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Integrated Approach for the Management of Chilli Leaf Curl Virus (ChiLCV) Disease of Chilli (*Capsicum annuum* L.)

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ABSTRACT

Chilli leaf curl virus (ChiLCV) disease caused by Begomovirus (family Geminiviridae) has emerged as a serious threat to the successful cultivation chilli (*Capsicum annuum* L.) production in India and worldwide, which is drastically decreases yield. An integrated approach was developed for the management of ChiLCV disease of chilli using strategies such as growing border crop, use of reflective mulches, soil application of organic amendment and the spray of insecticides for management of the vector. The results of the experiments from the three years pooled data, pesticides with label claims, yield and cost-benefit ratio indicated that treatment comprising application of neem cake @ 1.0 kg/m² in the seedbed, covering of nursery with 40 mesh white nylon net, spraying of Cyantraniliprole 10.26 OD @ 1.2 ml/l three days before transplanting, seedling dip of Imidacloprid 17.8 SL @ 0.5 ml/l and planting of two rows of maize border crop in the main field along with sliver agrimulch sheet and the spray of Cyantraniliprole 10.26 OD @ 1.2 ml/l at seven days interval till fruit formation was found significantly superior over control in terms of per cent leaf curl incidence (4.02 %) and green fruit yield (136.40 q/ha) with better cost-benefit ratio (1:2.10). This integrated approach is safe and ecologically sound and seems to be a healthy tactic for disease management.

Keywords: Chilli leaf curl virus, Chilli, Cyantraniliprole, Border crop, Sliver agrimulch.

INTRODUCTION

Chilli (*Capsicum annuum* L.) is one of the most important constituents of the foods of tropical and subtropical countries and the fourth major crop cultivated worldwide. Their characteristics such as pungency, colour, aroma and flavour are desirable in a variety of culinary dishes around the world, which make them widely appreciated. Chilli is susceptible to various pathogens including viruses, which

can cause heavy production losses. So far 65 viruses have been reported, including begomoviruses causing chilli leaf curl virus (ChiLCV) disease infecting chilli throughout the world (Nigam et al., 2015). ChiLCV disease is the most destructive virus in terms of incidence and yield loss. In severe cases, 100 per cent losses of marketable fruit have been reported (Senanayake et al., 2007; Kumar et al., 2011a, b; & Senanayake et al., 2012).

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The characteristic symptoms of ChiLCV disease include upward curling, reduced size of leaves, puckering, stunted growth with no flowers and fruits in severely affected plants (Thakur et al., 2018). Begomoviruses are transmitted by the whitefly, *Bemisia tabaci*, and have circular single stranded one (i.e. monopartite, DNA-A) or two (i.e. bipartite, DNA-A and DNA-B) component genomes ranging in size from ~2.7 Kb (for monopartite species) to ~5.4 Kb (for bipartite species) (Prasanna et al., 2010). Till date, genome sequence of four begomoviruses infecting chilli, viz, Chilli leaf curl virus (ChiLCV), Tomato leaf curl New Delhi virus (ToLCNDV), Tomato leaf curl Joydebpur virus (ToLCJV) and Chilli leaf curl Palampur virus (ChiLCPV) has been characterized in India (Khan et al., 2006; Shih et al., 2006; & Kumar et al., 2011a,b). Chavan et al. (2010) recently identified Tomato Leaf Curl Virus (ToLCV) strain causing leaf curl disease in Tomato and Chilli in Maharashtra results in 90-100% yield loss.

The most effective management outlines that reduce whitefly populations and limit virus spread are those that use multiple approaches simultaneously. As for most pests, always ensure that transplants are free of both viruses and vectors before planting. Transplants should be produced in virus-free locations when possible. Alternative management strategies, such as the use of reflective mulches and insecticidal control of the vector, have also been shown to work best when implemented in a coordinated combination of approaches. Reflective metallic mulch is shown to reduce the incidence of pest species including whiteflies

(Csizinszky et al., 1999; Nyoike et al., 2008; & Simmons et al., 2010). Among the various methods of pest management, the use of insecticides forms the first line of defence against the insect vectors. Newer insecticide molecules are a better alternative to conventional synthetic insecticides in the context of environmentally kind management strategies so also to mitigate the adverse effect on the total environment.

The present studies were undertaken by keeping in view the importance of management of whitefly, since it is a potential vector of chilli leaf curl virus disease, with different strategies such as growing border crop, use of reflective mulches, soil application of organic amendment and spray of insecticides.

MATERIALS AND METHODS

The experiment was conducted at All India Coordinated Research Project (Vegetable Crops), Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India during the three consecutive year 2014-15, 2015-16 and 2016-17 in *Kharif* seasons using chilli cv. Pusa Jwala for the management of vector borne chilli leaf curl virus (ChiLCV) disease of chilli. The soil of the experimental field was black cotton soil. The experiment was laid out in a randomized block design with four replications consisting of six treatment combinations as shown below. The plot size was 2.4 x 3.15 m. Forty-five days old seedlings raised in the nursery were transplanted at a distance of 60 x 45 cm spacing. All recommended agronomic cultural practices were followed.

Details of various treatments used for the management of ChiLCV disease of chilli

- T₁ Spray of Acephate 75 SP @ 1.5 g/l+ Neem oil @ 2.0 ml/l at 7 days interval till fruit formation
- T₂ Spray of Fipronil 5 SC @ 1.0 ml/l+ Neem oil @ 2.0 ml/l at 7 days interval till fruit formation
- T₃ Spray of Imidacloprid 70 WG @ 2 g/15 l + Neem oil @ 2.0 ml/l at 7 days interval till fruit formation
- T₄ Spray of Cyantraniliprole 10.26 OD @ 1.2 ml/l at 7 days interval till fruit formation
- T₅ Spray of rotation of T₁ + T₂ + T₃ +T₄ sequential application at 7 days interval till fruit formation
- T₆ Control

Common to all treatments: Application of neem cake @ 1.0 kg/m² in the seedbed, covering of nursery with 40 mesh white nylon net, spraying of Cyantraniliprole 10.26 OD @ 1.2 ml/l three days before transplanting, seedling dip of Imidacloprid 17.8 SL @ 0.5 ml/l for 15 minutes and growing of two rows of maize as border crop in the main field 15 days before transplanting along with sliver agrimulch sheet. Treatment sprays were applied till fruit formation on crop.

Observations on leaf curl incidence, number of whitefly were recorded at seven days intervals starting from seven days after transplanting (DAT) upto the fruit formation and statistically analysed. Plot wise chilli fruit yield (recorded at each picking) were cumulated and converted into quintal/hectare and statistically analysed. Per cent disease incidence was calculated by using the following formula.

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

RESULT AND DISCUSSION

Reduction in leaf curl incidence

The data presented in Table 1 showed that all the Integrated management treatments recorded significant reduction in per cent disease incidence during all the years experimentation and on pooled mean basis. Treatment combinations (T4) of application of neem cake @ 1.0 kg/m² in the seedbed, covering of nursery with 40 mesh white nylon net, spraying of Cyantraniliprole 10.26 OD @ 1.2 ml/l three days before transplanting, seedling dip of Imidacloprid 17.8 SL @ 0.5ml/l and growing of two rows of maize border crop in the main field along with sliver agrimulch sheet and spray of Cyantraniliprole 10.26 OD @ 1.2 ml/l recorded significantly lowest per cent ChiLCV disease incidence during all the years and on pooled mean basis (4.02%). It was found significantly superior over all other treatments. This was followed by treatment T5 (6.88%), T2 (7.26%) and T1 (8.04%) which was at par with each other. The control recorded highest incidence of ChiLCV (17.51%).

Reduction in whitefly population

The data presented in Table 2 showed that all the Integrated management treatments recorded significant reduction in whitefly population during all the years experimentation and on pooled mean basis. Treatment combinations (application of neem

cake @ 1.0 kg/m² in the seed bed, covering of nursery with 40 mesh white nylon net, spraying of Cyantraniliprole 10.26 OD @ 1.2 ml/l three days before transplanting, seedling dip of Imidacloprid 17.8 SL @ 0.5ml/l and growing of two rows of maize border crop in the main field along with sliver agrimulch sheet) and spray of Cyantraniliprole 10.26 OD @ 1.2 ml/l recorded significantly lowest whitefly population during all the years and on pooled mean basis (1.15). It was found significantly superior over all other treatments. This was followed by treatment T5 (2.74), whereas treatment T2 (3.71) and T1 (3.91) was on par with each other. The control recorded highest whitefly population (8.50).

Yield and economics

All the Integrated management treatments recorded a significant increase in chilli green fruit yield during all the years experimentation and on pooled mean basis (Table 3). Treatment combinations (T4) of application of neem cake @ 1.0 kg/m² in the seed bed, covering of nursery with 40 mesh white nylon net, spraying of Cyantraniliprole 10.26 OD @ 1.2 ml/l three days before transplanting, seedling dip of Imidacloprid 17.8 SL @ 0.5 ml/l and growing of two rows of maize border crop in the main field along with sliver agrimulch sheet and spray of Cyantraniliprole 10 OD @ 1.2 ml/l recorded significantly highest chilli green fruit yield during all the years and on

pooled mean basis (136.40 q/ha). It was found significantly superior over all other treatments. This was followed by treatment T5 (115.25 q/ha), whereas T2 (98.86 q/ha) and T1 (98.21 q/ha) which was at par with each other. The control recorded lowest fruit yield (75.02 q/ha).

The data presented in Table 4 showed that the highest cost benefit ratio (1:2.21) was achieved with the treatment combinations (T5) of application of neem cake @ 1.0 kg/m² in the seedbed, covering of nursery with 40 mesh white nylon net, spraying of Cyantraniliprole 10.26 OD @ 1.2 ml/l three days before transplanting, seedling dip of Imidacloprid 17.8 SL @ 0.5 ml/l and growing of two rows of maize border crop in the main field along with sliver agrimulch sheet and the sequential application of Acephate 75 SP, Fipronil 5 SC, Imidacloprid 70 WG along with Neem oil and Cyantraniliprole 10.26 OD. This was followed by treatment T4 (1:2.10), T1 (1:2.09), T2 (1:2.04) and T3 (1:2.04). However, Cyantraniliprole 10.26 OD and Fipronil 5 SC has label claim on chilli, whereas, Acephate 75 SP and Imidacloprid 70 WG do not have label claim. Hence, treatment T4 was considered for integrated disease management based on label claim and cost benefit ratio (1:2.10).

The results are in conformity with Sastry et al. (1977), Raghupathi and Sabitha (1994) and Swathi and Gaur (2017) who observed the disease spread can be minimised by growing border crop like maize before transplanting vegetable crop which prevents incoming viruliferous whiteflies from entering into the crop. Several studies demonstrated are reduction in infestation by insect pests and incidence of insect-vectored viral infection in vegetable crops by the use of reflective mulch. Silver or grey reflective mulches have been used successfully to delay and reduce the incidence of vector borne virus diseases in crops (Brown et al., 1993; Stapleton & Summers, 2002; Summers & Stapleton, 1999,

2002; & Kousik et al., 2008). Similar result was observed by Sarkar et al. (2018) at the coastal zone of Odisha in the management of chilli leaf curl virus disease in through integrated approach (4.90%). Cyantraniliprole is a second generation new anthranilic diamide molecule with broad spectrum activity against insect pests (Selby et al., 2013). Cyantraniliprole is a xylem systemic insecticide with translaminar activity and having root systemicity and foliar penetration, that has demonstrated cross-spectrum activity on chewing and sucking arthropod pests (Tiwari & Stelinski, 2013; & Barry et al., 2014). High susceptibility of whitefly to cyantraniliprole may be attributed to unique mode of action of this new molecule which activates ryanodine receptors (RyRs) and cause an uncontrolled release of Ca⁺² ions which leads to muscle paralysis and death (Cordova et al., 2006; & Sattelle et al., 2008). Cyantraniliprole has high potency on key whitefly species, including *Bemisia tabaci* (Castle et al., 2009; Palumbo, 2009, 2010; & Stansly et al., 2010). Not much literature is available on the toxicity of cyantraniliprole against whitefly on chilli.

The present findings were also in conformity with the results of Jacobson et al. (2011), Fettig et al. (2011), Caballero et al. (2015), Kodandaram et al. (2015), Dale and Borden (2018) and Mirala and Gopali (2019) who reported the effectiveness of cyantraniliprole against other insect pests of various host plants. The unique mode of action of cyantraniliprole on insect muscles induces rapid feeding cessation, resulting in inhibition of feeding damage, reproduction, and mobility, and as a consequence, reduction of virus transmission, which has been demonstrated on thrips, aphids, and whiteflies, vectors of Tospovirus, Potyvirus, and Begomovirus (TYLCV), respectively (Jacobson & Kennedy, 2011a, 2013a,b; & Cameron et al., 2014).

Table 1: Effect of integrated management on the incidence of leaf curl of chilli (Pooled data *kharif* 2014-15, 2015-16 and 2016-17)

Treatments Details		Leaf curl incidence (%)			
		2014-15	2015-16	2016-17	Pooled mean
T1	Spray of Acephate 75 SP @ 1.5 g/l+ Neem oil @ 2.0 ml/l at 7 days interval till fruit formation	3.69 (11.03)*	11.06 (19.36)	9.37 (17.75)	8.04 (16.04)
T2	Spray of Fipronil 5 SC @ 1.0 ml/l+ Neem oil @ 2.0 ml/l at 7 days interval till fruit formation	3.35 (10.51)	10.40 (18.77)	8.01 (16.30)	7.26 (15.19)
T3	Spray of Imidacloprid 70 WG @ 2 g/15 l + Neem oil @ 2.0 ml/l at 7 days interval till fruit formation	4.79 (12.57)	14.21 (22.08)	11.58 (19.85)	10.19 (18.16)
T4	Spray of Cyantraniliprole 10.26 OD @ 1.2 ml/l at 7 days interval till fruit formation	0.69 (4.75)	6.82 (15.05)	4.54 (12.25)	4.02 (10.68)
T5	Spray of rotation of T ₁ + T ₂ + T ₃ +T ₄ sequential application at 7 days interval till fruit formation	2.93 (9.81)	10.07 (18.43)	7.65 (15.54)	6.88 (14.73)
T6	Control	8.21 (16.56)	23.98 (29.27)	20.35 (26.76)	17.51 (24.19)
	SEm ±	0.76	1.08	1.00	0.56
	CD at 5%	2.31	3.26	3.03	1.58
	CV %	13.96	10.56	11.02	11.65
* Figures in parenthesis are angular transformations					

Table 2: Effect of integrated management on the population of whitefly (Pooled data *kharif* 2014-15, 2015-16 and 2016-17)

Treatments Details		Number of whitefly/leaf			
		2014-15	2015-16	2016-17	Pooled mean
T1	Spray of Acephate 75 SP @ 1.5 g/l+ Neem oil @ 2.0 ml/l at 7 days interval till fruit formation	3.34 (1.82)*	4.18 (2.03)	4.22 (2.05)	3.91 (1.97)
T2	Spray of Fipronil 5 SC @ 1.0 ml/l+ Neem oil @ 2.0 ml/l at 7 days interval till fruit formation	3.08 (1.76)	4.01 (1.99)	4.03 (2.00)	3.71 (1.92)
T3	Spray of Imidacloprid 70 WG @ 2 g/15 l + Neem oil @ 2.0 ml/l at 7 days interval till fruit formation	4.43 (2.10)	4.83 (2.19)	4.73 (2.15)	4.66 (2.14)
T4	Spray of Cyantraniliprole 10.26 OD @ 1.2 ml/l at 7 days interval till fruit formation	0.84 (0.90)	1.33 (1.15)	1.28 (1.14)	1.15 (1.06)
T5	Spray of rotation of T ₁ + T ₂ + T ₃ +T ₄ sequential application at 7 days interval till fruit formation	2.92 (1.71)	2.67 (1.64)	2.63 (1.61)	2.74 (1.65)
T6	Control	7.27 (2.70)	9.15 (3.02)	9.09 (3.02)	8.50 (2.91)
	SEm ±	0.06	0.07	0.09	0.04
	CD at 5%	0.19	0.24	0.30	0.13
	CV %	6.67	7.60	9.80	8.32
* Figures in parenthesis are square root transformed values					

Table 3: Effect of integrated management on the green fruit yield of chilli (Pooled data *kharif* 2014-15, 2015-16 and 2016-17)

Treatments Details		Green fruit yield (q/ha)			
		2014-15	2015-16	2016-17	Pooled mean
T1	Spray of Acephate 75 SP @ 1.5 g/l+ Neem oil @ 2.0 ml/l at 7 days interval till fruit formation	106.63	81.03	93.86	98.21
T2	Spray of Fipronil 5 SC @ 1.0 ml/l+ Neem oil @ 2.0 ml/l at 7 days interval till fruit formation	109.39	83.59	96.69	98.86
T3	Spray of Imidacloprid 70 WG @ 2 g/15 l + Neem oil @ 2.0 ml/l at 7 days interval till fruit formation	103.24	79.76	92.19	94.83
T4	Spray of Cyantraniliprole 10.26 OD @ 1.2 ml/l at 7 days interval till fruit formation	145.51	120.03	134.58	136.40
T5	Spray of rotation of T ₁ + T ₂ + T ₃ +T ₄ sequential application at 7 days interval till fruit formation	120.63	101.87	115.89	115.25
T6	Control	84.66	58.10	71.72	75.02
	SEm ±	6.08	5.96	5.95	3.04
	CD at 5%	18.65	18.12	18.25	8.83
	CV %	10.99	13.77	18.05	10.44

Table 4: Cost-benefit ratio of leaf curl of chilli as affected by integrated management treatments

Treatment details		Total cost of treatment (Rs./ha)	Yield (q/ha)	Cost of production (Rs./ha)	Gross Income (Rs./ha)	Net Profit (Rs./ha)	Cost Benefit Ratio
T1	Spray of Acephate 75 SP @ 1.5 g/l+ Neem oil @ 2.0 ml/l at 7 days interval till fruit formation	6855	98.21	70705	147315	76610	1:2.08
T2	Spray of Fipronil 5 SC @ 1.0 ml/l+ Neem oil @ 2.0 ml/l at 7 days interval till fruit formation	8875	98.86	72787	148290	75503	1:2.04
T3	Spray of Imidacloprid 70 WG @ 2 g/15 l + Neem oil @ 2.0 ml/l at 7 days interval till fruit formation	6275	94.83	69804	142245	72441	1:2.04
T4	Spray of Cyantraniliprole 10.26 OD @ 1.2 ml/l at 7 days interval till fruit formation	30175	136.40	97653	204600	106947	1:2.10
T5	Spray of rotation of T ₁ + T ₂ + T ₃ +T ₄ sequential application at 7 days interval till fruit formation	11807	115.25	77276	172875	95599	1:2.24
T6	Control	-	75.02	61647	112530	50883	1:1.83

CONCLUSION

Considering the efficacy, insecticide label claim of Central Insecticides Board & Registration Committee (CIBRC) and economics, application of neem cake @ 1.0 kg/m² in the seedbed, covering of nursery with 40 mesh white nylon net, spraying of Cyantraniliprole 10.26 OD @ 1.2 ml/l three days before transplanting, seedling dip of Imidacloprid 17.8 SL @ 0.5 ml/l and growing of two rows of maize border crop in the main field along with sliver agrimulch sheet and five sprays of Cyantraniliprole 10.26 OD @ 1.2 ml/l at seven days interval till fruit formation was found significantly superior over control in terms of per cent leaf curl

incidence and green fruit yield with better cost benefit ratio.

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