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Research Article

Impacts of safer strategies for management of chilli pests with emphasis on under-storey repellent crop

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Abstract: Some safer strategies were designed and evaluated for management of apical leaf curling (ChiLCV) in chilli *Capsicum annum* L. and its vectors. The strategies were designed emphasizing on the repellent crop theory and the components like physical barrier, adult-trapping, plant sanitation, foliar application of phytochemicals and minimal application of synthetic organic pesticide. The crop was infested by some sucking pests namely, Chilli thrips *Scirtothrips dorsalis* Hood, aphid *Aphis gossypii* Glover, yellow mite *Polyphagotarsonemus latus* (Banks) and whitefly *Bemsia tabaci* (Gennadius). However, the populations of aphid and whiteflies were low and leaf curl virus which is vectored by any of the above creatures, did not appear in the present studies. Some management strategies were devised to suppress the pest populations as well as their damage and obtain good yields. However, strategies with phytochemical-based treatments which utilized neem seed kernel extract (NSKE) and rose apple *Syzygium Jambos* leaf extract (rose apple LE), could not offer satisfactory protection and yield was also quite low. But when these treatments had the support of a limited quantity of synthetic/semi-synthetic pesticides like emamectin benzoate (one application) and chlorfenapyr (one application) along with the plant fractions, showed much better suppression of pest populations like thrips and yellow mite as well as apical leaf curling intensity (0.94–1.12%). In all the treatments except chemical check and untreated check, some components were utilized as common part and these were: yellow sticky trap, repellent cropping with coriander and holy basil and plant sanitation. The strategies effectively suppressed the landing response and development of the pest populations which resulted in lower crop damages and sponsored good yields. These were safer to non-target beneficial creatures, cost-effective and comparable to chemical method.

Keywords: Chilli, leaf curling, pests, safer management

Introduction

Chilli (*Capsicum annum* L.) suffers from infestation by a number of pests but critical one that may lead to crop failure is the apical leaf curling problem. Feeding by insects like thrips *Scirtothrips dorsalis*, yellow mite *Polyphagotarsonemus latus*, aphid *Aphis gossypii* and white fly (*Bemisia tabaci*) may impart the curling or any one or more of the above mentioned species may vector chilli leaf curl virus (ChiLCV) (Venkatesh *et al*., 1998; Dhawan *et al*., 2002). Managing apical leaf curling in chilli through chemical method is a popular and widely preferred approach

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(Shivalingaswamy and Satpathy, 2007). It is now a quite common scenario that the farmers are applying pesticides once in every week. It has to be conceded that synthetic organic pesticides invite a large number of serious unintended consequences like environmental contamination, health hazards, instability of ecosystem, destruction of beneficial creatures, huge accumulation in biological systems, pesticide resistance, resurgence and replacement of pests, apart from the prohibitive cost of protection (Ramanjaneyulu *et al*., 2009). This sequence has pushed the entire farming community into a cloud of uncertainty and agony that requires immediate and stable solution. Safer, stable and effective solution for this problem can only be developed and standardized through a system of approach which considers the pests, plants and ecosystem altogether. Pest problem begins only after arrival of the pest on the target plants and hence, measures or approaches that deter or discourage pest arrival and its population development, in principle, should result in effective pest suppression. Keeping this proposition in mind, a pest management module was designed which emphasized on the role of repellent crop in deterring pest arrival and /or population development on chilli. The impact of the pest management modules on non-target beneficial creatures of the chilli ecosystem was also assessed.

Materials and Methods

Materials: Plant materials like chilli seeds *Capsicum annum* L. (Cultivar Bullet), coriander *Coriandrum sativum* L. seeds (local genotype) (Apiaceae), holy basil *Ocimum tenuiflorum* L. seeds (local genotype) (Lamiaceae), leaves of rose apple *Syzygium jambos* Alston (Myrtaceae) and neem seed kernel extract (NSKE) (40% ai) were used in the present study. Coriander and holy basil were selected as treatment component because both contain volatiles and are known to repel sucking insects like aphid, whitefly, jassid; in the present study, these were assumed to produce some allelochemicals that were likely to repel chilli pests. Chemicals-thiamethoxam (40EC), abamectin (1.8 EC), rynaxypyr (20 SC), emamectin benzoate (5 SG), chlorfenapyr (10 SC), as well as other materials such as yellow sticky trap (50cm x 25cm) and nylon net (red color were used in this study.

Preparation of rose apple leaf extract (rose apple LE**):** 5 kg fresh leaves were crushed in a blender and added to 5 L of hot water (100°C) (1:1 w/v). This mixture was kept in the shade for 24 h. A clear extract was obtained by sieving. This extract was used as the stock solution.

Methods: The experiments were carried out in farm fields in the new alluvial zone, North 24 Parganas, West Bengal, India during winter seasons of 2012 and 2013. These were set out in randomized block design with six treatments including one treated and one untreated check, replicated four times in plots of 4× 4m size. Crops were sown on 20th October and the plantations were maintained for 150 days. Standard agronomic practices were followed to ensure optimal crop stand. It included: manures-8 t of FYM, 200 kg neem cake; fertilizers-a basal dose of 60 kg N, 60 kg P_2O_5 and 30 kg K_2O were applied per hectare at the time of final ploughing and after 45 days of planting, three split doses of 20 kg N plus 10 kg K_2O each were applied at 15 days interval followed by irrigation; inter-culture-manual weeding and spading done between rows at 15-day-interval up to 120 days after transplanting (DAT) starting with 30 DAT; irrigation-plots were sprinkled with water to keep the soil moist and irrigations were given each time after application of fertilizer. Nursery bed was covered with red colored nylon net to prevent landing of vectors like white fly, thrips, aphid *etc*.

Treatments: The following components were utilized as common blanket for the treatments in the main field: (a) yellow sticky traps set above canopy level (b) repellent crop strips: 20 cm-wide mixed strips of coriander and basil (3:1) between rows of chilli plants (c) maintenance of plant sanitation-removal of broken or twisted branches and maintenance of clear basal stems (15 cm or more). Red colored nylon net cover (50 cm above canopy) was provided for the entire experimental field. Foliar treatments were applied as mid-volume prays at 500 L /ha. Neem seed kernel extract (NSKE) was applied adding a tinge of common detergent and removing brown froth after mixing it with water. The treatments were : T1 (NSKE)-Prophylactic application of NSKE at 7 ml/L, applied on 7, 14, 26, 50, 65 and 80 days after transplanting (DAT); T2 (rose apple LE)–Prophylactic application of rose apple LE at 97.8 g/L, applied on 7, 14, 21, 34, 41, 47, 59, 66 and 73 DAT; T3 (NSKE + emamectin benzoate + chlorfenapyr) – (a) NSKE at 7, 14, 21 and 50 DAT + (b) emamectin benzoate at 12 g ai/ha on 29 DAT + (c) chlorfenapyr at 1.98 g ai/L on 63 DAT; T4 (rose apple LE + emamectin benzoate + chlorfenapyr)–(a) rose apple LE at 97.8 g/L on 7, 14, 21 and 49 DAT + (b) emamectin benzoate at 12 g ai/ha on 27 DAT + (c) chlorfenapyr at 1.98g ai/L on 55 DAT; T5 (chemical check)–scheduled applications of thiamethoxam at 2 g ai/L on 10, 43 and 76 DAT + abamectin at 14 g ai/ha on 21 and 54 DAT + rynaxypyr at 80 g ai/ha on 32 and 65 DAT. T6–untreated check. Observations on the number of white fly, jassid, aphid and yellow mite were taken at 10-day-interval starting from 10 days after transplanting; these were taken from randomly selected four young leaves/shoot at 5 shoots/ plant and at 4 plants per plot, excluding the border ones. For calculating the intensity of leaf curling, four plants were randomly selected from each plot and top ten leaves of five shoots per plant were observed for curling and finally the percentile was worked out. The crop was maintained for 150 days. Fruiting started between 40-42 DAT and all the fruits were weighed at the time of harvest and progressively summed up. Record on the natural enemies was taken from randomly selected 4 plants per plot while bee pollinators were recorded from the entire plot starting from 10 DAT at 20 day-intervals. Natural enemies included general predators like spiders *Lycosa pseudoannulata* (Boesenberg & Strand), *Tetragnatha maxillosa* Thorel, *Argiope pulchella* Thorel and *Oxyopes* sp, coccinellids *Coccinella septumpunctata* L., *Cheilomenes sexmaculata* (Fabricius), *Micraspis* sp. and two *Coccinella* spp. and syrphid fly *Eupeodes* (= *Syrphus*) *confrater* (Wiedemann) (small numbers); the bee species was common honey bee *Apis mellifera* L. and immature and mature stages were counted altogether. Increase or decrease in yield over the treated check was calculated using the following standard formula:

$$YE(\%) = \frac{Yt - Yc}{Yc} \times 100$$

Where YE is yield efficiency, Yt is yield in treatment and Yc is yield in control.

Collected data were then subjected to pooled analysis of variance and the treatments were compared at 5% level of significance following F test.

Results and Discussion

Results (Tables 1 and 2) indicated that all the treatments were effective in suppressing the pest population buildup and their damage on the crop. However, efficacy levels differed amongst the treatments and some of the differences were statistically significant. Management modules were designed emphasizing the role of repellent crops in suppressing or deterring pest populations so that resultant crop damage is minimized. Sap sucking by thrips and yellow mite definitely causes some damages to plants but they are of greater significance as vector of leaf curl virus and incidentally, this problem did not crop up in the present studies. These two sucking pests, thrips and yellow mite, were encountered in the present investigation in substantial numbers. Two more sucking pests, aphid and whitefly were also found in small numbers; both the species can cause substantial damage under unrestricted growth option but in the present case, all the treatment modules effectively checked their population development. Treatments T1 (NSKE) and T2 (rose apple LE) were phytochemical-based and results indicated that both of them suppressed the thrips population up to a certain level but neither was effective against the yellow mite. Mean number of thrips and yellow mites in these treatments varied between 4.2 to 8.1 /shoot and 7.1 to 9.7/shoot, respectively. Treatments T3 and T4 included synthetic (chlorfenapyr) and semi-synthetic (emamectin benzoate) pesticide components in addition to plant fractions (NSKE in T3 and rose apple LE in T4) and these synthetic/semi-synthetic molecules markedly suppressed the populations of both the sucking pest species. T3 recorded mean of 1.2-4.6 thrips/apical shoot while in T4 the numbers varied between 1.8-5.1/apical shoot as observed on different DAT. Both the treatments were also found highly effective against the yellow mite and actually, no mite was found in either treatment from 40 DAT onward. Treatments T3 and T4 were statistically at par (equivalent) but both were significantly superior to T1 and T2. Treated check (T5) suppressed thrips population but the efficacy level was inferior to the sustainable treatments T3 and T4 and actually, 70 DAT onward thrips population increased unabated exhibiting resurgence. However, the treated check was highly effective against yellow mite and exterminated it. Yet, due to resurgent thrips populations, the intensity of leaf curling (3.52%) was significantly higher in T5 as compared to T3 (0.94%) and T4 (1.12%). Leaf curling in T3, T4 and T5 were found only in the early vegetative phase, up to about 25DAT and hence the mean score of curling was so low in those treatments. Phytochemicals alone (T1 and T2) could not offer adequate protection and recorded quite high apical leaf curling (12.3-13.4%) and eventually, substantial reduction in yield (T1: 29.75% reduction; T2: 32.23% reduction) over treated check (yield: 12.1 t/ha). Sustainable treatment T4 also sponsored good yields (11.9 t/ha), though showed marginally lower yield as compared to chemical check (T5). The ultimate balance sheet for pest management reflects in the cost-economics and two treatments, T3 and T4 offered better benefit-cost ratio (BCR) over chemical check (1.42) which had seven rounds of toxic sprays (Table 3). The best BCR was recorded in T3 (1.82) followed by T4 (BCR: 1.63) while the phytochemical treatments showed poor ratios (T1: 0.63; T2: 0.53).

Table 1 Impact of the treatments on the populations of thrips *Scirtothrips dorsalis* on chilli plants recorded at 10 to 90 days after transplanting.

Treatments	Mean no. of thrips / four top leaves								
	10	20	30	40	50	60	70	80	90
T1	8.1	4.9	5.4	6.2	6.7	5.1	6.3	6.8	7.2
T2	7.9	4.8	5.1	5.2	5.8	6.2	6.5	7.1	7.8
T3	8.5	4.9	2.2	3.4	1.2	3.3	2.2	3.2	4.6
T4	7.8	4.7	3.1	2.2	1.8	3.4	2.1	2.8	5.1
T5	8.3	2.8	4.3	4.7	3.5	3.2	4.8	8.8	10.8
T6	8.2	12.3	15.2	18.3	19.1	20.4	22.8	22.9	24.1
SEM (±)	0.78	0.81	0.62	0.61	0.58	0.82	0.59	0.51	0.61
CD (p = 0.0)	2.31	2.34	1.86	1.82	1.62	2.48	1.74	1.53	1.89

Abbreviations: T1: NSKE, T2: rose apple leaf extract, T3: NSKE + emamectin benzoate + chlorfenapyr, T4: rose apple leaf extract + emamectin benzoate + chlorfenapyr, T5: treated check, T6: untreated check, CD: Critical difference.

Table 2 Impact of the treatments on the populations of yellow mite *Polyphagotarsonemus latus* on chilli plants recorded at 10 to 90 days after transplanting.

Treatments	Mean no. of yellow mites / four top leaves									Curled leaf (%)[1]
	10	20	30	40	50	60	70	80	90	
T1	7.8	9.6	7.4	8.6	7.5	7.8	8.2	8.6	9.2	12.3
T2	7.1	9.7	8.2	8.5	8.7	7.9	8.1	8.2	8.8	13.4
T3	6.8	7.5	0.8	-	-	-	-	-	-	0.94
T4	7.5	7.2	1.2	-	-	-	-	-	-	1.12
T5	8.2	3.2	-	-	-	-	-	-	-	3.52
T6	7.9	7.6	14.6	18.6	19.7	20.8	25.8	30.6	34.7	60.9
SEM (±)	0.71	0.68	0.42	0.21	0.19	0.24	0.23	0.17	0.17	0.36
CD (p = 0.05)	2.12	2.08	1.26	0.62	0.58	0.72	0.65	0.54	0.48	1.06

Abbreviations: T1: NSKE, T2: rose apple leaf extract, T3: NSKE + emamectin benzoate + chlorfenapyr, T4: rose apple leaf extract + emamectin benzoate + chlorfenapyr, T5: treated check, T6: untreated check, CD: Critical difference. [1]Mean of four observations at 40, 70, 100 and 130 days after transplanting.

Table 3 Impact of the treatments on the yield and cost economics.

Treatments	Yield (t / ha)	Yield efficiency (%)	Benefit-cost ratio (BCR)
T1	8.5	29.75(-)	0.62
T2	8.2	32.23(-)	0.53
T3	12.6	4.13(+)	1.82
T4	11.9	1.65(-)	1.63
T5	12.1	-	1.42
T6	1.2	90.0(-)	0.08
SEM (±)	1.26		
CD (p = 0.05)	3.82		

Abbreviations: T1: NSKE, T2: rose apple leaf extract, T3: NSKE + emamectin benzoate+ chlorfenapyr, T4: rose apple leaf extract + emamectin benzoate + chlorfenapyr, T5: treated check, T6: untreated check, CD: Critical difference, (+) and (-) indicate increase and decrease in yield over treated check, respectively.

Records (Table 4) on the non-target impact showed that the phytochemical-based treatments were safe to predatory coccinellids and spiders and also to visiting bee populations. Populations of both of the generalist predator groups increased slowly but steadily. The sustainable treatments, on the other hand, showed a reduction in the populations of spiders and coccinellids from 50 DAT onward (chlorfenapyr component was introduced on 63 DAT in T3 and on 55 DAT in T4) and were found inferior to T1 and T2 but significantly superior to T5 (chemical check). T5 strongly impacted the bees and though T3 and T4 (both having chlorfenapyr component) showed some negative impact on bees (slow increase), both were much safer over T5.

The pest management module was designed emphasizing the active role of *'anti-insect plant factor'* or *'repellency factor'* because plant volatiles are known to play an important role in the host selection process. In the present studies, mixed strips of two plant species were incorporated: coriander and basil in 3:1 ratio. Rationale was to musk the volatiles of the host plant so that the pests fail to recognize their host and this will translate into lower intensity of infestation and damage. This worked out as was expected. Both the plant species contain a number of flavonoids, saponins, phenols, terpenes, sterols and essential oils which produce the characteristic aroma for them (Taniguchi *et al*., 1996; Ramadan and Morsel, 2002; Kitajima *et al*., 2003; Laakaso *et al*., 1990; Maheshwari *et al*., 1987). Volatiles or allelochemicals secreted by plants either attract or repel insect pests and influence their landing response (Finch and Collier, 2003). Compositions of these plant volatiles are different for different species. It appeared that, in the present study, the allelochemicals secreted by chilli, basil and coriander were mixed up in the air resulting in molecular crowding which created confusion in pest populations. Their sensory systems failed to detect the host plants which resulted in inferior landing response; that means, coriander-basil combination successfully acted as repellent crop group. Red-colored nylon net was included as the component primarily for three reasons: disruption in the host selection process by the insects which are attracted by green canopy, encouraging inappropriate landing and as physical barrier to flying adults. Visual stimuli appeared to have been interrupted by red color and those still managing to reach over the field, at least part of the population, failed to land on to the crop plants. This contributed to inferior landing response and lower count of the pest populations. Plant sanitation was maintained through periodic removal of older leaves and broken or twisted branches along with pest populations (specially, white fly, aphid, thrips and mite) and maintenance of clear basal stems (15cm or more). These factors directly lowered the pest population densities and their damages. Yellow sticky traps were set above canopy level to catch insects like thrips, white fly and alate aphids. The traps were procured locally to keep cost low and set as hanging (roving, implies better catch of flying insects like white fly, thrips, alate aphids etc.) instead of being fixed, in order to cover better air-space. In brief, the treatment compliments either discouraged the insects to move into field or removed them at the very beginning of the population build up. It means, inferior landing response coupled with inappropriate landing response, interruption in host selection process, antifeedant and repellent action of phytochemicals, physical removal through sticky trap, net barrier and phytosanitation that resulted in suppression of pest populations and their damages. NSKE is known to contain a number of biologically active principles (alkaloids) and for this reason it has shown repellency, antifeedancy, anti-growth activities and direct toxicity against a number of insects (Schmutterer, 1990; Chakraborti and Chatterjee, 1999). Plant fractions of rose apple is also known to contain a number of biologically active principles like jambosine, hydrocyanic acid, ellagic acid and terpenoids like pinene, limonene, ocimene, α-pinene, camphene, limonene, cadinene, borneol and α-terpineol. Some of these phytochemicals are toxic while some others have strong aroma (Slowing *et al*., 1994; Chakravarty *et al*., 1998; Hoang and Nguyen, 2004). The active principles definitely also acted as feeding deterrent to the insect pest populations and thus helped in keeping them away from the experimental plots. Impact of the treatments on the predatory fauna in chilli ecosystem showed that all the treatments, except chemical check, were safe to the composite predatory populations as observed at different DAT which included four species of spiders, five species of coccinellids and one species of syrphid (*Syrphus* sp.) (Table 4). Chemical check appeared unsafe for the generalist predators like spiders and coccinellids, highly toxic for the bees and actually, wiped away the populations of both coccinellids and bees as observed on 70 DAT onward. Following treatment, the predators in chemical check migrated and at least some of them and/or new populations moved into those plots which actually showed the countable numbers. Chilli ecosystem supports rich populations of different bee species by providing good amount of pollens as well as nectar. Holy basil is also known to work as a good refuge for natural enemies. Bee species is a very important biotic component of agrecosystems because they play defining roles in cross-pollinated crops as well as in commercial apiaries. Hence, bee toxicity of the pesticides and adverse impact of the pest management practices on bee populations are critically important. In the present study, chemical check was toxic to honey bees (*Apis* sp.) while the treatments based on the plant extracts like NSKE (T1) and rose apple LE (T2) were safe for the bee species. Bee numbers were consistent in these treatments, though increase rate was very slow; some bees emigrated while some others immigrated and overall impact showed a steady population. Sustainable treatments (T3 and T4) had chlorfenapyr component and this was the reason why there was little suppression of populations of predators and pollinators. Results showed that the rationally designed pest management module for the chilli pests including apical leaf curling which emphasized on exploiting the *repellent crop theory* was effective, sustainable, safer, and cost-effective and in general agreement with some earlier works (Venkatesh *et al.*, 1998; Ragupathi and Veeraragavathatham, 2002).

Table 4 Impact of the treatments on the density of predatory complex and pollinators in chilli field recorded at 10 to 90 days after transplanting.

Treatments	Mean no. of Coccinellids / plant[1]					Mean no. of spiders/plant[2]					Mean no. of honey bees /plot[3]				
	10	30	50	70	90	10	30	50	70	90	10	30	50	70	90
T1	3.5	4.7	5.4	5.8	6.2	3.2	4.6	5.2	5.3	5.6	1.2	1.3	4.6	5.2	5.1
T2	4.1	4.3	5.6	5.4	5.8	3.4	4.3	5.4	5.6	5.8	1.3	1.1	4.7	5.1	5.3
T3	3.2	3.9	3.7	3.8	4.2	3.5	3.6	3.5	3.1	2.7	1.1	1.2	3.8	4.2	4.3
T4	3.1	4.3	4.4	3.9	4.1	3.3	3.5	3.2	2.8	2.6	1.2	1.2	3.9	4.1	4.2
T5	3.2	1.2	0.84	-	-	3.5	1.2	1.6	1.4	1.4	1.3	0.6	1.2	-	-
T6	3.9	4.8	5.8	6.7	7.2	3.4	5.8	6.1	6.5	6.4	1.1	1.6	4.8	5.1	5.2
SEM (±)	0.61	0.42	0.41	0.43	0.41	0.22	0.36	0.27	0.28	0.34	0.23	0.21	0.37	0.42	0.36
CD (p = 0.05)	1.82	1.22	1.12	1.13	1.24	0.96	1.13	0.82	0.84	1.02	0.67	0.65	1.11	1.23	1.06

T1: NSKE, T2: rose apple leaf extract, T3: NSKE + emamectin benzoate+ chlorfenapyr, T4: rose apple leaf extract + emamectin benzoate + chlorfenapyr, T5: treated check, T6: untreated check, CD: Critical difference.
1: combination of 5 species, 2: combination of four species, 3: *Apis mellifera*

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اثرات به‌کارگیری استراتژی‌های امن‌تر برای مدیریت آفات فلفل با تأکید بر کاشت گیاهان دورکننده

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چکیده: برخی از استراتژی‌های امن‌تر برای مدیریت ویروس پیچیدگی برگ فلفل (ChiLCV) و ناقلین آن مورد بررسی قرار گرفت. این استراتژی‌ها با تأکید بر استفاده از گیاهان دورکننده، ایجاد موانع فیزیکی، به‌دام انداختن حشرات کامل، بهداشت گیاهی و استفاده از ترکیبات گیاهی با حداقل مصرف سموم شیمیایی طراحی شدند. گیاهان با آفات مکنده‌ای مانند تریپس فلفل *Scirtothrips dorsalis* Hood، شته جالیز *Aphis gossypii* Glover، کنه زرد *Polyphagotarsonemus latus* (Banks)، و سفید بالک پنبه *Bemsia tabaci* (Gennadius) آلوده شدند. اما جمعیت شته و سفید بالک پنبه کم بود و ویروس پیچیدگی برگ که با ناقلین ذکر شده منتقل می‌شود ظاهر نشد. برخی از استراتژی‌های مدیریتی برای توقف جمعیت آفت و هم‌چنین کاهش خسارت و برای تولید محصول خوب ابداع شدند. اما برخی استراتژی‌ها مانند استفاده از عصاره بذر چریش و عصاره برگ درخت جمبو *Syzygium Jambos* چندان مؤثر نبودند و میزان محصول پایین بود. اما زمانی‌که عصاره‌های فوق به‌همراه یک‌بار مصرف سموم شیمیایی امامکتین بنزوات و کلرفناپیر همراه بود توانست به‌طور مؤثری جمعیت تریپس، کنه زرد و شدت ویروس پیچیدگی برگ (۰/۹۸-۱/۱۲ درصد) را کنترل نماید. در تمام تیمارها به جز در تیمار شاهد از گشنیز و ریحان مقدس و بهداشت گیاهی استفاده شد. این استراتژی‌ها به‌طور مؤثری موجب کاهش استقرار آفت و کاهش خسارت و به‌دنبال آن محصول خوبی را در پی داشت. این استراتژی‌ها برای حشرات مفید غیر هدف امن بود و در مقایسه با روش کنترل شیمیایی مقرون به‌صرفه بودند.

واژگان کلیدی: فلفل، ویروس پیچیدگی برگ فلفل، آفات، مدیریت امن‌تر