measuring 1m x 1m. The crop was grown as per the package of practices of SKUAST-J. G-4 variety seeds were treated with chemicals before sowing and dried properly according to their respective treatments (Table 1). The disease incidence was recorded at 45, 60 and 75 days after transplanting. Per cent disease incidence, per cent disease reduction and whitefly count/plot were calculated by using the following formula [10].

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

Table 1: Insecticidal and botanical products used during the study

Tr. No.	Treatment details
T ₁	3 sprays of Imidacloprid 17.8 SL @ 0.5 ml lit ⁻¹ of water at 15 days interval
T ₂	3 sprays of Cyantraniliprole 10.26% OD @ 0.9g lit ⁻¹ of water at 15 days interval
T ₃	3 sprays of Fipronil 5% SC @ 1.5 ml lit ⁻¹ of water at 15 days interval
T ₄	3 sprays of Profenofos 50% EC @ 2 ml lit ⁻¹ of water at 15 days interval
T ₅	3 sprays of Neem oil based 0.03% WSP @ 5ml lit ⁻¹ of water at 15 days interval
T ₆	3 sprays of Chrysanthemum leaf extract @ 10 % concentration at 15 days interval
T ₇	3 sprays of Garlic extract @ 10 % concentration at 15 days interval
T ₈	3 sprays of Neem leaf extract @ 10 % concentration at 15 days interval
T ₉	Seed treatment with Imidacloprid @ 3g/kg of seed and 3 sprays of Neem oil @ 3% concentration at 15 days interval
T ₁₀	Soil drench with Cyantraniliprole @ 0.2ml lit ⁻¹ of water at the root zone within 7-10 days after transplanting and 3 sprays of Chrysanthemum leaf extract @ 5% concentration at 15 days interval
T ₁₁	Seed treatment with Fipronil @ 2-3g/kg seed at time of sowing and 3 sprays of Azadirachtin @ 3% concentration at 15 days interval
T ₁₂	No spray (Control)

Table 2. Distribution of chilli leaf curl viral disease during both cropping seasons in different areas of Jammu subtropics during 2024-25

District	Block	Village	GPS Coordinates		Variety/Hybrid	Crop Stage	Symptoms observed	Mean DI (%) 2024-25
Jammu	Marh		Latitude	Longitude				
		Makhyal	32.7680000	74.770000	Pant C-1	Fruiting	C, Vt, Cr, Sg	23.33
		Jaswan	32.8307007	75.293483	Local cv.	Fruiting	P, Vt, C, Sg	23.08
		Gajansoo	32.7394000	74.649240	Desi variety	Vegetative	Vt, C, B	24.29
		Manihal Brahmana	32.7560100	74.746900	Pujab Surakh	Vegetative	C, Vt, P, Cr, Sg	19.54
	R.S. Pura	Khana Chak	32.5741700	74.746900	Local cv.	Flowering	C, Vt, Cr, B	20.51
		Kalyana	19.2403000	73.130500	G-4	Flowering andfruiting	E, C, Y, B	23.33
		Chak bala	32.2456000	74.756000	Hybrid	Vegetative	C, Y, B	23.53
		Gazipur	23.9905000	90.387700	Local cv.	Vegetative	Y, B	20.00
		Badyal brahmna	32.6446000	74.732300	G-4	Vegetative	C, E,	22.67
	Bishnah	Kotli shah doula	32.7058119	74.873543	Pusa Jwala	Fruiting	C, Y, E, Yt	23.08
		Bishnah	32.6128000	74.889000	Local cv.	Vegetative	Vt, C, Y	24.00
		Kanshi Pura	29.2104000	78.961900	Punjab Surakh	Ripening	C, E, Y, P	20.00
		Makhanpur	32.5774769	74.828839	Hybrid	vegetative	Sg, C	22.86
		Chak Jarala	32.4900000	74.740000	Pusa Jwala	Flowering	C, P, E	19.12
		SuehChak	32.3400000	75.000000	Local cv.	Vegetative	C, Vt, Cr, B	24.19
		Mean						
Range							19.12-24.29	

Results

Field survey conducted during both the cropping seasons in 2024-25 across Jammu, Udhampur and Samba districts of the Jammu subtropics revealed the widespread presence of chilli leaf curl virus (ChiLCV) (Figure 2). Disease incidence ranged from 14.94% to 30.88%, averaging 22.35%. The highest incidence was recorded in Ferna village of Udhampur at 30.88%, while the lowest was in Sanoora village of Samba at 14.94%. In Jammu, DI varied between 19.12% (Chak Jarala) and 24.29% (Gajansoo) and in Udhampur, between 22.39% (Neeli) and 30.88% (Ferna). Samba district showed the lowest range, from 14.94% to 19.51% (Gho Brahmana) (Table 2).

All chemical treatments significantly reduced ChiLCV incidence. At 60 and 75 Days After Transplanting (DAT), seed treatment with Imidacloprid @ 3g/kg of seed and 3 sprays of Neem oil @ 3% concentration at 15 days interval was most effective with an average disease incidence 10.75% and 8.77%, respectively during both cropping seasons followed by Cyantraniliprole 10.26% OD (09.70% and 10.80%), Imidacloprid 17.8 SL (09.80% and 10.85%), Seed treatment with Fipronil @ 2-3g/kg seed and 3 sprays of Azadirachtin @ 3% (10.23% and 11.35%), Fipronil 5% SC (10.65% and 11.45%) and Profenofos 50% EC (10.67% and 11.70%) at 60 and 75 DAT also performed well and were at par with each other respectively during both seasons in 2024-25 (Table 3). Moderate control was seen in treatment with Cyantraniliprole @ 0.2ml lit⁻¹ of water and 3 sprays of Chrysanthemum leaf extract @ 5% concentration at 15 days interval (23.80% and 21.76%) at 60 and 75 DAT, respectively. Botanicals like Azadirachtin, neem, chrysanthemum and garlic extracts showed lower efficacy but still outperformed the untreated control (37.76% and 34.67%). The least average white fly count was observed in seed treatment with Imidacloprid @ 3g/kg of seed and 3 sprays of Neem oil @ 3% concentration at 15 days interval treatment with 10.11, 11.22 and 12.33 at 45 DAT, 60 DAT, 75 DAT. The highest white fly count was observed in 3 sprays of Chrysanthemum leaf extract @ 10 % concentration at 15 days interval treatment with 17.23, 20.12 and 21.23 at 45 DAT, 60 DAT and 75 DAT respectively, among all treatments other than control during both the cropping seasons of 2024-2025 (Table 3).

Udhampur	Chenani	Basti	33.0355000	75.285200	Arka Lohit	Flowering andfruiting	Cr, Vt, C, Ri	29.41	
		Nuglta	32.9160000	75.141600	Local cv.	Fruiting	B, Vt, C, Ri	25.33	
		Chenani	26.8140000	82.763000	G-4	Fruiting	Y, Vt, C, Sg	30.00	
		Champari	33.0364500	75.323980	G-4	Fruiting	B, Vt, C, Ri	26.25	
		Bashat	33.0293000	75.309100	Local cv.	Vegetative	Vt, C, Sg, Vc	26.67	
	Ramnagar	Ramnagar	32.8055000	75.316400	Local cv.	Ripening	C, B, Y, Vt	29.33	
		Dhandal	33.2574000	75.446100	Punjab Surakh	Ripening	Vt, C, Sg, B	26.92	
		Domail	33.0234000	70.746600	Andhra Jyoti	Flowering	Y, Cr, C, B, Vt	25.71	
		Neeli	32.8307007	75.293483	Hybrid	Vegetative	B, C, Vt, Y	22.39	
		Ghagote	33.1310000	75.598800	Kashi Anmol	Vegetative	Y, Cr, B, Ri	24.29	
	Udhampur	Salmeri	32.9547010	74.935221	Desi variety	Vegetative	C, Cr, B, Ri	26.87	
		Chari suwail	32.9165340	75.132607	Local cv.	Vegetative	C, B, Ri	27.14	
		Ferna	32.9165340	75.132607	Arka Lohit	Vegetative	Vt, C, Sg, B	30.88	
		Sambal	32.8830000	75.124730	Arka Lohit	Vegetative	B, Vt, C, Sg	26.32	
		Tikri	32.9294000	74.961800	Local cv.	Fruiting	C, B, Ri	30.00	
Mean							27.22±0.60		
Range							22.39-30.88		
Samba	Purmandal	Anandpur	32.6457600	75.067740	G-4	Flowering andfruiting	C, Vt, Cr, Sg	16.00	
		Birpur	33.2800000	75.160000	Local cv.	Fruiting	P, Vt, C, Sg	15.28	
		Purmandal	32.6958800	75.054860	Local cv.	Vegetative	Vt, C, B	18.82	
		Nagrota	32.6237190	75.064975	G-4	Vegetative	C, Vt, P, Cr, Sg	18.42	
		Mautliyan	32.5700000	75.120000	Desi variety	Vegetative	C, Vt, Cr, B	19.35	
	Ramgarh	Gho Brahmna	32.5541660	74.954292	Hybrid	Fruiting	E, C, Y, B	19.51	
		Chak Nanak	32.5335200	75.086940	Arka Lohit	Flowering andfruiting	Y, Cr, C, B, Vt	18.75	
		Chamaliyal	32.5100000	75.160000	Local cv.	Vegetative	B, C, Vt, Y	17.65	
		Rakh badotein	32.5681000	75.052400	Pusa Jwala	Fruiting	Y, Cr, B, Ri	16.67	
		Chak salarian	32.5092000	74.966200	Local cv.	Fruiting	C, Cr, B, Ri	17.74	
	Rajpura	Rajpura	32.4565800	75.091240	Pusa Jwala	Vegetative	C, B, Ri	15.71	
		Raghu chak	32.4485000	75.186400	Hybrid	Ripening	Vt, C, Sg, B	18.75	
		Mawa	32.5700000	75.120000	Andhra Jyoti	Flowering andfruiting	B, Vt, C, Sg	19.28	
		Sanoora	32.5628000	75.115800	Arka Lohit	Fruiting	C, B, Ri	14.94	
		Ghagwal	32.6540000	74.914000	Local cv.	Vegetative	Vt, C, Sg, B	18.67	
		Mean							17.73±0.40
		Range							14.94-19.51
		Overall Mean							22.35±0.64
		Overall Range							14.94-30.88

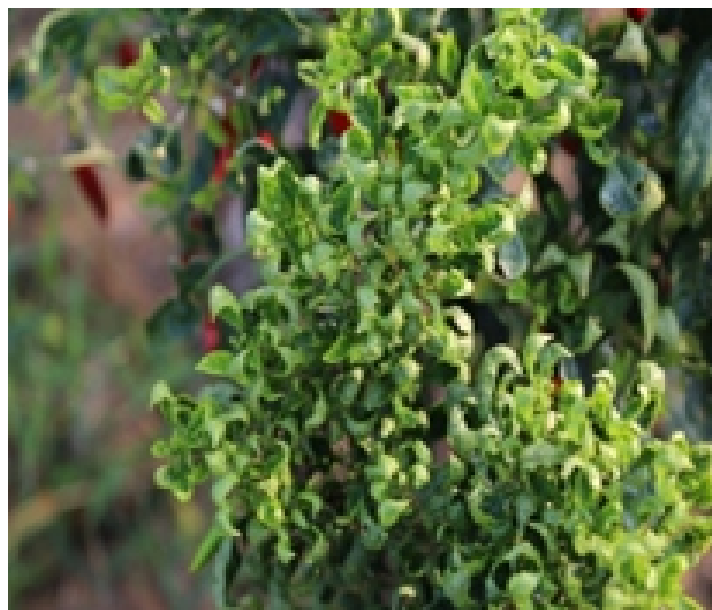
B: Bushy appearance, Vc: Vein clearing, C: Curling, Ri: Reduced internodes, Y: Yellowing, E: Enations, Sg: Stunted growth, Cr: Crinkling, Vt: Vein thickening, P: Puckering



Figure 2: Different locations surveyed in the Jammu subtropics during the study



a. Leaves with boat shape symptoms



b. Leaves with reduced size



c. Thickening of veins



d. Interveinal chlorosis



e. Internodes reduction



f. Curling of leaves

Figure 3. Different viral symptoms observed during survey

Table 3. Evaluation of different insecticides and botanicals during both the cropping seasons under field conditions in 2024-25

S. No.	Treatment Number	DI (%)	DI (%)	DI (%)	Per cent disease reduction (45 DAT)	Per cent disease reduction (60 DAT)	Per cent disease reduction (75 DAT)	Whitefly count/plot (45 DAT)	Whitefly count/plot (60 DAT)	Whitefly count/plot (75 DAT)
		45 DAT	60 DAT	75 DAT						
1.	T ₁	8.7	9.8	10.85	71	71.73	71.27	11.89	13	14.11
		-17.15	-18.24	-19.23						
2.	T ₂	8.1	9.7	10.8	73	72.02	71.4	11	12.11	13.22
		-16.54	-18.15	-19.19						
3.	T ₃	9.78	10.65	11.45	67.4	69.28	69.68	13.67	14.78	15.89
		-18.22	-19.05	-19.78						
4.	T ₄	9.8	10.67	11.7	67.33	69.22	69.01	14.56	15.67	16.78
		-18.22	-19.07	-20						
5.	T ₅	20.54	23.65	24.5	31.53	31.79	35.12	16.34	19.23	18.56
		-26.95	-29.1	-29.67						
6.	T ₆	20.76	23.87	24.8	30.8	31.15	34.32	17.23	20.12	21.23
		-27.11	-29.25	-29.87						
7.	T ₇	22.45	24	25	25.17	30.78	33.79	18.12	18.34	20.34
		-28.28	-29.33	-30						
8.	T ₈	21.54	22.89	24.6	28.2	33.98	34.85	19.01	17.45	19.45
		-27.65	-28.58	-29.73						
9.	T ₉	7.8	8.77	10.75	74	74.7	71.53	10.11	11.22	12.33
		-16.22	-17.23	-19.14						
10.	T ₁₀	20.46	21.76	23.8	31.8	37.24	36.97	15.45	16.56	17.67
		-26.89	-27.81	-29.2						
11.	T ₁₁	8.9	10.23	11.35	70.33	70.49	69.94	12.78	13.89	15
		-17.36	-18.65	-19.69						
12.	T ₁₂	30	34.67	37.76	-	-	-	19.9	21.01	22.12
		-33.21	-36.07	-37.91						
SE(m) ±		0.955	0.746	0.854						
C.D. at 5%		1.428	1.19	1.643						

Discussion

A survey in Jammu's subtropical region during the crop growing seasons in 2024-25 showed chilli leaf curl disease in all sites, with incidence ranging from 14.94% to 30.88%. Highest was recorded in Ferna and Chenani, while Sanoora in Samba had the lowest, likely due to better crop practices. Findings align with [3, 12]. Chilli plants with leaf curl disease showed severe symptoms like leaf puckering, curling and fruit deformities, with advanced infections leading to flower drop and poor fruit set. These observations are consistent with [13, 7]. To manage rising chilli leaf curl incidence, various treatments were evaluated, with imidacloprid + neem oil proving most effective at both 60 and 75 DAS. Botanical extracts showed moderate control, all outperforming the untreated control, aligning with [16, 14].

Conclusion

The chilli leaf curl disease was found to be widespread across all surveyed chilli-growing regions of the Jammu subtropics, with per cent disease incidence (PDI) ranging between 14.94% and 30.88%. The application of a combination of Imidacloprid (seed treatment) and Neem oil spray at 15-day intervals was found effective in managing the disease under field conditions. Regular foliar spraying of Imidacloprid along with Neem oil every 15 days significantly reduced losses due to chilli leaf curl virus and proved to be an efficient management strategy.

Future Scope of the Study

Future studies should focus on molecular characterization of virus strains and vector dynamics to strengthen predictive disease models. Screening and deployment of resistant chilli varieties, along with field validation of bio-intensive and eco-friendly management approaches, are essential for long-term sustainability. Integrating advanced diagnostic tools with region-specific management strategies will further enhance early detection and effective control of chilli leaf curl disease in the Agro-Himalayan region.

Conflict of Interest

The authors declare no conflict of interest.

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