Doi: HTTPS://DOI.ORG/10.23910/2/2021.0416c

Prevalence of Cotton Leaf Curl Virus Disease in North-West Part of Rajasthan and its Management

R. N. Sharma[1], R. B. Gaur[2] and V. Singh[2]

[1]College of Agriculture (S.K.N. Agriculture University, Jobner), Bharatpur, Rajasthan (321 201), India
[2]Agricultural Research Station (SKRAU), Sriganganagar, Rajasthan (335 001), India

Corresponding Author

R. N. Sharma
e-mail: rnsharma.patho@sknau.ac.in

Article History

Article ID: IJEP0416c
Received on 17th April, 2021
Received in revised form on 04th August, 2021
Accepted in final form on 22nd August, 2021

Abstract

Field survey to find out the severity of cotton leaf curl virus (CLCV) disease was undertaken during the year 2009. The cotton fields of 62 villages/ Chaks covering 7 tehsils of Sriganganagar and 7 tehsils of Hanumangarh district were surveyed which comprises North-West part of Rajasthan, India. Severe attack of CLCV (6.3–100%) in Sriganganagar tehsil; moderate attack (0–32.3%) in Srikaranpur, Sangaria and Hanumangarh tehsil; low level (0–10.8%) attack in Sadulsahar, Tibi and Nohar tehsil and traces level (0–5.7%) attack in Bhadra, Anupgarh, Raisinghnagar, Padampur and Suratgarh tehsil was observed. Further, a field trial was also laid out at ARS, Sriganganagar for the management of disease for two consecutive years (2010 and 2011). Minimum disease intensity (31.5%) and maximum reduction in disease intensity (37.5%) over control were observed in the foliar treatment of Acephate 60% WP + Kresoxim methyl 15% WG (750+187.5 g a.i. ha^{-1}) followed by Buprofezin 25% SC (250 g a.i. ha^{-1}). Acephate 75% SP (750 g a.i. ha^{-1}) provided 34.9 and 33.7% protection from the disease as compared to control.

Keywords: Cotton leaf curl virus, fungicide, insecticide, management, white fly

1. Introduction

Cotton leaf Curl Virus (CLCV) disease is one of the most devastating and serious problems particularly in northern cotton growing region of India that has the potential to inflict huge economic losses to cotton yield up to 81-88% (Leke et al., 2015; Kumar et al., 2016; Hasan et al., 2019). CLCV disease is caused by a circular single stranded DNA (monopartite or bipartite) Gemini virus belonging to genus Begomovirus and family Geminiviridae, in association with satellite molecules (Xiong et al., 2004; Ha et al., 2008). Its viral nature was established in 1926 (Singh et al., 1998). The disease is transmitted by ubiquitous vector known as white fly (*Bemisia tabaci*) in a persistent and circulative manner (Ruiz et al., 2006; Nogia et al., 2014; Sattar et al., 2017; Zerbini et al., 2017). In 1912, CLCV disease was first time reported scientifically from Nigeria on *Gossypium vitifolia* and *Gossypium peruvianum* (Farquharson, 1912). In India, it was first reported on American cotton (*G. hirsutum*) in Sriganganagar area of Rajasthan state (Ajmera, 1994).

The characteristic symptoms of CLCV disease are small vein thickening, upward and downward leaf curling or cupping, main vein thickening, development of leaf-like enations on the undersides of leaves (Qazi et al., 2007). In severe cases, reduction of internodal length leading to stunting and reduced flowering or fruiting and quality is also noted (Majeed et al., 1999). Infection of CLCV disease at seedling stage is very much destructive causing enormous yield losses (Kirkpatrick and Rothrock, 2001).

Cotton (*Gossypium hirsutum*) is an important crop cultivated throughout the world for fiber, feed, fuel and food (Chakravarthy et al., 2014). India occupying the largest production area of cotton, covering about 13 million ha with production and productivity of 37.1 million bales and 487 kg ha^{-1}, respectively, contributes world's 26% cotton production at 41% land devoted to cotton cultivation with 23% consumption (Anonymous, 2021a). It plays a dominant role in the industrial and agricultural economy of the country. It provides employment to over 51 million people directly and 68 million people indirectly, including unskilled women in India (Anonymous, 2021b). Due to its immense economic importance, it is also called "white gold". Cotton has multipurpose uses and it provides basic products like hulls, lint, linters, meal and oil (Desrochers and Szurmak, 2017). The North Zone of India covers 12% of the cotton area and 17% production (Anonymous 2019). Rajasthan also play a pivotal role in American cotton cultivation by covering 4.94 lakh ha area with production of 16.87 lakh bales and productivity of 580 kg ha^{-1} (Anonymous, 2018).

Per hectare yield of cotton in India is still lower against the world average of about 768 kg ha^{-1} (Anonymous, 2021a). Among the various biotic and abiotic factors responsible for its low production and productivity during the last two decade, cotton leaf curl virus (CLCV) disease has been found to be one of the major limiting factor (Humza et al., 2016).

CLCV disease is a serious constraint in cultivation of cotton, affected the production adversely which leads to deterioration of fiber quality and yield (Farooq et al., 2014; Vyas et al., 2017). Due to the wide proliferation and destructive nature of the CLCV disease, an attempt has been made to survey the cotton fields in North-West part of Rajasthan covering Sriganganagar and Hanumangarh districts to find out situation of the disease in the area. Keeping in view of the seriousness of the disease, a field research trial was conducted at Agricultural Research Station, Sriganganagar (Rajasthan) to evolve effective management strategy for CLCV disease. For this, insect growth regulator (IGR), insecticides and fungicide were selected for eco-friendly management of the disease.

2. Materials and Methods

2.1. Field survey

As the cotton crop occupies sizable area only in two districts *viz*., Sriganganagar and Hanumangarh which comprises North-West part of Rajasthan, the detail survey to find out the severity of CLCV disease at farmer fields and research farm was undertaken during the *kharif* season 2009. The cotton fields of 62 villages or Chaks covering 7 tehsils of Sriganganagar and 7 tehsils of Hanumangarh district were surveyed. The disease observations were taken on 100 randomly selected plants in each cotton field using 0-6 disease rating scale (Akthar et al., 2010) where: 0=Complete absence of symptoms; 1=Symptoms of vein thickening on a few upper leaves; 2=Symptoms of vein thickening, cupping and curling on few upper leaves; 3=25% plant affected with vein thickening, cupping, and curling, leafy enations; 4=50% plant affected with vein thickening, cupping, and curling, leafy enations; 5=75% plant affected with vein thickening, cupping, and curling, leafy enation; 6=plants stunted severely and complete plant affected with vein thickening, cupping and curling, and leafy enation.

Percent disease intensity (PDI) was calculated by using the following formula (Gaur and Sharma, 2010):

PDI=(∑ All numerical ratings/Total No. of plants observed× Maximum disease rating)×100

2.2. Management of cotton leaf curl virus (*CLCV*) *disease*

A field trial was laid out at Agricultural Research Station (S.K. Rajasthan Agricultural University), Sriganganagar (Rajasthan) to test the efficacy of different insect growth regulators (Buprofezin 20% WP, Buprofezin 25% SC), fungicides (Kresoxim methyl 15% WG, Kresoxim methyl 50% SC) and insecticides (Acephate 50% WP, Acephate 60% WP, Acephate 75% SP, Spinetoram 12% SC) and their different combinations in controlling the CLCV disease using susceptible cultivar RCH-134 Bt for two consecutive crop seasons (2010 and 2011). The treatments of foliar application were as: (i) Buprofezin 20% WP+Acephate 50% WP (250+625 g a.i. ha^{-1}), (ii) Buprofezin 25% SC (250 g a.i. ha^{-1}), (iii) Acephate 60% WP+Kresoxim methyl 15% WG (750+187.5 g. a.i. ha^{-1}), (iv) Kresoxim methyl 50% SC (187.5 g a.i. ha^{-1}), (v) Acephate 75% SP (562.5 g a.i. ha^{-1}), (vi) Acephate 75% SP (750 g a.i. ha^{-1}), (vii) Spinetoram 12% SC (36 g a.i. ha^{-1}), (viii) Spinetoram 12% SC (48 g a.i. ha^{-1}) and (ix) control (only water). The experiment was framed in randomized block design with three replications.

Data regarding CLCV disease severity was recorded on the basis of symptom appearance using the 0-6 disease rating scale as described earlier and calculated as per cent disease intensity (PDI). The incidence (%) of the disease was worked out on the basis of total plants observed. The Data were statistically analyzed using ANOVA. Per cent disease reduction (PDR) over control was calculated (Sharma et al., 2009) as:

PDR=(PDI in Control-PDI in treatment/PDI in control)×100

3. Results and Discussion

3.1. Disease severity

It was observed that Sriganganagar district was having higher average disease intensity (8.92%) as compared to Hanumangarh district (3.25). The range of disease intensity in different fields of cotton in Sriganganagar district was also very high reaching to the level of 0–100%. Whereas, in Hanumangarh district the disease ranged between 0–32.3% only (Table 1).

Out of 7 tehsils surveyed in Sriganganagar district, Sriganganagar tehsil was found to be heavily invaded by leaf curl virus showing average disease intensity of 45% within the range of 6.3–100%. Srikaranpur tehsil was next in order of disease intensity. But the intensity level was only 9.7% and disease ranged between 0–19.7% only. Minimum disease intensity was recorded in Anupgarh (0.3%) tehsil of the district. Two tehsils (Suratgarh and Raisinghnagar) were found free from leaf curl attack.

In Sriganganagar tehsil which showed highest leaf curl intensity (45%) among all, five villages *viz*., Kathlabana, Shivepurhead, Sadhuwali, Sujawalpur and Hindumalkot together form hot zone for leaf curl disease. The average disease intensity in this zone was between 66.3–78% and range of leaf curl intensity in different fields in this zone was between 50–86.8%. Frequent availability of irrigation water in this area and high population of weeds in cotton fields and adjoining area might be responsible for aggravated the disease as these conditions are favourable for survival and development of the white fly (*Bemisia tabaci*), the vector of cotton leaf curl virus.

However, the common cotton cultivars *viz*. RCH- 134, 6488, JKCH-1947 which were growing at cultivators fields when

Table 1: Prevalence of cotton leaf curl virus (CLCV) disease in Rajasthan during 2009

Sl. No.	District	Tehsil	Village or Chak	CLCV (PDI)	
				Average	Range
1.		Sriganganagar	1Y	22.6	13.2-30
2.			2Y	22.4	12.5-32.3
3.			3Y	45.8	45-48.8
4.			9Y	14.4	12.5-16.3
5.			Kalya	54.6	50-58.3
6.			Kathlabana	70.0	62.5-77.5
7.			Shivpur head	78.0	70.5-85.0
8.			Sadhuwali	71.4	50-86.8
9.			Sujawalpur	66.3	52.5-80.0
10.			Hindumalkot	65.4	56.8-82.5
11.			12 Z	12.2	6.3-20.0
12.			Mirzewala	12.9	7.5-23.8
13.			13Q	15.7	8.8-52.3
14.			Daulatpura (3Q)	30.2	9.3-69.0
15.			7Q	51.9	49.5-54.3
16.			6Q	52.8	50-55
17.			23ML	36.1	20.2-52.0
18.			24ML	44.7	7.5-71.7
19.			ARS Farm	87.6	62.9-100
		Tehsil average	45.0	6.3-100	
20.	Sriganganagar	Srikaranpur	10 W	7.5	0-15
21.			Kaminpura	6.3	0-18.8
22.			Naggi	15.2	0-19.7
		Tehsil average	9.7	0-19.7	
23.		Raisinghnagar	1 PTD	0	0
24.			Kikarwali	0	0
25.			Bhompura	0	0
		Tehsil average	0	0	
26.		Padampur	Rattaiwala	1.5	0-5.7
27.			Swantsar	0.8	0-1.5
28.			Ghamurwali	0.5	0-2.0
		Tehsil average	0.9	0-5.7	
29.		Anupgarh	Salimpura	0	0
30.			Samejakhoti	0.8	0-1.5
		Tehsil average	0.3	0-1.5	
31.		Sadulsahar	Mammar	0.5	0-2
32.			Lalgarh	1.5	0-5
33.			Banwali	1.5	0-5
		Tehsil average	1.2	0-5	

Table 1: Continue...

Sl. No.	District	Tehsil	Village or Chak	CLCV (PDI)	
				Average	Range
34.		Suratgarh	Paliwala	0	0
35.			Manaksar	0	0
			Tehsil average	0	0
		District average		8.92	0-100
36.		Hanumangarh	Jhandawali	10.7	2.3-24.5
37.			15HMH	21.8	12.3-31.3
38.			NandramkiDhani	0	0
39.			Jhamber	0	0
40.			Masani	0	0
41.			Makkasar	4.7	0-9.3
42.			18HMH	10.5	9.5-11.5
43.			Jodkian	0	0
44.			Naurangdaisar	0	0
45.			Dalia	17.9	9.7-32.3
		Tehsil average	6.6	0-32.3	
46.		Pelibanga	Khotanwali	0	0
47.	Hanumangarh		Goluwala	5.4	0-10.7
		Tehsil average	2.7	0-10.7	
48.		Tibi	Kamrani	8.5	2.3-10.8
49.			Tibi	2.3	0-4.5
50.			Sherakhan	0	0
51.			Silwana	0	0
		Tehsil average	2.7	0-10.8	
52.		Rawatsar	3RWB	7.7	6.8-8.5
53.			Munda	0	0
		Tehsil average	3.9	0-8.5	
54.		Nohar	Jhajarwas	5.5	0-11.5
55.			Faifana	2.5	0-3.5
56.			Pandusar	0	0
		Tehsil average	2.7	0-3.5	
57.		Bhadra	Chhanibari	0	0
58.			Nangal	0	0
		Tehsil average	0	0	
59.		Sangaria	Santpura	18.1	5-46
60.			Bhakarawali	5.4	0-20.3
61.			Nukera	1.5	0-7.5
62.			Indergarh/ Rasuwala	0	0
			Tehsil average	6.3	0-20.3
		District average		3.25	0-32.3

observed at Research farm of Agricultural Research Station (ARS), indicated much higher leaf curl intensity compared to under farmers fields. At Research farm, the average leaf curl intensity was 87.6% with the range of 62.9–100%. This higher disease intensity may be attributed due to continuous inoculums build up at farm because of planting of large number of susceptible material year after year.

Hanumangarh district indicated only 3.25% average leaf curl intensity ranging between 0–32.3%. Hanumangarh tehsil and Sangaria tehsil showed average leaf curl intensity of 6.3 to 6.6%. However, range of leaf curl intensity in Hanumangarh tehsil was higher i.e. 0–32.3% compared to 0–20.3% in Sangaria tehsil. Bhadra tehsil was found completely free from leaf curl attack. In four tehsils of the district *viz*., Pelibanga, Tibi, Nohar and Rawatsar, the average disease intensity ranged from 2.7–3.9% only. The range of disease intensity was high (0-10.8 %) in Tibi tehsil.

The overall leaf curl disease situation in both the districts indicated severe attack (25-50%) in Sriganganagar tehsil, moderate attack (5.1–25%) in Srikaranpur, Sangaria and Hanumangarh tehsil, low level (1.1–5%) attack in Sadulsahar, Tibi and Nohar tehsil and traces level (0–1%) attack in Bhadra, Anupgarh, Raisinghnagar, Padampur and Suratgarh tehsil .

3.2. Management of cotton leaf curl virus (*CLCV*) *disease*

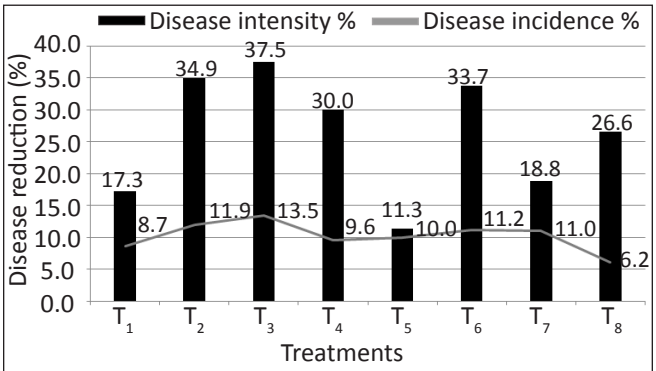
On the basis of pooled data of two years (2010 and 2011), it was evident that minimum disease intensity (31.5%) and maximum reduction in disease intensity over control (37.5%) were observed in foliar treatmentof Acephate 60% WP+Kresoxim methyl 15% WG @ 750+187.5 g a.i. ha^{-1} followed by Buprofezin 25% SC @ 250 g a.i. ha^{-1} and Acephate 75% SP @ 750 g a.i. ha^{-1} exhibited 32.8 and 33.4% disease intensity and rendered 34.9 and 33.7% protection from the disease as compared to control. Foliar spray of Kresoxim methyl and Spinetoram were found next in order of efficacy in controlling the disease. Rest of the treatments showed low to moderate efficacy against the disease.

As far as disease incidence is concerned, minimum disease incidence (45.0%) and maximum reduction in disease incidence over control (13.5%) was observed in treatment where foliar spray of Acephate 60% WP+Kresoxim methyl 15% WG @ 750+187.5 g a.i. ha^{-1} was done. Next best treatments were Buprofezin 25% SC @ 250 g a.i. ha^{-1} and Acephate 75% SP @ 750 g a.i. ha^{-1} providing 11.9 and 11.2% protection from the disease compared to control. Rest of the treatments exhibited low to moderate potential in controlling the disease (Table 2 and Figure 1).

Present results are in agreement with those who estimated annual CLCV disease incidences as 37.5, 63.6 and 38.8% in three North-West Indian states *viz*., Haryana, Punjab and Rajasthan, respectively (Bhattacharyya et al., 2017; Nenavath et al., 2017; Biswas et al*.,* 2020). The CLCV disease management can be done through control of its vector (white fly). Similar to present findings, the efficacy of Acephate and

Table 2: Effect of different insect growth regulator (IGR), fungicide and insecticides on cotton leaf curl virus disease severity and incidence

Sl. No.	Treatment	Dose (g a.i. ha^{-1})	PDI	Disease Incidence (%)
			Pooled (2010-11)	Pooled (2010-11)
1.	Buprofezin 20% WP+Acephate 50% WP	250+625	41.7 (39.1)	47.5 (42.0)
2.	Buprofezin 25% SC	250	32.8 (32.3)	45.8 (39.0)
3.	Acephate 60% WP+Kresoxim methyl 15% WG	750+187.5	31.5 (30.3)	45.0 (39.2)
4.	Kresoxim methyl 50% SC	187.5	35.3 (32.2)	47.0 (40.4)
5.	Acephate 75% SP	562.5	44.7 (41.3)	46.8 (41.0)
6.	Acephate 75% SP	750	33.4 (28.3)	46.2 (38.0)
7.	Spinetoram 12% SC	36	40.9 (38.3)	46.3 (40.3)
8.	Spinetoram 12% SC	48	37.0 (33.4)	48.8 (42.4)
9.	Untreated control	-	50.4 (45.4)	52.0 (48.9)
CD (p=0.05)			8.94	8.41
CV (%)			9.81	8.47



T_1: Buprofezin 20% WP+Acephate 50% WP (250 + 625 g a.i/ ha^{-1}); T_2: Buprofezin 25% SC (250 g a.i. ha^{-1}); T_3: Acephate 60% WP+Kresoxim methyl 15% WG (750+187.5 g a.i. ha^{-1}); T_4: Kresoxim methyl 50% SC (187.5 g a.i. ha^{-1}); T_5: Acephate 75% SP (562.5 g a.i. ha^{-1}); T_6: Acephate 75% SP (750 g a.i. ha^{-1}); T_7: Spinetoram 12% SC (36 g a.i. ha^{-1}); T_8: Spinetoram 12% SC (48 g a.i. ha^{-1})

Figure 1: Per cent reduction in cotton leaf curl virus disease over control under different treatments

Buprofezin against the vector (white fly) of the CLCV disease has already been established (Ali et al., 2005; Anonymous, 2010) who reported Acephate and Buprofezin to be effective in reducing the white fly population. Buprofezin is the first insect growth regulator in the world which inhibits chitin formation thereby causing abnormal endocuticular deposition and abortive molting. As a result of chitin deficiency, the procuticle of the insects loses its elasticity and the insect is unable to complete the molting process which leads to death of insect (De Cock and Degheele, 1998). The difference among efficacy of different insecticides against cotton white fly is mainly due to different locations and agro-climatic conditions of their experiment.

4. Conclusion

The present findings revealed that cotton leaf curl virus disease is a major constraint in the cotton cultivation in North-West part of Rajasthan ranging from 0 to 100% intensity. Though the foliar sprays of Acephate + Kresoxim methyl (750+187.5 g a.i. ha^{-1}) proved most effective against the disease, Acephate is no more in use. Thus, foliar sprays of Buprofezin (250 g a.i. ha^{-1}) may be recommended for the eco-friendly management of the disease.

5. References

Ajmera, B.D., 1994. Occurrence of leaf curl virus on American Cotton (*G. hirsutum*) in North Rajasthan. Paper presentation in 'National Seminar on Cotton Production Challenges in 21st Century' held during 18-20 April, 1994 at Hisar, India.

Ali, M.A., Rafiq-ur-Rehman, R., Tatla, Y.H., Ali, Z., 2005. Evaluation of different insecticides for the control of whitefly on cotton crop in Karor district Layyah. Pakistan Entomologist 27(1), 5–8.

Anonymous, 2010. Annual report of all India co-ordinated cotton improvement project for the year 2009–10 (Entomology report), Coimbatore-641 003 (Tamil Nadu).

Anonymous, 2019. Annual report, 2018-19. ICAR-All India Co-ordinated research project on cotton, Coimbatore-641 003 (Tamil Nadu).

Anonymous, 2021a. National cotton scenario. Website of cotton corporation of India: https://cotcorp.org.in.

Anonymous, 2021b. *Overview:* Cotton industry and Exports. India Brand Equity Foundation(IBEF). Website: www.ibef.org.

Anonymous, 2018. Rajasthan agricultural statistics at a glance 2017–18, 98p.

Bhattacharyya, U.K., Godara, S., Kumar, P., Monga, D., Biswas, K.K., 2017. Recent status and distribution pattern of cotton leaf curl disease in North-West India: An alarming situation in future cotton cultivation. The Indian Journal of Agricultural Sciences 87(5), 624–33.

Biswas, K.K., Bhattacharyya, U.K., Palchoudhury, S., Balram, N., Kumar, A., Arora, R., 2020. Dominance of recombinant cotton leaf curl Multan-Rajasthan virus associated with cotton leaf curl disease outbreak in North-West India. PLoS ONE 15(4), e0231886. https://doi.org/10.1371/journal.pone.0231886.

Chakravarthy, V.S., Reddy, T.P., Reddy, V.D., Rao, K.V., 2014. Current status of genetic engineering in cotton (*Gossypium hirsutum*): An assessment. Critical Reviews in Biotechnology 34(2), 144–160.

De Cock, A., Degheele, D., 1998. Buprofezin: A novel chitin synthesis inhibitor affecting specially plant hoppers, white fly and scale insects. In: Ishaaya, I., Degheele, D. (Eds.), Insecticides with novel modes of action. Applied agriculture. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-03565-8-5. PP 74–91.

Desrochers, P., Szurmak, J., 2017. Long distance trade, locational dynamics and by-product development: Insights from the history of the American cottonseed industry. Sustainability 9, 579–607.

Farooq J., Farook, A., Riaz, M., Shahid, M.R., Saeed, F., Iqbal, M.S., Hussain, T., Batool, A., Mahmood, A., 2014. Cotton leaf curl virus disease a principal cause of decline in cotton productivity in Pakistan (a mini review). Canadian Journal of Plant Protection 2(1), 9–16.

Farquharson, C., 1912. Report of mycologist. Report of Mycologist.

Gaur, R.B., Sharma, R.N., 2010. Prevalence of canker in Kinnow (*Citrus deliciosa* Ten.) and its management. Indian Phytopathology 63(3), 345–347.

Ha, C., Coombs, S., Revill, P., Harding, R., Vu, M., Dale, J., 2008. Molecular characterization of begomoviruses and DNA satellites from vietnam: Additional evidence that the new world geminiviruses were present in the old world prior to continental separation. Journal of General Virology 89(1), 312–326.

Hasan, I., Rasul,S., Malik, T.H., Qureshi, M.K., Aslam, K., Shabbier, G., Habib-ur-Rehman Athar, H.R., Manzoor, H., 2019. Present status of cotton leaf curl virus disease (CLCUVD): a major threat to cotton production. International Journal of Cotton Research and Technology 1(1), 1–13.

Humza, M., Iqbal, B., Ali, S., 2016. Management of cotton leaf curl virus disease and its vector through *in vivo* evaluation of organic nutritional amendments, organic oils and insecticides. Journal of Plant Pathology and Microbiology 7(12), 387–391.

Kirkpatrick, T.L., Rothrock, C.K., 2001. Compendiumof cotton diseases (2nd Ed.). The American Phytopathological Society, Minnesota, 100 p.

Kumar, R., Sain, S.K., Monga, D., Kranthi, S., Nagrare, V.S., Kranthi, 2016. White fly and cotton leaf curl disease management strategies for cotton in North India. ICAR-CICR Technical Bulletin No. 1/2016. pp. 1–12.

Leke, W.N., Mignouna, D.B., Brown, J.K., Kvarnheden, A., 2015. Begomo virus disease complex: Emerging threat

to vegetable production systems ofWest and Central Africa. Agriculture Food Security 4(1), 1–17.

Majeed, A., Husnain, T., Riazuddin, S., 1999. Transformation of virus-resistant *Gossypium hirsutum* L. genotype CIM-443 with pesticidal gene. Plant Biotechnology 17(2), 105–110.

Nenavath, B., Bhattacharyya, U.K., Sharma, A., Kumar, P., Raheja, S., Arora, R., Kumar, A., Palchoudhury, S., Monga, D., Biswas, K.K., 2017. Current distribution and severity of leaf curl Begomovirus disease in cotton growing areas of North-West India. Journal of Mycology and Plant Pathology 47(3), 259–272.

Nogia, V.K., Singh, V., Meghwal, R.R., 2014. Effect of cotton leaf curl virus infected plants on the biology of the whitefly, *Bemisiatabaci* (*Hemiptera: Aleyrodidae*): Vector–virus mutualism. Phytoparasitica 42(5), 619-625.

Qazi, J., Amin, I., Mansoor, S., Iqbal, M.J., Briddon, R.W., 2007. Contribution of the satellite encoded gene βc1 to cotton leaf curl disease symptoms. Virus Research 128(1-2), 135–139.

Ruiz, L., Janssen, D., Martin, G., Velasco, L., Segundo, E., Cuadrado, J.P., 2006. Analysis of the temporal and spatial disease progress of *Bemisiatabaci* transmitted cucurbit yellow stunting disorder virus and cucumber vein yellowing virus in cucumber. Plant Pathology 55(2), 264–275.

Sattar, M.N., Iqbal, Z., Tahir, M.N., Ullah, S., 2017. The prediction of a new CLCuD epidemic in the old world. Frontiers in Microbiology 8, 631, https://doi.org/10.3389/fmicb.2017. 00631.

Sharma, R.N., Maharshi, R.P., Gaur, R.B., 2009. Bioefficacyofphytoextracts in controlling post-harvest blue mould rot (*Penicillium italicum*) of kinnow (*Citrus deliciosa*) fruits. Journal of Mycology and Plant Pathology 39(3), 480–483.

Singh, J., Sohi, A.S., Brar, D.S., Denholm, I., Russell, D., Briddon, R., 1998. Management of cotton leaf curl virus disease in India. Proceedings of the world cotton research conference-2, Athens, Greece, September 6–12, 1998, 941–944.

Vyas, M., Raza, A., Ali, M.Y., Ashraf, M.A., Mansoor, S., Shahid, A.A., Brown, J.K., 2017. Knock down of whitefly gut gene expression and mortality by orally delivered gut gene-specific dsrnas. PloS one 12(1), e0168921.

Xiong, Z., Nadeem, A., Weng, Z., Nelson, M., 2004. Cotton leaf curl virus is distinct from cotton leaf crumple virus. University of Arizona, 25–55.

Zerbini, F.M., Briddon, R.W., Idris, A., Martin, D.P., Moriones, E., Navas-Castillo, J., Rivera-Bustamante, R., Roumagnac, P., Varsani, A., 2017. ICTV virus taxonomy profile: geminiviridae. Journal of General Virology 98, 131–133.