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Current scenario of chilli leaf curl virus disease in major chilli growing regions of north Karnataka, India

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Abstract
Chilli is an economically important spice as well as vegetable crop and affected by leaf curl disease caused by chilli leaf curl virus a begomovirus transmitted by Bemisia tabaci is one of the main constraints hindering its cultivation worldwide. Due to its continuing and rapid spread, leaf curl disease epidemics are observed across the agro climatic regions of India. Information of its distribution, severity, host cultivars and vector abundance help in determining its management. The present investigation was carried out to assess the current status of chilli leaf curl virus disease incidence in North Karnataka is undertaken during 2023-24. Survey results revealed the prevalence of ChLCV across the region ranging from 4.76 to 92.67 per cent incidence. Among the six districts surveyed, the highest incidence of 53.49 per cent was noticed in Ballari district followed by Raichur (48.68%), Yadgir (38.04%), Haveri (37.96%), Dharwad (24.46%) and minimum incidence was observed in Gadag district (14.25%). The highest disease incidence was found in Ballari and Raichur districts. On different varieties/hybrids maximum incidence of chilli leaf curl virus was observed on Byadgi Kaddi (52.75%), least incidence on HPH-5531 (25.63%) and Mahyco (14.34%). Due to the consistent availability of primary inoculum sources and the annual cultivation of chilli for both green and dry fruits, coupled with the presence of a whitefly biotype complex and alternate hosts like cotton and brinjal, there is a significant increase in whitefly populations near chilli crops. This information helps in identifying the virus and vector free less intensive areas for successful chilli cultivation and also develops suitable and effective chilli leaf curl disease management strategies.

Keywords: Chilli, chilli leaf curl virus, survey, disease incidence

Introduction

Chilli (*Capsicum annuum* L.) is an important spice and vegetable crop belonging to the family Solanaceae, grown both in tropical and subtropical regions of the world (Kumar and Rai 2005) [7]. It has high export potential and huge demand both domestically and internationally. However, its production potential is suppressed by many pests and diseases. Chilli crop also suffers from a large number of fungal, bacterial, viral and nematode diseases. Several virus diseases *viz*., chilli mosaic virus, chilli venial mottle virus, cucumber mosaic virus, chilli leaf curl virus, pepper vein banding virus are perinnial problems associated with chilli. Among the different fungal, bacterial and virus diseases the leaf curl disease caused by chilli leaf curl virus (ChLCV) having a ssDNA belong to group begomovirus transmitted by *B. tabaci* (Brown *et al*. 1995) [2] is one of the main constraints hindering its cultivation worldwide.

Chilli leaf curl virus infected chilli plants known to produce different symptoms like mild to severe leaf curling, puckering, blistering of leaves, crinkling and narrowing and swollen veins, stunted growth and a bushy appearance. Plants that are severely infected may not produce any fruit, while those that are less infected may produce fruits that are significantly smaller in size etc., these symptoms result in heavy yield losses as reported by (Oraon and Tarafdar, 2018) [13] and Thakur *et al*. (2018) [18]. In addition to that, thrips, mites and whiteflies have been reported to produce leaf curl complex and cause losses in chilli. Earlier some workers conducted studies on virus diseases on chilli by considering the destructive nature, the extent of yield losses due to leaf curl complex ranged from 25 to 80 per cent (Ilyas and Khan. 1996) [5]. The chilli leaf curl virus (ChLCV) disease on chilli was first reported in Pakistan by (Shih *et al*. 2003) and in India by (Senanayake *et al*. 2007) [15, 16].

In order to support the studies of its epidemiology, collection of information related to cropping system, soil type and weather conditions which are pre-requisite to take final decision on sustainable disease management practices were also considered. In view of economic importance of the disease, the primary objective of the current study was aimed to assess chilli leaf curl virus disease incidence and to know its scenario in chilli growing districts of North Karnataka, India.

Material and methods

A roving survey was carried out to assess the incidence and present status of chilli leaf curl virus disease under field conditions in major chilli growing areas of Karnataka *viz*., Raichur, Ballari, Gadag, Haveri, Yadgir and Dharwad districts during *Kharif* 2023-24. Chilli leaf curl virus disease incidence and severity were assessed based on the external symptoms of the disease. In each district, at least two taluks were selected. In each taluk two villages and in each village two fields were selected. In each field, randomly selected plot of 10×10 sq m area and infected plants out of total plants was recorded and the per cent disease incidence was calculated using the formula given below. The chilli leaf samples from symptomatic plants and whitefly samples from infected chilli crops in different locations were collected for further analysis. During the survey, data on district, taluk, village, latitude, longitude, stage of the crop,

name of variety, soil type, types of symptoms, surrounding crops or weed hosts, per cent disease incidence were recorded. Global Positioning System (GPS) way points were also recorded. The data collected were imported to draw the spatial map of leaf curl disease distribution using the software.

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Results and discussion

A comprehensive survey conducted during the Kharif 2023-24 season in key chilli-growing areas of Northern Karnataka provided detailed insights into the prevalence and distribution of chilli leaf curl virus disease across the examined plots. The severity of chilli leaf curl disease varied from 4.76 per cent to 84.53 per cent across all surveyed plots, with the maximum incidence of 84.53 per cent recorded at the Kalmala village in Raichur district. Conversely, the least incidence of 4.76 per cent was recorded in Sandigavada village in Gadag district (Table 1). The GIS mapping also reveals the same results (Figure 1) this lower incidence is attributed to effective pest and disease management practices and a reduced vector population in the region. Districts wise data envisaged that, the highest incidence of 53.49 per cent was noticed in Ballari district followed by Raichur (48.68%), Yadgir (38.04%), Haveri (37.96%), Dharwad (24.46%) and minimum incidence was observed in Gadag district (14.25%) (Table 2 & Figure 2). Taluk wise data revealed that, highest mean incidence was showed in Siruguppa taluk of 59.91 per cent and lowest mean incidence was in Rona taluk of 10.53 per cent (Figure 3).

Table 1: Incidence of chilli leaf curl disease (ChLCD) in major chilli growing districts of North Karnataka during *Kharif* 2023-24

District	Taluk	Village	GPS coordinates		Variety/Hybrid	Crop stage	Soil type	Symptoms observed	Disease incidence (%)	Weed hosts
			Latitude	Longitude						
Ballari	Ballari	Sindegeri	15.38133	76.908728	Byadgi Dabbi	Fruit ripening	Red soil	Y, Vc, Ic, Bsl	52.41	*Phy, Ege*
		Kollur	15.279592	76.911738	Byadgi Kaddi	Fruiting	Black soil	Ic, Y, C, Vc	62.23	*Phy, Por, Ain, Ege*
			15.270031	76.911546	Byadgi Dabbi	Fruit ripening	Black soil	Y, Ic, M, Vc	48.56	*Phy, Ege*
		Ballari rural	15.199138	76.91102	HPH-5531	Fruit ripening	Black soil	Y, Ic	39.65	*Phy, Ain*
			15.199205	76.910882	HPH-5531	Fruit ripening	Black soil	Y, Ic	32.52	*Phy, Ege*
	Mean incidence								**47.07**	
	Siruguppa	Tekkalakote	15.519543	76.881006	Byadgi Kaddi	Fruit ripening	Black soil	Y, C, Sg, Ic Vc	63.45	*Phy, Por, Avi*
			15.519578	76.881153	Byadgi Dabbi	Fruit ripening	Black soil	Ic, Vc, Vt, C	56.68	*Phy, Cal*
		Bhyrapura	15.464073	76.889087	Local cv.	Fruiting	Black soil	Y, Ic, C, P, Vc, Bsl	92.67	*Phy, Avi, Ain, Ege*
			15.464115	76.889087	Byadgi Kaddi	Fruiting	Black soil	C, Bsl, Ic, Vc	54.32	*Phy, Aas, Cal*
			15.425833	76.89965	HPH-5531	Fruiting	Black soil	Y, Ic, C, Vc, Vt	32.43	*Phy*
	Mean incidence								**59.91**	
Dharwad	Annigeri	Annigeri	15.405074	75.409338	HPH-5531	Fruit ripening	Black soil	C, Bsl, Y	9.82	*Phy, Ege*
			15.405224	75.409433	HPH-5531	Fruit ripening	Black soil	M, Y, Bsl	16.73	*Phy, Por, Ain*
		Bhadrapur	15.386342	75.390097	HPH-5531	Flowering	Black soil	Y, Ic, Bsl	18.45	*Phy, Cal*
			15.386185	75.390245	HPH-5531	Flowering	Black soil	C, Cr, Bsl	11.34	*Phy, Avi, Aas*
	Mean incidence								**14.08**	
	Hubballi	UAS, Campus	15.493317	74.98644	Byadgi Kaddi	Fruit ripening	Black soil	Y, C, Bsl	43.33	*Phy, Ege*
		Horticulture garden	15.482097	74.97943	HPH-5531	Fruit ripening	Red soil	C, Y, Bsl	26.42	*Phy, Por*
	Mean incidence								**34.87**	
	Kundgol	Kundgol	15.260546	75.176244	HPH-5531	Fruit ripening	Black soil	Y, R, C	23.45	*Phy*
			15.260615	75.17954	HPH-5531	Fruit ripening	Black soil	Y, Ic, Bsl	18.45	*Phy*
		Shirur	15.225268	75.235997	Byadgi Dabbi	Flowering	Black soil	Y, Ic, C	31.42	*Phy, Ain*
	Mean incidence								**24.44**	
Gadag	Rona	Bhasalapur	15.688175	75.712485	Local cv.	Fruiting	Black soil	C, Ic, Sg	25.32	*Phy, Ain*
			15.688028	75.711895	Mahyco	Flowering	Black soil	Y, C, Sg	6.72	*Phy*

		Sandigavada	15.674032	75.651275	HPH-5531	Fruiting	Black soil	C, Y	4.76	*Phy*
			15.674413	75.651198	HPH-5531	Flowering	Black soil	C, Y	5.32	*Phy*
	Mean incidence								**10.53**	
	Gadag	Yavagala	15.697353	75.522105	HPH-5531	Fruiting	Black soil	Y, Sg	13.68	*Phy, Por*
			15.697352	75.522108	HPH-5531	Fruiting	Black soil	C, Y, Sg	11.42	*Phy, Ege*
		Gadag rural	15.473325	75.602046	Mahyco	Fruiting	Black soil	C, Y	16.87	*Phy*
			15.47329	75.601974	Mahyco	Flowering	Black soil	C, Y, Sg	19.43	*Phy, Avi*
		Gadag Betageri	15.450796	75.655175	Local cv.	Fruiting	Black soil	Y, Sg	28.49	*Phy*
	Mean incidence								**17.97**	
Haveri	Haveri	Jagamanakoppa	14.810197	75.427332	Local cv.	Fruit ripening	Black soil	C, Y, Bsl	24.35	*Phy*
			14.810324	75.427448	Byadgi Kaddi	Fruit ripening	Black soil	C, Y, Sg	43.65	*Phy, Cto*
		Yattinahalli	14.806326	75.424395	Byadgi Kaddi	Fruit ripening	Black soil	C, Y, Vt, Sg	34.67	*Phy, Cro, Avi*
			14.806432	75.424532	Byadgi Dabbi	Fruit ripening	Black soil	Y, Vt, Vc, Sg	36.23	*Phy*
	Mean incidence								**34.72**	
	Ranebennur	Honnatti	14.750623	75.636833	Byadgi Kaddi	Fruit ripening	Red soil	Y, Vc, Vt, Bsl	60.49	*Phy, Avi, Ege*
			14.750721	75.636896	Byadgi Dabbi	Fruit ripening	Red soil	C, Y, Bsl	42.32	*Phy, Por*
		Yellapur	14.730845	75.616473	Local cv.	Fruit ripening	Black soil	Y, C, R	26.45	*Phy, Ain*
			14.730898	75.616402	Byadgi Dabbi	Fruit ripening	Black soil	Y, C, Vc, R	35.56	*Phy, Cal*
	Mean incidence								**41.20**	
Raichur	Raichur	Kalmala	16.21339	77.198688	Rudhira	Fruit ripening	Black soil	Y, C, Bsl, Sg	84.53	*Phy, Cto, Cro*
			16.21398	77.198702	Rudhira	Fruit ripening	Black soil	C, R, Y, Sg	72.42	*Phy, Cal, Cto*
		Marichethal	16.10985	77.30945	Indam-5	Fruit ripening	Black soil	Y, C, R	45.32	*Phy, Cto*
		Nelhal	16.14472	77.28073	Indam-5	Fruit ripening	Black soil	C, Y, B	38.42	*Phy, Avi, Cto*
		Dinni	16.10876	77.25784	Byadgi Dabbi	Fruit ripening	Black Soil	C, Y, Sg, Vc	53.21	*Phy, Avi, Ain*
		Pesaldinni	16.13014	77.27793	Byadgi Kaddi	Fruit ripening	Black soil	B, Bsl, Vc, Vt	46.76	*Phy, Ain, Cto*
	Mean incidence								**56.78**	
	Devadurga	Gabburu	16.298979	77.158122	Local cv.	Fruit ripening	Black soil	Y, C, Ic, Bsl	74.32	*Phy, Cal*
			16.31117	77.127976	Guntur Sannam	Vegetative	Black soil	Y, C, Bsl	24.54	*Phy*
		Maladakal	16.309591	77.108012	Byadgi Dabbi	Fruit ripening	Black soil	C, Y, R	65.43	*Phy, Cal, Avi*
		Masarkal	16.355077	77.035171	HPH-5531	Fruit ripening	Black soil	C, B, Ic	43.67	*Phy, Ege, Cal*
			16.355117	77.035089	HPH-5531	Fruit ripening	Black soil	C, B, Bsl	47.98	*Phy, Ege, Avi*
		Devadurga	16.444857	76.92548	HPH-5531	Fruit ripening	Black soil	C, Y, Vc, Vt	32.45	*Phy, Cal*
			16.44488	76.925437	Guntur Sannam	Fruit ripening	Black soil	C, Y, Bsl	19.45	*Phy*
		Huvinhadgi	16.463571	76.922655	Guntur Sannam	Fruit ripening	Black soil	C, Y, Ic, B	27.45	*Phy, Ege*
			16.463336	76.922292	Guntur Sannam	Fruit ripening	Black soil	C, Y, Bsl, R	23.21	*Phy, Por, Avi*
		Miyapur	16.378962	77.006182	Byadgi Dabbi	Fruit ripening	Black soil	C, Y, Sg, R	56.68	*Phy, Cal, Chm*
		Devergud	16.405583	76.974207	HPH-5531	Fruit ripening	Black soil	C, B, Bsl	37.36	*Phy, Ege*
			16.405748	76.974547	HPH-5531	Fruit ripening	Black soil	C, Bsl, Sg	34.67	*Phy*
	Mean incidence								**40.60**	
	Lingasugur	Eachanhal	16.21799	76.444197	Guntur Sannam	Fruit ripening	Red soil	C, Bsl, B	42.34	*Phy, Cal*
		Yargunti	16.202955	76.442137	Guntur Sannam	Fruit ripening	Red soil	C, Y, Bsl	45.78	*Phy, Ege, Por*

		Sunkal	16.204363	76.400443	Local cv.	Fruit ripening	Red soil	C, Y, R, Sg	64.32	*Phy, Cal, Ege*
		Halbhavi	16.204802	76.438952	Byadgi Kaddi	Fruit ripening	Red soil	C, Y, Bsl, B	56.21	*Phy, Cal*
		Jawoor	16.187747	76.350542	Byadgi Dabbi	Fruit ripening	Black soil	C, Y, B, R	62.32	*Phy, Ege*
		Julgudda	16.124162	76.332972	HPH-5531	Fruit ripening	Black soil	C, Y, Bsl, B	42.43	*Phy*
		Palgal dinni	16.124626	76.291174	HPH-5531	Fruit ripening	Black soil	C, Y, R, Bsl	36.45	*Phy*
	Mean incidence								**49.98**	
	Manvi	Hokrani	16.052223	77.137191	Byadgi Dabbi	Fruit ripening	Black soil	C, Y, Vt, Vc	56.25	*Phy, Ege*
		Kurdi	16.087703	77.165641	HPH-5531	Fruit ripening	Black soil	C, Y, Bsl, B	38.45	*Phy, Por, Cal*
	Mean incidence								**47.35**	
Yadgir	Shorapur	Arkera khalsa	16.548842	76.810818	Local cv.	Fruit ripening	Black soil	C, Y, Vt, Vc	63.24	*Phy, Por*
			16.54885	76.811078	HPH-5531	Fruit ripening	Black soil	C, Y, Bsl	23.42	*Phy, Cal*
		Mandgalli	16.563405	76.82908	Guntur Sannam	Fruit ripening	Black soil	C, Y	25.34	*Phy, Avi*
		Konganda	16.573169	76.839842	HPH-5531	Fruit ripening	Black soil	C, Y, Vt, Vc	21.34	*Phy, Cal*
	Mean incidence								**33.34**	
	Shahapur	Hattiguduru	16.637838	76.863774	HPH-5531	Fruit ripening	Black soil	C, Y, Bsl	19.43	*Phy*
			16.638037	76.863295	HPH-5531	Fruit ripening	Black soil	C, Y, Vc	24.45	*Phy, Cal*
		Doranahalli	16.722491	76.899298	Byadgi Dabbi	Fruit ripening	Black soil	C, Y, R, B	42.12	*Phy, Avi*
			16.723408	76.903665	Byadgi Kaddi	Fruit ripening	Black soil	C, Y, Ic, Bsl	62.43	*Phy, Ege*
			16.724287	76.940848	Byadgi Dabbi	Fruit ripening	Black soil	C, Y, Sg	34.32	*Phy, Por*
		Gundhalli	16.71184	77.002647	Local cv.	Fruit ripening	Black soil	C, Y, R, Sg	52.87	*Phy, Cal, Por*
			16.71198	77.002734	Local cv.	Fruit ripening	Black soil	C, Y, Vc, Vt	63.62	*Phy, Ege*
	Mean incidence								**42.74**	

Note

Symptoms abbreviations

B: Bushy appearance, C: Curling, M: Mottling, Y: Yellowing, Sg: Stunted growth, Vt: Vein thickening, Cr: crinkling, P: Puckering, Ve: Vein clearing, R: Reduced internodes

Cultivar abbreviation

Local cv: Local cultivar, HPH-5531: Hot Pepper Hybrid-5531

Weed host abbreviation

Phy- Parthenium hysterophorus, Ege- Euphorbia geniculata, Avi- Amaranthus viridis. Ain- Aeschynomene indica, Por- Portulaca, Cal- Calyptocarpus, Cto-Cassia tora, Ase- Alternanthera sessilis. Chi-Cassia nigricans. Cro- Croton, Cal-Chenopodium album.

Table 2: Mean incidence of chilli leaf curl virus disease in different taluks and districts of North Karnataka during *Kharif* 2023-24

District	Taluk	Mean incidence (%)	District mean incidence (%)
Ballari	Ballari	47.07	53.49
	Siruguppa	59.91	
Dharwad	Annigeri	14.08	24.46
	Hubballi	34.87	
	Kundgol	24.44	
Gadag	Rona	10.53	14.25
	Gadag	17.97	
Haveri	Haveri	34.72	37.96
	Ranebennur	41.20	
Raichur	Raichur	56.78	48.68
	Devadurga	40.60	
	Lingasugur	49.98	
	Manvi	47.35	
Yadgir	Shorapur	33.34	**38.04**
	Shahapur	42.74	

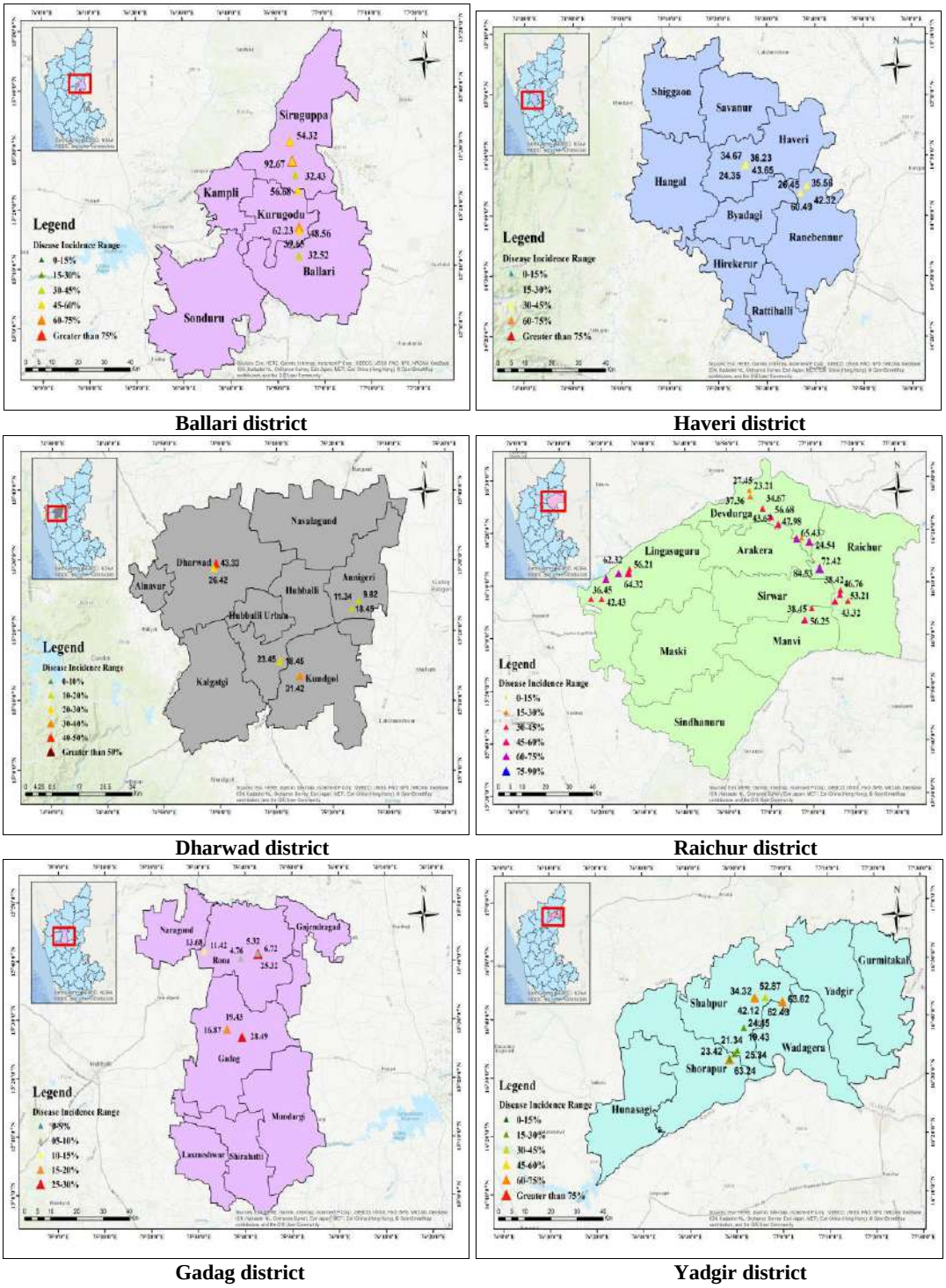

Fig 1: GIS mapping of chilli leaf curl virus disease incidence in different districts of North Karnataka, India

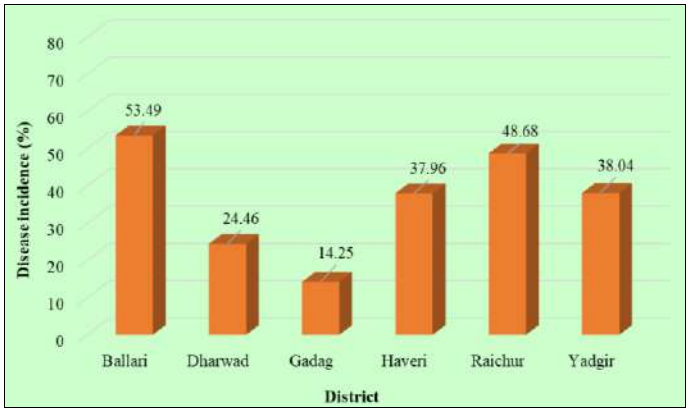

Fig 2: Mean incidence of chilli leaf curl virus disease in different districts of North Karnataka during *Kharif* 2023-24

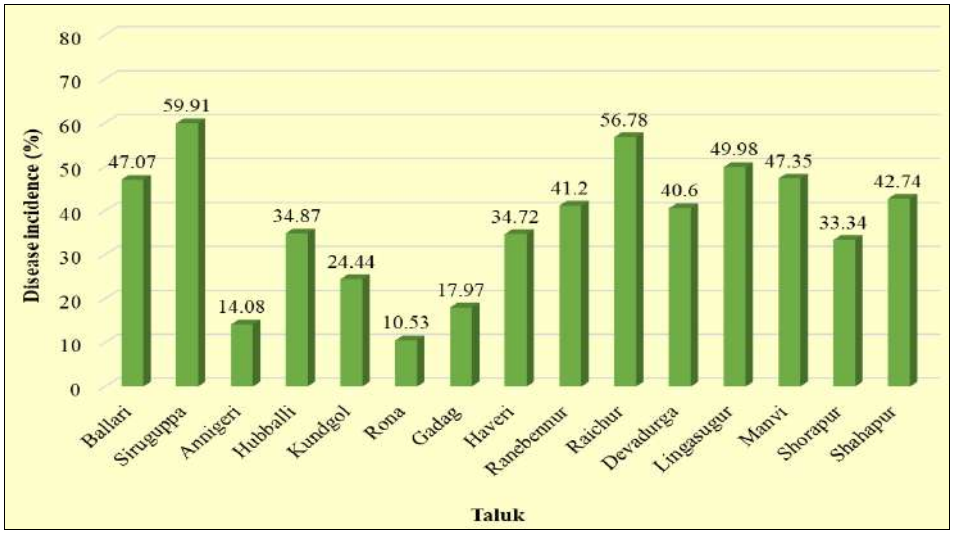

Fig 3: Mean incidence of chilli leaf curl virus disease in different taluks of North Karnataka during *Kharif* 2023-24

Table 3: Status of chilli leaf curl virus disease on different varieties/hybrids in districts of North Karnataka region

Sl. No.	Variety/Hybrid	Mean incidence (%)
1	HPH-5531	25.63
2	Rudhira	78.47
3	Indam-5	40.87
4	Byadgi Kaddi	52.75
5	Byadgi Dabbi	48.10
6	Local cultivar	51.56
7	Guntur Sannam	29.73
8	Mahyco	14.34

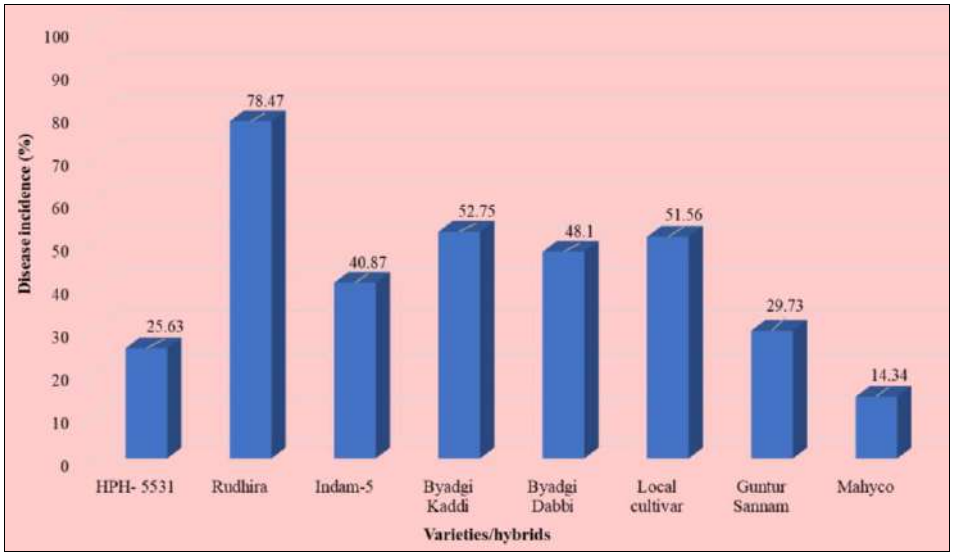

Fig 4: Mean incidence of chilli leaf curl virus disease in different varieties/hybrids growing in North Karnataka during *Kharif* 2023-24

Vein clearing

Vein thickening and enations

Fig 5: Different symptoms of chilli leaf curl virus disease observed during survey in North Karnataka region

In addition to this, the mean severity of chilli leaf curl virus disease was documented on different varieties/hybrids grown in the North Karnataka region. Among the varieties/hybrids grown the maximum incidence was observed on Rudhira (78.47%) followed by Byadgi Kaddi (52.75%), Local cultivar (51.56%), Byadgi Dabbi (48.10%), Indam-5 (40.87%), Guntur Sannam (29.73%) and HPH-5531 (25.63%) and least incidence on Mahyco (14.34%) (Table 3 and Figure 4).

Observations made during the survey indicated that, majority of chilli plots visited exhibited characteristic begomoviral disease symptoms, including inter-veinal chlorosis, downward leaf curling and upward curling, reduced leaf size, boat-shaped leaves, and yellowing. Finally infected plants show bushy appearance, stunted growth, reduced leaf size with an apical bunchy top and extensive leaf curling at the early stage of infection and fail to produce flowers and fruits (Figure 5).

The highest disease incidence was found in Ballari and Raichur districts. Due to the consistently availability of primary inoculum sources and the annual cultivation of chilli for both green and dry fruits, coupled with the presence of a whitefly biotype complex and alternate hosts like cotton and brinjal, there is a significant increase in whitefly populations near chilli crops. Additionally, weed hosts such as Parthenium, *Euphorbia geniculata* and *Cassia tora*, *Abutilon sp. Alternanthera Sp*. in bunds sheltered for survival of the virus during the off-season and further supported by whitefly proliferation (Manjesh, 2018) [10]. The global distribution of begomoviruses parallels the distribution of whiteflies worldwide (Brown *et al*., 1995) [2]. The vectors get perpetuated more in this cropping ecosystem and cause more economic losses in chilli due to the extensive spread of the leaf curl virus by vectors (Czosnek *et al*., 2017) [4].

The variation in disease incidence may also be influenced by external environmental factors affecting whitefly populations (Meghashree, 2017) [11], the presence of different virus strains (Khan *et al*., 2013; Zehra *et al*., 2017) [6, 20], management practices implemented, and host

resistance to both the virus and the whitefly vector (Kushwaha *et al*., 2015) [8]. During the survey, infected chilli crop across the six districts exhibited distinctive leaf curl symptoms, including upward curling, leaf crowding, vein thickening, bushy appearance, puckering, yellowing, enations and reduced internodes, consistent with earlier reports (Muniyappa and Veeresh, 1984, Senanayake *et al*., 2012, Chaubey and Mishra, 2017, Uday *et al*., 2017, Manjesh, 2018, Sudhapatil, 2018, Mallikharjunarao, 2020 and Ashwathappa, 2021) [1, 3, 9, 10, 11, 14, 17, 19].

Vector populations associated with the disease were observed in all the visited plots, though their numbers varied based on the cultivation practices employed. In some instances, farmers applied insecticides intensively but were unable to eradicate the virus from the plants, which had already been infested during the seedling or early vegetative stages after transplanting. Additionally, weeds surrounding the infested chilli plots displayed virus symptoms, potentially serving as reservoirs for the virus and vector during the off-season. Notably, the incidence of ChiLCV was detected in all cultivars grown, regardless of soil type. This information is valuable for identifying virus- and vector-free less intensive areas for successful chilli cultivation and for developing effective management strategies for chilli leaf curl disease.

Conclusion

The study on the spatial distribution of chilli leaf curl disease reveals that disease incidence varied across the study area, primarily due to the presence of diverse vector populations, alternate hosts for the vector and virus, and their survival and spread during the off-season. While farmers are implementing intensive management practices against the vector, these efforts contribute to increased cultivation costs. The information gathered can inform the development of effective management strategies for controlling both chilli leaf curl virus disease and its vectors. Additionally, the findings highlight the importance of sanitation practices to eliminate alternate hosts of the virus and vector. Regions with low virus and vector loads may serve as beneficial areas for cultivating disease-free crops.

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