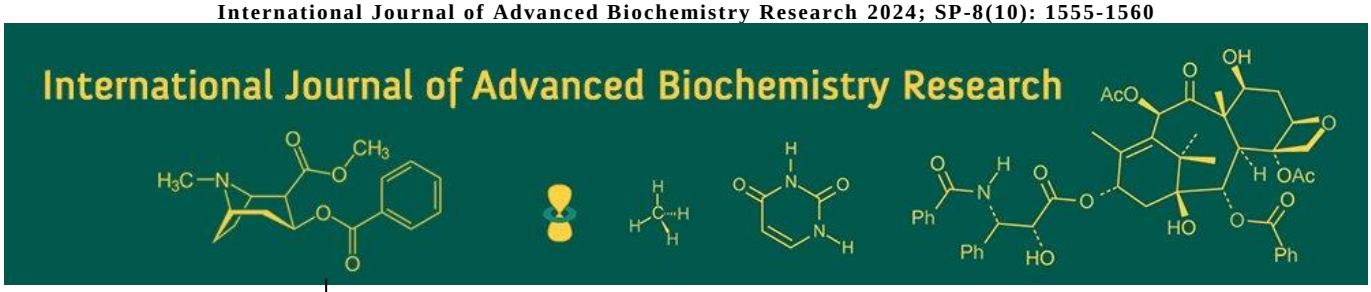

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Survey of viral pathogens affecting hot and sweet pepper in Anantapur district of Andhra Pradesh

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Abstract
Hot and sweet pepper is an economically important crop in tropical and subtropical regions, valued for its use as a vegetable, spice and herb. However, it is susceptible to various viral diseases, including hot and sweet pepper leaf curl disease (ChiLCD), which poses significant threats to crop yield worldwide. To assess the prevalence of ChiLCD in Anantapur district Andhra Pradesh, a roving field survey was conducted during the 2021-22 *kharif* season, covering 45 randomly selected fields across nine villages and eight mandals. The survey revealed an average incidence of leaf curl virus at 12%, with rate ranging from 6.0% to 25.0%. Further, 45 viral-infected chilli samples collected from various locations in Anantapur district were analyzed using DAC-ELISA and PCR to detect major viral pathogens affecting the crops. Among the samples, 26 were positive for begomoviruses via PCR, while DAC-ELISA identified 19 samples infected with potyviruses and tobamoviruses, including combinations of mixed infections. These findings underscore the critical need for integrated management approaches to reduce the prevalence of viral diseases in chilli crops and improve overall productivity and sustainability in Anantapur chilli cultivation.

Keywords: Begomovirus, ChiLCD, survey of begomovirus

Introduction
Hot and sweet peppers classified under *Capsicum annuum* are valuable agricultural commodities cultivated as vegetables, spices and herbs across various regions, particularly in tropical and subtropical climates. These crops hold high economic value and are predominantly cultivated as cash crops in Asia and Africa. Approximately 70% of the world's production of dry hot peppers is concentrated in Asia, with India contributing a significant 40% of the global output (FAO, 2022) [5]. As both the largest consumer and exporter of hot peppers, India leads in production, particularly in Andhra Pradesh, which accounts for 52% of the country's hot pepper production, followed by Telangana with 20% (Spice Board India, 2023) [11]. Despite their economic importance, hot and sweet peppers are highly susceptible to a range of diseases, including fungal, bacterial and viral infections, which severely impact crop quality and yield. Globally, over 65 viral diseases have been reported in pepper crops, posing serious threats to production. Among these, chilli leaf curl disease (ChiLCD) is particularly concerning as it is widespread and causes significant damage in hot and sweet peppers. ChiLCD is caused by more than 12 different viruses, including the chilli leaf curl virus (ChLCV) and is primarily transmitted by the whitefly (*Bemisia tabaci*) cryptic species complex and through grafting (Nigam *et al*., 2015; Senanayake *et al*., 2012) [8, 9].
In India, begomoviruses, particularly those causing leaf curl diseases, have led to substantial yield losses of up to 90% over the past two decades, representing a critical limiting factor for hot and sweet pepper production (Suresh *et al*., 2013) [12]. The impact of ChiLCD on pepper crops has driven the need for effective control measures, as the disease can lead to severe economic losses in pepper producing regions. To better understand and manage the prevalence of ChiLCD in Andhra Pradesh, one of India's key pepper producing states, a roving field survey was conducted in the Anantapur district. This survey aimed to assess the occurrence and distribution of ChiLCD and to categorize the types of cultivars grown whether susceptible, resistant or tolerant.

Additionally, the study sought to identify other begomovirus species infecting hot and sweet peppers and to characterize the range of symptoms associated with these viral infections.

The findings from this survey are anticipated to be instrumental in developing targeted management strategies to control ChiLCD and mitigate its impact on pepper production. By characterizing viral symptomatology and understanding the distribution of ChiLCD and associated viruses, the study contributes valuable insights that could enhance disease resistance breeding programs and inform integrated pest management practices. The ultimate goal is to reduce yield losses, improve crop resilience and ensure stable pepper production in affected regions, benefiting both local economies and the global pepper supply chain.

Materials and Methods

Survey and collection hot pepper infected samples

The roving field survey was conducted in the key pepper-growing regions across several locations within Anantapur district Andhra Pradesh, during the *kharif* season of 2021-22. The surveyed areas included eight mandals: Peddapappur, Tadipatri, Putluru, Yadiki, Gooty, Parigi, Nallamada and Lepakshi (Fig. 3). In each of these mandals, one representative village was selected with the exception of Putluru, where two villages were chosen due to the high prevalence of pepper cultivation. This approach ensured that a wide geographical area with diverse growing conditions and cultivation practices were covered providing a comprehensive assessment of disease prevalence in the region. In each selected village, a minimum of five fields were randomly chosen to evaluate disease incidence, ensuring a representative sampling within each location. Disease incidence was assessed through visual examination of the plants in each field following a methodical walk-through across the rows. This systematic sampling allowed for a consistent and thorough examination of the crop, enabling accurate estimations of ChiLCD prevalence. During the survey, data were recorded on multiple parameters including prevalence of chilli leaf curl disease (ChiLCD), symptom variation and crop variety. This categorization helps in understanding the resistance profile of popular cultivars in the region. The percent disease incidence (PDI) for each field was calculated using the following formula:

$$\text{Disease incidence} = \frac{\text{Total No. of infected plants}}{\text{Total No. of plants}} \text{ X } 100$$

A total of 45 viral-infected pepper samples were collected from hot and sweet pepper crops within Anantapur district Andhra Pradesh. These included 35 hot pepper samples and 10 sweet pepper samples. The sampled plants exhibited a range of distinct viral disease symptoms, which includes mosaic, mottling, severe leaf curl, vein enation, vein thickening, marginal rolling, yellowing of leaves, stunted growth, reduced flower and fruit production. In addition to symptomatic samples, one asymptomatic (symptom-free) sample from both hot and sweet pepper plants was collected from each location. These asymptomatic plants serve as control samples, enabling a comparative analysis to confirm the presence or absence of viral infections. Analyzing both symptomatic and asymptomatic samples allows for a better understanding of viral infection dynamics and the potential for latent infections, where the virus is present but not visibly expressed in plant symptoms. The collected samples, which represent diverse symptoms and varying levels of disease impact will be subjected to further laboratory analysis to identify specific viral agents responsible for ChiLCD and other viral symptoms.

Detection of viruses

Total of 45 viral-infected hot and sweet pepper samples were collected from plants that showed different kinds of symptoms (mosaic, mottling, leaf puckering, vein enation, vein clearing, vine thickening, marginal rolling and yellow mosaic and curling of leaves). These samples were brought to Plant Pathology laboratory, Indian Institute of Horticultural Research, Bengaluru. Initially the samples were tested by DAS-ELISA using different known antibodies to understand the status of different viruses associated hot pepper, which are more prevalent of Anantapur district Andhra Pradesh on hot and sweet pepper. The important viruses tested included chilli veinal mottle virus (ChiVMV), cucumber mosaic virus (CMV), tobacco mosaic virus (TMV), tomato mosaic virus (ToMV), tomato mottle mosaic virus (ToMMV), tomato brown rugose fruit virus (ToBRFV) and groundnut bud necrosis virus (GBNV) (DMSZ, Germany), as well as PCR using begomoviral specific primers to confirm mixed infection of different viruses under field conditions. All the samples (45 viral-infected hot and sweet pepper) were also tested to know the status of begomovirus by PCR using primers (OY2395F/680R) specific to DNA-A component of begomovirus genome (Venkataravanappa *et al*., 2021) [13].

Results and Discussion

Symptomatology of viruses affected hot and sweet pepper

During a roving survey across 45 hot and sweet pepper fields in Anantapur district, the most prominent symptoms observed were severe leaf curling, crinkling, leaf rolling and shortened internodes are the key indicators of chilli leaf curl disease (ChiLCD) (Fig. 1a and 1b). These symptoms were consistently present across all surveyed villages in the eight mandals, highlighting the widespread nature of ChiLCD in the region. Additional symptoms such as mosaic (Fig. 1c), vein clearing (Fig. 1d) and blistering were also frequently observed in each mandal. Symptom diversity was notable with additional signs like mottling, veinal banding (Fig. 1b) and leaf distortion observed primarily in the mandals of Peddapappur, Putluru, Yadiki, Parigi, Nallamada and Lepakshi. Interestingly, these particular symptoms were not detected in Tadipatri and Gooty suggesting possible regional or cultivar-specific variations in viral strain prevalence. More severe symptoms, including stunted plant growth and reduced fruit size were documented in fields located in Peddapappur, Gooty, Parigi and Nallamada, while Tadipatri, Putluru, Yadiki and Lepakshi showed no such severe infestations. This symptom variability may indicate the presence of different viral strains or varying environmental conditions and farmers predominantly grow widely recognized pepper cultivars including Swarna, Byadagi, Sonali Max, Dhruva and Rizwan Red with Byadagi and Rizwan Yellow being particularly popular have some tolerance to diseases. The symptoms observed align closely with findings by Devi *et al*. (2019) [3], who reported similar ChiLCD symptoms such as upward and downward leaf

curling, leaf puckering and crinkling in infected plants.

In addition to ChiLCD symptoms, signs typical of tospovirus infections such as mottling, vein banding and necrotic rings and spots were also noted in some fields. These observations are consistent with previous studies by Chaithanya *et al*. (2022) [1], who reported symptom variations including severe fruit dropping, absence of fruits and whitefly presence near infected pepper fields. These findings reinforce earlier research by Chattopadhyay *et al*. (2008) [2] and Shafiq *et al*. (2010) [10] as well as Dore *et al*. (2017) [4] which suggested that while controlling whitefly populations can reduce the spread of vector-borne diseases, viral infections causing leaf curl remain irreversible and challenging to manage once plants are infected.

These observations underline the complex nature of viral infections in pepper crops in Anantapur, where multiple viral strains and vector presence contribute to a diverse range of symptoms and disease severity. This study findings underscore the need for integrated disease management strategies and the development of resistant pepper cultivars to combat the persistent impact of ChiLCD and related viral infections on pepper production.

Fig 1: Characteristic symptoms of hot pepper leaf curl disease (ChiLCD) and mosaic symptoms. a. Severe leaf curling; b. Leaf rolling and veinal banding; c.; deformation and chlorosis; d. Mosaic

The percent disease incidence (PDI) of chilli leaf curl disease (ChiLCD) was recorded across hot and sweet pepper fields (Table 1), with values ranging from 6% to 25%. The highest PDI (25%) was observed in Vankarakunta village of Nallamada mandal, followed closely by Muchukota village in Peddapappur mandal with a PDI of 23.18% (Fig. 2). In contrast, the lowest disease incidence was recorded in Putluru, Yadiki and Gooty mandals which showed a mean PDI of 7.69%.

Across all surveyed fields, severe leaf curl symptoms, a hallmark of ChiLCD were consistently present. Additionally, high populations of sucking insect pests notably thrips and whiteflies were observed in various densities at both the vegetative and post-reproductive stages of the pepper plants. The presence of these vectors in such abundance likely contributes to the persistent spread of ChiLCD in these fields as both whiteflies and thrips are known vectors for viral transmission in peppers.

The high incidence of ChiLCD and vector populations can likely be attributed to agricultural practices in the region. Continuous monocropping of peppers without rotation is common, which may contribute to a build-up of virus inoculum and pest populations in the fields over successive growing seasons. Furthermore, indiscriminate use of insecticides aimed at controlling whitefly and thrip populations could be exacerbating the issue. Frequent and unregulated application of insecticides can lead to pest resistance and can disrupt natural predator populations that help control these pests. As a result, pest populations often experience resurgence, with whiteflies in particular thriving under such conditions.

The combined effects of monocropping and indiscriminate pesticide use create a conducive environment for the development and spread of viral diseases like ChiLCD. These practices highlight the need for integrated pest management (IPM) strategies in pepper cultivation, which could include crop rotation, selective pesticide use and biological control methods to reduce reliance on chemical controls. Implementing such strategies may help lower pest pressure, reduce disease incidence and promote healthier more sustainable pepper production in Anantapur and similar regions.

Table 1: Percentage of Disease incidence observed in surveyed mandals

S. No.	Name of the Mandal	Name of the Village	Variety/ Hybrid	No. of Field surveyed	Stage of the crop	Percentage of Disease incidence						
						Mottling, veinal banding, leaf distortion symptoms	Mosaic blistering symptoms	Necrotic rings, apical stem necrosis symptoms	Leaf curling, leaf rolling symptoms	Mean percentage of Disease incidence (PDI)	Latitude	Longitude
1	Peddapappur	Muchukota	Swarna	5	Post Reproductive	10.0	2.0	0.7	80	23.18	14.840	77.861
2	Tadipatri	Eguvapalli	Sonali Max	5	Reproductive	0.0	2.0	0.0	35	9.25	14.0454	78.0533
3	Putluru	Yellanur	Byadagi	5	Reproductive	1.0	0.6	0.0	30	7.90	14.4213	78.0423
4	Putluru	Putluru	Byadagi	5	Reproductive	0.0	1.0	0.0	23	6.00	14.5024	77.5735
5	Yadiki	Yadiki	Dhruva	5	Reproductive	0.5	1.2	0.0	34	8.93	14.5500	78.0123
6	Gooty	Gooty	Byadagi	5	Post Reproductive	0.0	2.4	0.3	29	7.93	15.0631	77.3635
7	Parigi	Yerragunta	Rizwan Red	5	Reproductive	2.5	8.0	1.0	30	10.38	13.5436	77.2859
8	Nallamada	Vankarakunta	Local Varities	5	Post Reproductive	6.0	12.0	5.0	77	25.00	14.226	77.974
9	Lepakshi	Neredumuddapalee	Rizwan Yellow and Red	5	Post Reproductive	2.0	3.0	0.0	35	10.00	13.846	77.763
									Mean	12.06		

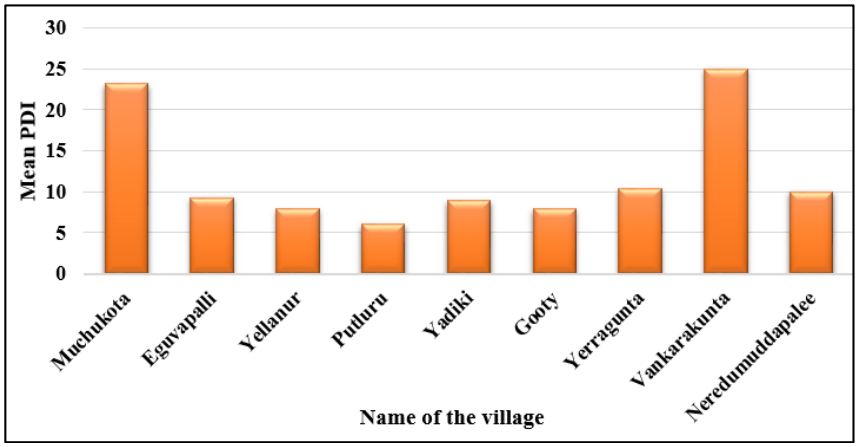

Fig 2: Mean percentage of disease incidence of selected villages in Anantapur District

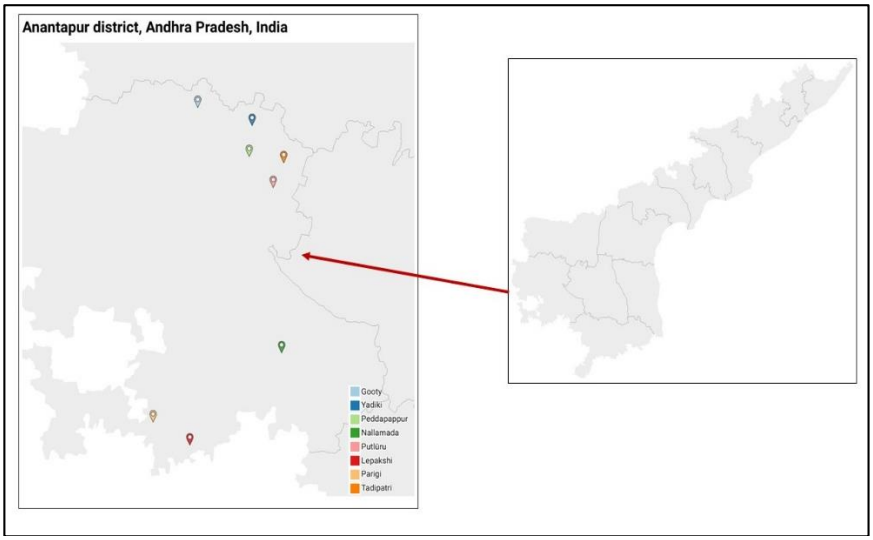

Fig 3: Anantapur district map

Detection of viruses in chilli by DAC-ELISA

Total of 45 viral-infected chilli samples collected from various locations in district were analyzed using DAC-ELISA with polyclonal antisera and PCR for virus detection. This dual approach aimed to accurately identify the presence of major viral pathogens affecting the crops. Out of the 45 samples tested, 26 were positive for begomoviruses *via* PCR while DAC-ELISA revealed that 19 samples were infected with potyviruses and tobamoviruses (Table 2).

Further infection percentages for each virus type were calculated 57% of the tested samples were positive for

begomoviruses making this group the most prevalent among the tested viral pathogens. While 35% of the samples tested positive for tobamoviruses which are typically seed-borne and easily spread through plant handling also caused notable damage in the fields. and 28% of the samples showed positive for potyviruses which are often transmitted by aphids can lead to mosaic and mottling symptoms in pepper crops. In addition to single-virus infections mixed infections involving multiple viruses were identified. 11% of the samples were found to contain all three viruses begomovirus, tobamovirus and potyvirus indicating the occurrence of complex infections which are typically more challenging to manage and often result in compounded symptom severity. While 26% of the samples showed a mixed infection of begomovirus and tobamovirus and 15% of the samples were positive for both begomovirus and potyvirus another combination that is expected to exacerbate symptom expression and impact on crop yield. However, 13% of the samples displayed infection by both potyvirus and tobamovirus which can also lead to complex symptoms, including mosaic patterns and distorted leaf growth (Fig. 4). These findings underscore the complexity of viral infections in chilli crops in Anantapur, where both single and mixed infections contribute to significant disease pressure. The high prevalence of mixed infections may be attributed to the presence of multiple virus vectors, continuous cropping without rotation and overlapping crop cycles which can facilitate viral spread and infection. A literature review by Laprom *et al*. (2019) [7] analyzed 2,149 samples and identified with different viruses such as begomovirus, cucumber mosaic virus (CMV), chilli veinal mottle virus (ChiVMV) and tomato necrotic ringspot virus (TNRV), respectively. Additionally, research by Kenyon *et al*. (2014) reported the identification of thirteen begomovirus species in infected tomato, pepper and eggplant crops across various countries in Southeast and East Asia highlighting the widespread distribution and diversity of begomoviruses in the region. These findings underline the significant impact of begomoviruses and other viruses, such as CMV, ChiVMV and TNRV in vegetable crops across Southeast Asia, with regional variations in virus prevalence potentially linked to local agricultural practices, environmental conditions and vector populations.

Table 2: Mapping of viral diseases in Chilli

District	Location	Total No. of samples collected	PCR	RT-PCR
Anantapur	Muchukota	5	2	3
	Eguvapalli	5	4	1
	Yellanur	5	3	2
	Putluru	5	4	1
	Yadiki	5	3	2
	Gooty	5	3	2
	Yerragunta	5	2	3
	Vankarakunta	5	2	3
	Neredumuddapalee	5	3	2

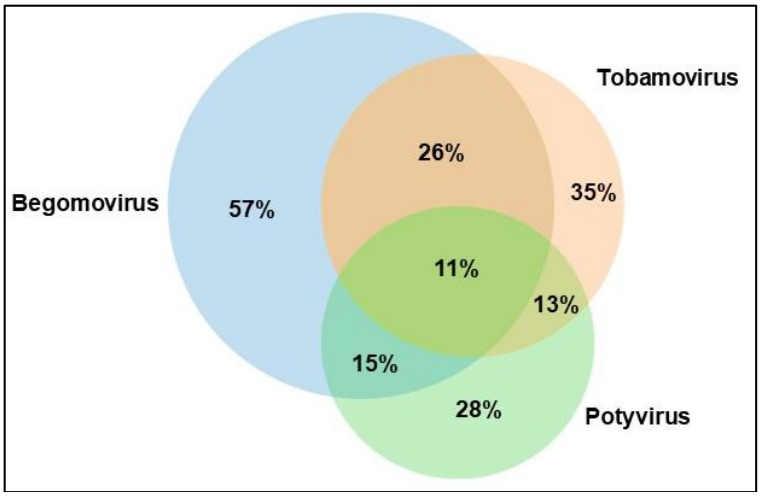

Fig 4: Venn diagram of virus infestation in samples collected from Anantapur district

Conclusion

The survey conducted across 45 chilli fields in Anantapur district, Andhra Pradesh identified chilli leaf curl disease (ChiLCD) as the predominant viral disease affecting hot and sweet pepper crops, followed by infections from potyviruses, cucumoviruses and tobamoviruses with incidence rates ranging from 6% to 25%. The most common symptoms observed were severe leaf curling, followed by mosaic and mottling patterns, which are indicative of viral infection. Molecular analysis confirmed the presence of both single and multiple viral infections across the surveyed fields highlighting the complexity of viral pressure on chilli crops in the region. These findings underscore the urgent need for comprehensive management strategies to address viral diseases in chilli crops. Integrated management approaches are recommended, including effective vector control to manage whitefly populations (the primary vectors), the use of virus-resistant cultivars to minimize susceptibility and crop rotation to reduce the buildup of virus reservoirs in the soil. Together, these strategies could help reduce the prevalence of viral diseases in chilli crops and improve overall productivity and sustainability in Anantapur chilli cultivation.

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References

1. Chaithanya BH, Srinivas T, Reddy BVB. Survey and molecular identification of Begomovirus associated with chilli Leaf Curl Disease in Kurnool district of

Andhra Pradesh. Indian Journal of Agricultural Research. 2022. DOI: 10.18805/IJARe.A-6028.
2. Chattopadhyay B, Singh AK, Yadav T, Fauquet CM, Sarin NB, Chakraborty S. Infectivity of the cloned components of a begomovirus: DNA beta complex causing chilli leaf curl disease in India. Archives of Virology. 2008;153(3):533-539.
3. Devi BD, Reddy MR, Padmodaya B, Reddy VLN, Srilatha V. Survey for the incidence of viral diseases in chilli in Andhra Pradesh. International Journal of Current Microbiology and Applied Sciences. 2019;8(11):2136-2143.
4. Dore R. Biological and molecular characterization of chilli leaf curl virus (ChiLCV) in south Gujarat [MSc thesis]. Dept. of Plant Pathology, Navsari Agricultural University, Navsari. 2017.
5. Food and Agriculture Organization of the United Nations (FAO). FAOSTAT: Crops and livestock products. 2022.
6. Kenyon L, Kumar S, Tsai WS, Hughes JD. Virus diseases of peppers (*Capsicum* spp.) and their control. Advances in Virus Research. 2014;90:297-354.
7. Laprom A, Nilthong S, Chukeatirote E. Incidence of viruses infecting pepper in Thailand. Biomolecular Concepts. 2019;10(1):184-193.
8. Nigam K, Suhail S, Verma Y, Singh V, Gupta S. Molecular characterization of begomovirus associated with leaf curl disease in chilli. World Journal of Pharmaceutical Research. 2015;4(3):1579-1592.
9. Senanayake DMJB, Varma A, Mandal B. Virus-vector relationships, host range, detection and sequence comparison of Hot pepper leaf curl virus associated with an epidemic of leaf curl disease of chilli in Jodhpur, India. Journal of Phytopathology. 2012;160:146-155.
10. Shafiq M, Shaheen A, Yusuf Z, Rob W, Briddon, Shahid M. Pepper leaf curl Lahore virus requires the DNA-B component of Tomato leaf curl New Delhi virus to cause leaf curl symptoms. Virological Journal. 2010;7:367.
11. Spice Board of India. State-wise Hot pepper production in India. 2023.
12. Suresh LM, Malathi VG, Shivanna. Molecular detection of begomoviruses associated with a new yellow leaf crumple disease of Cucumber in Maharashtra, India. Phytopathology. 2013;66(3):294-301.
13. Venkataravanappa V, Prasanna HC, Reddy CL, Chauhan N, Shankarappa KS, Reddy MK. Molecular characterization of recombinant bipartite begomovirus associated with mosaic and leaf curl disease of Cucumber and Muskmelon. Indian Phytopathology. 2021;74:775-785.