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Abundance of major sucking insect pests on chilli in relation to weather factor and their management with newer insecticide molecules during rabi season under red and lateritic zone of West Bengal

Bimal Mondal, Palash Mondal and Manas Patra

Abstract
Seasonal abundance of chilli aphids initiated on or before 3rd week of January and chilli thrips initiated on or before 4th week of January at early stages of the crop. Aphid population build up gradually increased and attained at peak on 4th week of February and remained high till 3rd week of March. Thrips population was high in the field in 9 to 11 Meteorological Standard Weeks (MSW). In the present investigation, population fluctuations of chilli aphid affected mainly by three weather parameters as this was evident from the negative correlation with minimum temperature (r=-0.141), rainfall (r=-0.474) and relative humidity (r=-0.454). However, relative humidity (r=-0.616*) showed significant negative correlation in the population fluctuation of chilli thrips. Results on multiple regression analysis revealed that 31.3% (R^2= 0.312) variation in aphid population was happened due to the abiotic factors while it was 45.4% (R^2= 0.0.454) for thrips population.
Results on efficacy of the seven insecticides revealed that both aphid and thrips population was significantly lower in Imidaclorprid (T_4) and Thiamethoxam (T_2) at different days after both spraying as compared to control. The highest yield (88.71 q/ha) was obtained in T_4 (Imidaclorprid) which was statistically significant to T_8 (Control). As far as the incremental cost benefit ratio (IBCR) is concerned, an outstanding outcome has been observed on performance of the treatments. The IBCR for Imidaclorprid (4.17) recorded maximum followed by Thiamethoxam (4.02) and Fipronil (3.93).

Keywords: chilli, thrips, aphid, population, insecticide

Introduction
Chilli (*Capsicum annuum* L.) is an important vegetable cum spice crop grown in almost all parts of tropical and subtropical regions of the world. In India, chilli is an important agricultural crop, not only because of its economic importance, but also for the nutritional value of its fruits which are excellent source of natural colours and antioxidant compounds (Nevarro *et al.*, 2006) [13]. The attractive colour is because of presence of a pigment known as 'Capsanthin' and the pungency due to an alkaloid "capsaicin".
India is the world leader in chilli production followed by China and Pakistan. In India, chilli was grown on an area of 1.81 lakh ha and annual production of 19.97 lakh tones and with an average productivity of 11 mt/ha in the year 2014-2015. (Source: Ministry of Agriculture, Govt. of India.). Among chilli producing states in the country, Andhra Pradesh contributes 49% followed by Orissa (18%), Karnataka (15%), Maharashtra (6%), West Bengal (5%), Rajasthan (4%) and Tamil Nadu (3%) (www.ikisan.com). In West Bengal, the major chilli growing districts are Murshidabad, South 24-Parganas, North 24-Parganas, Nadia, East Midnapore, West Midnapore, Coochbehar, Jalpaiguri and Birbhum. During 2010-11, in West Bengal 61,400 tons of chilies were produced from 52,453 ha (http://wbagrimarketingboard.gov.in/) while in Birbhum district it was 2.5 metric tons (http://birbhum.gov.in/AGRI/agri.htm).
Although the crop has got great export potential besides huge domestic requirements, a number of limiting factors have been attributed for low productivity of which losses due to insect pests and mites are significant (Anon, 1987) [2]. So far, 293 insect and mite species were reported on chilli (Butani, 1976) [5]. The surveys conducted by Asian Vegetable Research and Development Centre (AVRDC) in Asia revealed that the major pests of chilli are thrips,

Scirtothrips dorsalis Hood; aphids, *Myzus persicae* Sulzer, *Aphis gossypii* Glover, yellow mite, *Polyphago tarsonemus latus* Banks and fruit borer, *Heliothis armigera* Hubner (Berke and Shieh, 2000) [4] of which *S. dorsalis, A. gossypii, P. latus* and *H. armigera* are mainly responsible for inflicting yield loss up to 75% or more in Indian sub-continent (Sarkar *et al*., 2015) [20].

The prevalence and buildup of *S. dorsalis* in chilli is mostly governed by weather parameters like temperature, relative humidity, rainfall, sunshine hours. Furthermore, the weather parameters vary greatly from place to place and season to season (Dhaka and Pareek, 2008) [6]. For effective pest management, study on the influence of the various factors responsible for population fluctuation on a particular crop might assist in prediction of its occurrence in a given area (Subharani and Singh, 2007) [21]. Thus the knowledge of the influence of weather parameters of chilli will help to develop a forecasting system and to implement timely plant protection measures.

Chemical insecticides play an important role in combating the pest problem. However, to tackle the increasing menace of the pest farmers have a habit of resorting excessive and often indiscriminate use of insecticides which pushes up the cost of production and at the same time inviting the problem of resistance to commonly used insecticides in chilli. Besides this, insecticidal residues in chillies have been reported by various workers in India (Dhotre *et al.,* 2001) [7]. Now-a-days, the pesticide residues in chilli are a major non-tariff barrier for export of chillies to developed countries. It, therefore, is imperative to resort to other non-chemical pest management strategies such as use of organic amendments, use of newer molecules, along with some conventional insecticides may be helpful in population management of the insect with little disturbance of the agro-ecosystem.

Keeping this background information in view, a detailed study was undertaken with the following objectives.

1. To study the population dynamics of *A. gossypii* and *S. dorsalis* infesting chilli in relation to change of seasons and crop growth.
2. To study the impact of weather factors on population abundance of *A. gossypii* and *S. dorsalis*.
3. To find out the efficacy of different newer molecules against *A. gossypii* and *S. dorsalis* in chilli.
4. Cost effective study of different agro-chemicals in relation to yield of chilli.

Material Methods

The field experiment was conducted during rabi season in the year 2014-2015, at Binuria village, Sriniketan. The village is situated at 23.66^{0}N latitude, 87.66^{0}E longitude and at an average altitude of 58.90 m above mean sea level (www.indiamapia.com).

The experiment was carried out in Randomized Block Design (RBD) with eight treatments including control. Each treatment was replicated thrice and the different treatments were allotted randomly in plots.

Experiment details

Crop	:	Chilli (Variety: *Tejaswini*)
Date of sowing	:	1st December 2014
Date of transplanting	:	30th December 2014
Insecticidal treatment	:	Seven along with one control
No. of plots	:	24
Plot size	:	4 x 2.5 sq. m
Sample size	:	5 plants/plot
Harvesting of fruits	:	Starting at 85 days after transplanting
No. of harvesting	:	7 at 5 days interval
Last date of harvesting	:	07.05.2015
No. of insecticidal spray	:	2 (30 and 50 days after transplanting)

Treatment details

The details of the treatments as well as the experimental layout for evaluation different agro-chemicals are as follows:

Treatments	Agro-chemicals with rate of application	Spraying interval
T_1	Fipronil 5% SC @ 1 ml/lt of water	1st spraying at 30 days after transplanting (DAT) and 2nd spraying at 50 DAT with a spraying interval of 20 days
T_2	Thiamethoxam 25% WG @ 1gm/3lt of water	
T_3	λ-cyhalothrin 5% EC @ 1 ml/lt of water	
T_4	Imidaclorprid 17.1% SL @ 1ml/5lt of water	
T_5	Emamectin benzoate 1.9 EC @1 ml/lt of water	
T_6	Diafenthiuron 50% WP @ 1gm/lt of water	
T_7	Fenpropathin 10% EC @ 1ml/lt of water	
T_8	Control (water without any insecticide)	

The insecticides were sprayed with the help of a knapsack sprayer fitted with hollow cone nozzle. The insecticides were sprayed with a volume of water at the rate of 500 l/ha. The target insects were aphid, *A. gossypii* and chilli thrips *S. dorsalis.*

Observation

Both aphid and thrips infested plants were observed minutely and damage symptom was recorded digitally. To study the population density of aphid, five plants were selected randomly from each plot and tagged. Three leaves from the upper, middle and lower canopies from each sampled plants were collected and observed very carefully and minutely with the help of magnifying glass (10x) for the presence of insect. For observation of thrips a pot containing kerosinized water was placed under the selected plant and each twig was shaked gently. Thrips which fell on the water were noted down. These observations were recorded in different standard weeks at seven days interval starting from one week after transplanting (DAT) upto last harvesting of fruits. Seasonal fluctuation of population of insect was recorded with respect to crop growth stages and abiotic factors. Correlation and regression studies between insect population and weather parameters were studied to find out their impact on population build up of thrips (Gomez and Gomez, 1984) [8].

To study the efficacy of different agro-chemicals, observation on population of aphid and thrips was recorded one day before each spraying as pre-treatment count as well as 3, 7 and 14 days after spraying. These bioassay data were subjected to analysis of variance after making necessary transformation (Gomez and Gomez, 1984) [8] for comparison of treatment means.

First harvesting was done at 85 DAT and successive plucking was made at an interval of 5 days. Fruit yield of each plot was taken from whole population separately and total yield of each treatment was calculated by cumulating the successive plucking from respective plots. Thereafter, yield per plot was computed to quintal per hectare. To compare the yield performance of chilli in different treatments, analysis of variance was carried out in randomized block design. The per cent increase of yield in treatment over control was calculated from the following formula (Vanisree *et al.*, 2013) [22].

$$\text{Percent increase of yield in treatment over control} = \frac{\text{Yield in treatment} - \text{Yield in control}}{\text{Yield in control}} \times 100$$

Analysis of incremental benefit-cost ratios (IBCR) was carried out to find out the cost effective treatment. The analysis was done by estimating different cost of cultivation and return from fruit yield in each treatment after converting them to one hectare of land and the ratio was calculated using following formula:

$$\text{IBCR} = \frac{\text{Net gain in treatment}}{\text{Total cost in treatment}}$$

Where, Net gain in treatment = Realization over control – Total cost in treatment

Realization over control = Total gain in treatment – (Total gain in control- Total cost in control)

Results and Discussion

The results regarding impact of climatic factors on the population build up of major insect pests of chilli and their management with some newer molecules of insecticide to obtain higher yield have been discussed here under.

A. Effect of weather factors on population dynamics of insect pests of chilli

The population dynamics of *A. gossypii* and *S. dorsalis* on chilli during the different crop growth periods was examined critically in relation to some important climatic factors viz. temperature (maximum and minimum), rainfall, relative humidity and sunshine hour.

a. Effect of weather factors on population of *A. gossypii*

Population of chilli aphids initiated on or before 3rd meteorological standard week (MSW) i.e. during 3rd week of January at early stages of the crop growth period. Population build up gradually increased and attained at peak on 8 MSW (4th week of February) and remained high till 3rd week of March. Aphids population was high in the field from 5th to 11th MSW (Table 1 and Fig. 1). Thereafter, the population gradually decreased and disappeared after 4th week of April.

Meena *et al*., (2013) [11] revealed that the incidence of aphids (*A. gossypii*) appeared on the chilli crop soon after transplanting. The peak population of aphid (9.3 aphid/ 3 leaves/ plant) was recorded in the first and second week of September. Correlation coefficient values worked out for incidence of aphid and weather parameters revealed that all the abiotic parameters were non-significant at 5 per cent level.

Perusal of Table 2 revealed that the weather parameters played an important role on population build-up of chilli aphid, *A. gossypii* as this was evident from the negative correlation with Minimum temperature (r=-0.141), rainfall (r=-0.474) and relative humidity (r=-0.454). However, maximum temperature (r=0.052) and sunshine hour (r=0.184) have positive correlation on the insect population fluctuation.

Sahu *et al*., (2015) [18] revealed that the infestation of aphid on chilli began in the first week of February (5th MSW) and reached its peak in the 2nd week of February (6th MSW). The aphid population was negatively correlated to minimum temperature and positively influenced by morning relative humidity.

b. Effect of weather factors on population of *S. dorsalis*

Population of chilli thrips also found to initiate at early stages of the crop (before 4th week of January). Thrips population was high in the field in 9th to 11th standard week. Thereafter, the population gradually decreased and disappeared after 1st week of May (Table 1 and Fig. 2). Sanap *et al.* (1985) [19] recorded the appearance of thrips in 1st week of August and the population increased gradually till September and declined thereafter. Similarly, Ningappa (1972) [14] observed *S. dorsalis* throughout the year. The population reached its peak during October and thereafter gradually declined from November onwards reaching the lowest level in May.

Persual of Table 2 revealed that the weather parameters played an important role on population buildup of chilli thrips as relative humidity showed significant effect (r=-0.616*). Maximum temperature (r=0.144), Minimum temperature (r=0.001) and sunshine hour (r=0.130) have positive but non-significant correlation with chilli thrips while rainfall (r=-0.416) was negativly correlated. Similar observation was recorded by Sanap *et al.* (1985) [19] where they revealed that high temperature and rainfall caused dramatic decline in population during the month of May-June and November-December.

Table 1: Incidence of two major sucking pests of chilli at different growth stages of the crop during 2014-15

Standard weeks	Crop growth stages	Aphid (No./leaf/plant)	Thrips (No./leaf/plant)
3(3rd week January)	4-6 leaves	0.32	0
4(4th week January)	6-8 leaves	1.81	0.14
5(1st week February)	1-2 Twigs	4.89	1.46
6(2nd week February)	>3 Twigs	5.23	2.19
7(3rd week February)	Vegetative	5.92	3.39
8(4th week February)	Peak vegetative	6.45	3.91
9(1st week March)	Flower initiation	6.07	4.08
10(2nd week March)	Peak flowering	5.24	4.51
11(3rd week March)	Fruit initiation	4.67	5.08
12 (4th week March)	Fruiting	3.06	2.41
13 (1st week April)	Peak fruiting	2.11	1.60
14(3rd week April)	Peak fruiting	0.17	0.76
15(4th week April)	Fruiting & Senescence	0	0.22
16(1st week May)	Senescence & Harvesting	0	0

Table 2: Correlation between different weather parameters and mean population of *A. gossypii* and *S. dorsalis* in chilli

Weather parameters	Aphid* (No./leaf/plant)	Thrips* (No./twig/plant)
Max. temperature (^{0}c)	0.052	0.144
Min. temperature (^{0}c)	-0.141	0.001
Rainfall (mm)	-0.474	-0.416
Relative humidity (%)	-0.454	-0.616*
Sunshine (h)	0.184	0.130
*Correlation coefficient values are significant at p=0.05		

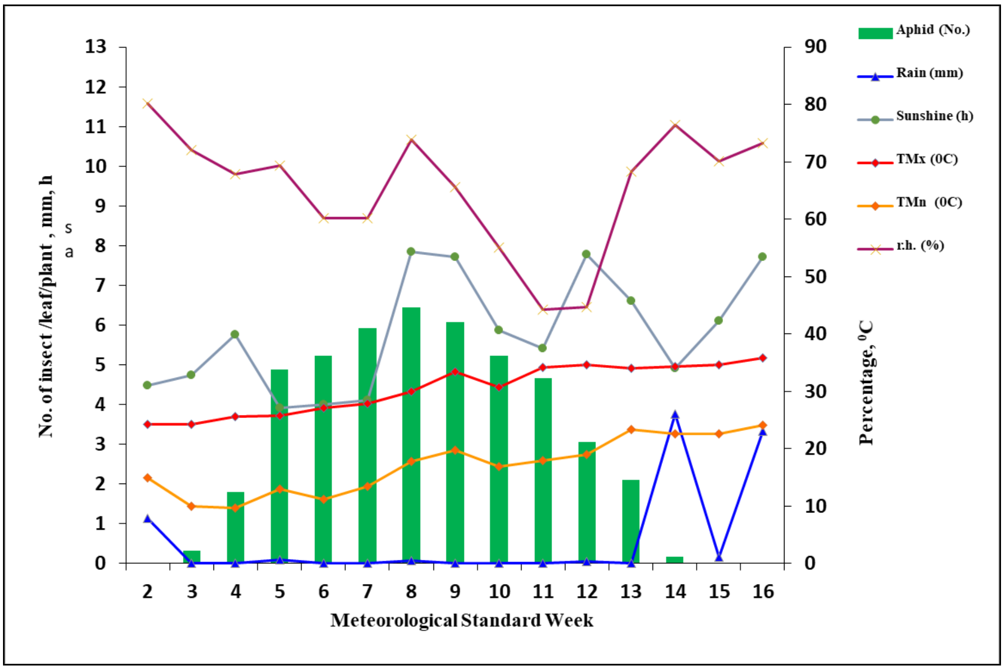

Fig 1: Effect of weather parameters on the population of *A. gossypii* at different meteorological standard weeks.

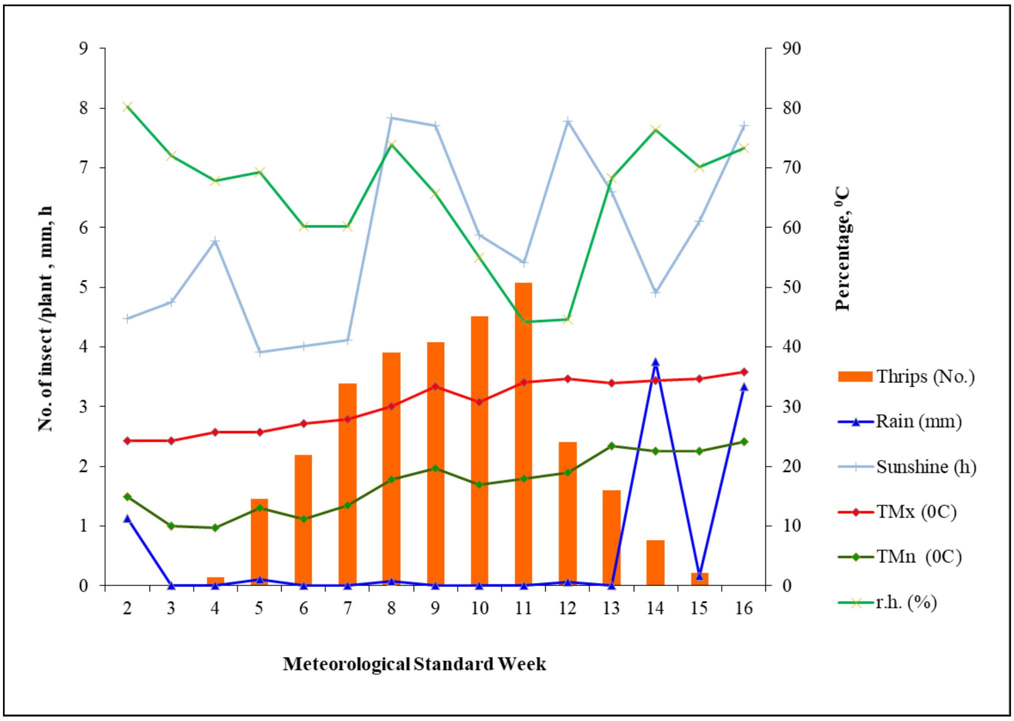

Fig 2: Effect of weather parameters on the population of *S. dorsalis* at different Meteorological standard weeks.

B. Multiple interactions of ecological parameters with population of aphid and thrips

Chilli aphid and thrips have immense potentiality to damage the crop in favourable weather conditions. Earlier reports on these aspects revealed that many time the crop suffered from havoc yield loss caused by these pests. Therefore, an attempt has been made to study the combined effect of weather factors on the variation of population build up of aphid and thrips on chilli.

Multiple regression analysis was worked out to find out the combined effect of the abiotic factors on population abundance of the insect on the crop. For this purpose

coefficient of determination (R^2) was computed.
The coefficient of determination (R^2) between aphid population and independent variables was 0.313 which indicated that 31.3% variation in insect population was caused due to the abiotic factors (Table 3). Similarly, the coefficient of determination (R^2) between thrips population and independent variables was 0.454 which indicated that 45.4% variation in insect population was caused due to the abiotic factors (Table 4). The correlation co-efficient between thrips population and maximum temperature was statistically significant and the regression equation fitted with maximum temperature showed that with a increase of one unit of maximum temperature would result in an increase of 3.77 thrips/ leaf (Varadharajan and Veeravel, 1995) [23]. During an experiment at Anand, Gujarat, Panickar and Patel (2001) [16] observed significant negative relationship between population of *S.dorsalis* on chilli and minimum temperature (r=0.62), mean relative humidity (r=0.63) and mean vapour pressure (r=0.71).

Table 3: Regression coefficient between abiotic factors and *A. gossypii* on chilli

Independent Variables	Partial regression coefficient (b)	Standard error of 'b'	Standard partial regression coefficient (β)	Student 't' value`	Statistical significance at 5%
Max. temperature(X_1)	0.077	0.804	0.127	0.096	NS
Min. temperature (X_2)	-0.119	0.594	-0.223	-0.200	NS
Rainfall (X_3)	-0.690	1.050	-0.282	-0.657	NS
Relative humidity (X_4)	-0.060	0.146	-0.264	-0.414	NS
Sunshine hour (X_5)	0.204	0.783	0.115	0.261	NS
The prediction equation for insect population: $Y= 5.966+0.077X_1-0.119X_2-0.690X_3-0.060X_4+ 0.204 X_5$					
Coefficient of determination (R^2) = 0.313^{NS}					
Contribution of all the abiotic factors on insect population: 31.3%					
NS: Non significant					

Table 4: Regression coefficient between abiotic factors and *S. dorsalis* on chilli

Independent Variables	Partial regression coefficient (b)	Standard error of 'b'	Standard partial regression coefficient (β)	Student 't' value`	Statistical significance at 5%
Max. temperature(X_1)	-0.340	0.784	-0.760	-0.433	NS
Min. temperature (X_2)	0.302	0.555	0.843	0.543	NS
Rainfall (X_3)	-0.273	0.603	-0.194	-0.453	NS
Relative humidity (X_4)	-0.133	0.114	-0.759	-1.168	NS
Sunshine hour (X_5)	0.139	0.473	0.113	0.295	NS
The prediction equation for insect population: $Y= 15.305-0.340X_1+ 0.302X_2-0.273X_3–0.133X_4+ 0.139 X_5$					
Coefficient of determination (R^2) = 0.454^{NS}					
Contribution of all the abiotic factors on insect population: 45.4%					

C. Bioefficacy of different insecticides against aphid and thrips

a. Bioefficacy of different insecticides against *A. gossypii*

Perusal of Table 5 revealed that aphid populations in different treatments though showed a slight fluctuation but recorded *at par* with each other. However, in every treatment pre-treatment count was higher than the post treatment count except untreated control. After spraying of the insecticides, the insect populations decreased significantly in different treatments. Analysis for comparison of different treatments after three days of first spraying revealed that average aphid populations was significantly lower in all the treatments as compared to control. Further, the results revealed that aphid population was significantly lower in T_4 (Imidaclorprid 17.1 SL) as compared to T_7 (Fenpropathrin 10 EC), T_5 (Emamectin benzoate 1.9 EC) and T_6 (Diafenthiuron 50 WP) except T_2 (Thiamethoxam 25 WG), T1 (Fipronil 5 SC) and T_3 (Lambda-cyhalothrin 5 EC). Population reduction over control revealed 71.08-82.44% protection in different treatments among which T_4 exerted highest protection followed by T_2 (81.65%), T1 (81.23%) and T_3 (74.95%).

The mean data on efficacy of different treatments against this insect showed significantly lower population as compared to control after 2nd spraying against the chilli aphid. Among the treatments T_4: Imidaclorprid 17.1 SL proved most effective as compared to other treatments. Population of the insect increased with the advancement of time after spraying in all the treatments. However, population of the insect was significantly low in all the treatments as compared to control. Among the treatments, T_4 (Imidaclorprid 17.1 SL) proved best followed by T_2 (Thiamethoxam 25 WG), T_1 (Fipronil 5 SC), T_3 (Lambda-cyhalothrin 5 EC), T_7 (Fenpropathrin 10 EC), T_5 (Emamectin benzoate 1.9 EC) and T_6 (Diafenthiuron 50 WP). Population reduction over control revealed 72.64-86.63% protection in different treatments among which T_4 exerted highest protection followed by T_2 (85.85%). Population of the insect gradually decreased with the advancement of age of the crop and with the increase of the environmental temperature. Jana *et al*. (2006) [9] conducted the similar experiment and observed that among fenpropathrin 30 E.C. (Meothrin), imidacloprid 200 S.L. (Confidor) and dimethoate 30 E.C. (Rogor) against *A. gossypii*, fenpropathrin 30 EC at 0.1% was the most effective dose in reducing aphid population by 90%.

b. Bioefficacy of different insecticides against *S. dorsalis*

Perusal of Table 6 revealed that thrips populations in different treatments recorded at par before taking any control measure. Besides, in every treatment pre-treatment count was higher than the post treatment count. After the intervention by the insecticidal application the insect populations further decreased significantly in all the treated plots. The results showed that T_4 (Imidaclorprid 17.1 SL) proved most effective followed by T_2 (Thiamethoxam 25 WG), T_1 (Fipronil 5 SC), T_3 (Lambda-cyhalothrin 5 EC), T_7 (Fenpropathrin 10 EC), T_5 (Emamectin benzoate 1.9 EC) and T_6 (Diafenthiuron 50 WP). Population reduction over control revealed 45.19-75.48% protection in different treatments among which T_4 exerted highest protection and T_6 showed the least.

After second spraying showed significantly lower thrips population in all the treatments as compared to control. Among different insecticidal treated treatments, minimum insect population was observed again in T_4 (Imidaclorprid 17.1 SL) which was very closely followed by T_2 (Thiamethoxam 25 WG) and T1 (Fipronil 5 SC) at three days after spraying and the same trend was followed till 14 days after spraying.

The treatment, T_3 (Lambda-cyhalothrin 5 EC) and T_7 (Fenpropathrin 10 EC) also found efficacious against the insect and proved better than both T_5 (Emamectin benzoate 1.9 EC) and T_6 (Diafenthiuron 50 WP). Percent protection offered by different treatments was in order of T_4 (85.83%) >T_2 (82.69%) > T_1 (80.58%) >T_3 (72.17%) >T_7 (69.64%) >T_5 (67.99%) >T_6 (65.54%). In the same way, Patnaik *et al.* (1985) was assessed the efficacy of six insecticides against *S. dorsalis* on chilli. The treatments were two sprays of 0.12% Sevisulf (carbaryl with sulfur), 0.06% dimethoate, 0.07% endosulfan, 0.02% fenvalerate, 0.05% formothion or 0.05% thiometon given 65 and 85 days after transplanting. Plots treated with fenvalerate had the lowest damage index, the lowest incidence of the pests and gave the highest fruit yields, followed by those treated with dimethoate, Sevisulf and formothion. Similarly, Mondal and Mondal (2012) [12] concluded that the module having one spray of Boom Tet followed by Abamectin and again Boom Tet at 21 days interval proved most effective in reducing the pest population in chilli.

Table 5: Efficacy of different treatments against chilli aphid, *A. gossypii* after spraying during 2014-15

Treatments	No. Aphid/Leaf/Plant											
	1st Spray						2nd Spray					
	PTC (1 DBS)	Post-treatment count				% Reduction over control	PTC (1 DBS)	Post-treatment count				% Reduction over control
		3 DAS	7 DAS	14 DAS	Mean			3 DAS	7 DAS	14 DAS	Mean	
T_1 : Fipronil 5 SC	4.79 (2.30)	0.89 (1.18)	0.77 (1.13)	1.39 (1.37)	1.00	81.23	4.17 (2.16)	0.79 (1.14)	0.58 (1.04)	0.41 (0.95)	0.59	84.58
T_2 : Thiamethoxam 25 WG	4.77 (2.30)	0.88 (1.17)	0.74 (1.11)	1.35 (1.36)	0.99	81.65	4.11 (2.15)	0.71 (1.10)	0.54 (1.02)	0.36 (0.93)	0.54	85.85
T_3 : Lambda-cyhalothrin 5 EC	4.73 (2.29)	1.17 (1.30)	1.11 (1.27)	1.74 (1.50)	1.34	74.95	4.24 (2.18)	0.97 (1.21)	0.88 (1.17)	0.69 (1.09)	0.85	78.37
T_4 : Imidaclorprid 17.1 SL	4.80 (2.30)	0.82 (1.14)	0.72 (1.10)	1.32 (1.35)	0.95	82.44	4.08 (2.14)	0.68 (1.09)	0.51 (1.00)	0.32 (0.91)	0.50	86.63
T_5 : Emamectin benzoate 1.9 EC	4.81 (2.30)	1.31 (1.35)	1.21 (1.31)	1.87 (1.54)	1.46	73.10	4.29 (2.19)	1.22 (1.31)	1.00 (1.22)	0.83 (1.15)	1.02	74.33
T_6: Diafenthiuron 50 WP	4.82 (2.31)	1.39 (1.37)	1.33 (1.35)	2.01 (1.58)	1.58	71.08	4.33 (2.20)	1.29 (1.34)	1.11 (1.27)	0.88 (1.17)	1.09	72.64
T_7 : Fenpropathrin 10 EC	4.79 (2.30)	1.24 (1.32)	1.18 (1.30)	1.83 (1.53)	1.42	73.85	4.25 (2.18)	1.01 (1.23)	0.91 (1.19)	0.77 (1.13)	0.90	77.14
T_8 : Control	4.81 (2.30)	5.02 (2.35)	5.31 (2.41)	5.99 (2.55)	5.44	-	6.41 (2.63)	6.32 (2.61)	6.14 (2.58)	5.29 (2.41)	5.92	-
SEm (±)	0.021	0.043	0.050	0.055	-	-	0.056	0.046	0.043	0.050	-	-
C.D. (p=0.05)	NS	0.130	0.150	0.160	-	-	0.170	0.140	0.130	0.150	-	-
C.V.	9.41	9.23	8.92	10.07	-	-	10.06	9.87	9.91	10.12	-	-

PTC: Pre-treatment count; DBS: Day before spraying
DAS: Days after spraying; NS: F-test non-significant at p=0.05
Figures in parentheses indicate $\sqrt{(x+0.5)}$ transformed values

Table 6: Efficacy of different treatments against chilli thrips, *S. dorsalis* after spraying during 2014-15

Treatments	No. Thrips/Leaf/Plant											
	1st Spray						2nd Spray					
	PTC (1 DBS)	Post-treatment count				% Reduction over control	PTC (1 DBS)	Post-treatment count				% Reduction over control
		3 DAS	7 DAS	14 DAS	Mean			3 DAS	7 DAS	14 DAS	Mean	
T_1 : Fipronil 5 SC	1.49 (1.41)	0.41 (0.95)	0.57 (1.03)	1.39 (1.37)	0.79	68.97	2.77 (1.81)	0.36 (0.93)	0.47 (0.98)	0.96 (1.21)	0.60	80.58
T_2 : Thiamethoxam 25 WG	1.47 (1.40)	0.38 (0.94)	0.51 (1.00)	1.18 (1.30)	0.69	72.53	2.69 (1.79)	0.28 (0.88)	0.39 (0.94)	0.88 (1.17)	0.52	82.69
T_3 : Lambda-cyhalothrin 5 EC	1.43 (1.39)	0.77 (1.13)	0.91 (1.19)	1.64 (1.46)	1.11	54.71	2.84 (1.83)	0.63 (1.06)	0.78 (1.13)	1.22 (1.31)	0.88	72.17
T_4 : Imidaclorprid 17.1 SL	1.48 (1.41)	0.32 (0.91)	0.42 (0.96)	1.12 (1.27)	0.62	75.48	2.63 (1.77)	0.21 (0.84)	0.31 (0.90)	0.72 (1.10)	0.41	85.83
T_5 : Emamectin benzoate 1.9 EC	1.51 (1.42)	0.89 (1.18)	1.04 (1.24)	1.92 (1.56)	1.28	50.26	2.91 (1.85)	0.79 (1.14)	0.89 (1.18)	1.42 (1.39)	1.03	67.99
T_6: Diafenthiuron 50 WP	1.52 (1.42)	0.99 (1.22)	1.17 (1.29)	2.11 (1.62)	1.42	45.19	2.93 (1.85)	0.88 (1.17)	0.97 (1.21)	1.51 (1.42)	1.12	65.54
T_7 : Fenpropathrin 10 EC	1.49 (1.41)	0.84 (1.16)	0.98 (1.22)	1.87 (1.54)	1.23	51.69	2.89 (1.84)	0.71 (1.10)	0.83 (1.15)	1.38 (1.37)	0.97	69.64
T_8 : Control	1.51 (1.42)	2.02 (1.59)	2.23 (1.65)	3.49 (2.00)	2.58	-	3.81 (2.08)	3.92 (2.10)	4.10 (2.14)	4.66 (2.27)	4.23	-
SEm (±)	0.033	0.046	0.053	0.063	-	-	0.050	0.053	0.046	0.063	-	-

C.D. (p=0.05)	NS	0.140	0.160	0.190	-	-	0.150	0.160	0.140	0.170	-	-
C.V.	8.99	9.87	8.78	9.58	-	-	10.16	9.96	10.04	10.21	-	

PTC: Pre-treatment count; DBS: Day before spraying
DAS: Days after spraying; NS: F-test non-significant at p=0.05
Figures in parentheses indicate √(x+0.5) transformed values

D. Performance of different treatments on pod yield of chilli

Pod yield corresponding to different treatments were statistically analyzed and presented in Table 7. All the treatment produced higher yield than control (50.18 qt/ha). The highest yield was obtained in T_4: Imidaclorprid 17.1 SL (88.71 qt/ha) which statistically superior to T_5: Emamectin benzoate 1.9 EC (79.43 qt/ha) and T_6: Diafenthiuron 50 WP (77.02 qt/ha). However, the treatment T_4 failed to produce significantly higher yield than T_2: Thiamethoxam 25 WG (87.92 qt/ha), T_1 : Fipronil 5 SC (86.94 qt/ha), T_3 : Lambda-cyhalothrin 5 EC (84.29 qt/ha) and T_7 : Fenpropathrin 10 EC (84.09 qt/ha). Results also revealed that the treatment T_4 produced 76.78% more yield over control followed by T_2 (75.21%), T_1 (73.26%), T_3 (67.98%), T_7 (67.58%), T_5 (58.29%) and T_6 (53.49%). Reddy and Puttaswamy (1983) estimated yield loss in different varieties of the chilli grown in different places and cropping seasons in Andhra Pradesh during 1985-87. Joint infestation of *S. dorsalis* and *P. latus* caused losses of 34.14% yield while overall reduction up to 76.68% due to *P. latus*, *S. dorsalis* and the noctuid, *S. litura*. (Ahamad *et al*., 1987). Krishnakumar (1995) also recorded a qualitative yield loss to the tune of 90% in capsicum and 11–32% quantitative loss in chilli. Again, Patel and Gupta (1996) reported that yield losses caused by *S. dorsalis* in green chilli were ranged from 60.5 to 74.3%. As far as the incremental benefit-cost ratio is concerned, the insecticide Imidaclorprid 17.1 SL proved best (4.17) followed by Thiamethoxam 25 WG (4.02), Fipronil 5 SC (3.93), Lambda-cyhalothrin 5 EC (3.67), Fenpropathrin 10 EC (3.66), Emamectin benzoate 1.9 EC (2.90) and Diafenthiuron 50 WP (2.74). The effectiveness of methomyl (Patnaik and Mahapatra, 1997) [17], imidacloprid (Ashokkumar, *et al*., 2005) [3] and triazophos (Kandasamy *et al*., 1990 and Anonymous, 2003) [10, 1] against *S. dorsalis* on chilli reported by earlier workers are in conformity with the present results. The BCR ratio was also calculated by Vishwakarma *et al.* (2010) [24] for different treatments having organic formulations and novel pesticides against yellow mite on *'Suryamukhi'* variety of chilli.

Table 7: Fruit yield and economics of chilli cultivation in different treatments during 2014-15.

Treatments	Production cost (Rs/ha)	Plant protection cost (Rs/ha)	Total cost (Rs/ha)	Yield (q/ha)	% Yield increased over control	Gross realization (Rs/ha) @ Rs.6,500/qt.	Net realization over control (Rs/ha)	Net gain (Rs/ha)	IBCR
T_1 : Fipronil 5 SC	57,000.00	3,055.00	60,055.00	86.94	73.26	5,65,110.00	2,95,940.00	2,35,885.00	3.93
T_2 : Thiamethoxam 25 WG	57,000.00	3,280.00	60,280.00	87.92	75.21	5,71,480.00	3,02,310.00	2,42,030.00	4.02
T_3 : Lambda-cyhalothrin 5 EC	57,000.00	2,650.00	59,650.00	84.29	67.98	5,47,885.00	2,78,715.00	2,19,065.00	3.67
T_4 : Imidaclorprid 17.1 SL	57,000.00	2,500.00	59,500.00	88.71	76.78	5,76,615.00	3,07,445.00	2,47,945.00	4.17
T_5 : Emamectin benzoate 1.9 EC	57,000.00	6,430.00	63,430.00	79.43	58.29	5,16,295.00	2,47,125.00	1,83,695.00	2.90
T_6: Diafenthiuron 50 WP	57,000.00	4,810.00	61,810.00	77.02	53.49	5,00,630.00	2,31,460.00	1,69,650.00	2.74
T_7 : Fenpropathrin 10 EC	57,000.00	2,560.00	59,560.00	84.09	67.58	5,46,585.00	2,77,415.00	2,17,855.00	3.66
T_8 : Control	57,000.00	-	57,000.00	50.18	-	3,26,170.00	-	-	-
SEm(±)				2.53					
C.D. (p=0.05)				7.61					
C.V.				9.87					

IBCR: Incremental benefit-cost ratio
Production cost includes all inputs and labour cost excluding plant protection cost (cost of insecticides + labour cost for spraying)

Conclusion

From the present findings it may be concluded that weather parameters have great impact on population build up of the insect pests. Hence, adjustment of time of planting may be taken into consideration and it will be better to transplant the crop early in the December month, so that the crop may pass the vulnerable stages before potential build of the pest population. Further, the novel insecticides of neonicotinoids compound viz Imidaclorprid, Thiamethoxam and Fipronil proved highly effective against the both sucking insects (*A. gossypii* and *S. dorsalis*) which can successfully be managed if applied during early vegetative period with little disturbance of the environment for higher production of chilli.

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