Original Research Article

Evaluation of different IDM modules against chilli viral complex

Abstract:

Three different modules were formulated and tested for the integrated management of the chilli viral complex at two different locations. Out of the three modules, the disease incidence was significantly less in module- 2 during both the years consecutively, which recorded 27.2 per cent during *Rabi* 2019-20 and 25.2 per cent during *Rabi* 2020-21 respectively. The correlation analysis for the whitefly population with weather parameters during *Rabi* 2019-20 and 2020-21 indicated that there existed a positive and significant correlation of whiteflies with minimum temperature, morning humidity and wind velocity; but there was a negative correlation with evening relative humidity and sunshine hours. In the present study, there was a significant increase in the intensity of the disease (viral complex) and there was a corresponding decrease in the yield, yield attributes of the chilli crop. The results markedly reported that there was a significant difference between the CBR of different modules in correspondence with the disease incidence which had a remarkable influence on the yield and yield attributes hence on the CBR. With the help of the present study it was evident that module 2 has lower cost of production along with enhanced yield and a profitable CBR.

Keywords : Chilli leaf curl, Integrated management.

Introduction:

Chilli (*Capsicum annuum* L.) is a highly valued cash crop. Besides its traditional use as vegetables, spices, condiments, sauces and pickles, it is also used in pharmaceuticals, cosmetic and beverages (Tiwari *et al.*, 2005). Chilli has exceptional nutritional value markedly for vitamin A and C. The major producer economies are China, Turkey, Mexico, Spain, USA, Indonesia, Nigeria, Egypt, Korea, Italy and India. During *Kharif* season, 2019-20, Telangana stood in second position in area, production and productivity of chilli *i.e.*, 2.98 lakh acres, production 3.06 lakh metric tonnes and productivity 1545 kg per acre. Major chilli growing districts are Khammam, Mahabubabad, Gadwal, Suryapet and Warangal (Rural). During 2020-21, 1.91 lakh acres was covered under chilli crop (Chilli outlook, 2020).

Chilli is predisposed to multitude of parasitic diseases caused by viruses, fungi and bacteria. Viruses are markedly notorious to incite wide range of symptoms such as mosaic, ring spot, curling, yellowing etc. Among them, chilli leaf curl is ubiquitous and initiate variable symptoms such as leaf curling, puckering and reduced size of leaves, closely set internodes and dwarfing of plants.

In tropical and subtropical parts of India leaf curl is a prime constraint to chilli productivity (Dhanraj *et al.*, 1968; Chattopadhyay *et al.*, 2008). Efforts were put to reduce the severity of the disease by deploying significant number of insecticides keeping the vector population under control, out of which, Imidacloprid 70 WS @ 5g/kg of seed was reportedly effective followed by Imidacloprid 200 SL @ 0.5 ml/l at 20 and 30 days after emergence in minimizing average population of whiteflies Rathod *et al.*, (2010). However, Zhang *et al.*, (2011) reported Imidacloprid and Thiamethoxam to be the most effective in controlling *B. tabaci* under laboratory conditions and also in field when used as a seed treatment. whitefly population as well as yellow mosaic virus incidence were less in Diafenthiuron 50 WP @ 600 g/ha, Imidacloprid 70 WG @ 75 g/ha and Thiamethoxam 25 WG @ 100 g/ha treatments compared to the untreated control (Gopalaswamy *et al.*, 2012).

In spite of extensive usage of these insecticides by chilli farmers in combinations etc., failed to minimize the losses. Upon that due to indiscriminate usage of insecticides, resurgence of pests, phyto-toxicity of fruits, destruction of earthworms, poor fruit setting due to killing of pollinators and other health hazards will be the disaster outcome (Sridhar *et al.*, 2014). Nimbalkar *et al.*, (1993) and Rashid *et al.*, (2012) who reported that neem oil significantly reduced the white fly population in cotton. Considering this scenario, some natural origin pesticides were used to develop a rational approach, effective and eco-friendly Integrated Disease Management Modules (IDMs) for sustainable production of chilli crop.

Materials and methods:

To determine efficacy of different modules for the management of chilli viral complex a field trial was conducted at farmer's field at Warangal district during *Rabi* 2019-20 and at College farm, College of Agriculture, Rajendranagar during *Rabi* 2020-21. Efficacy of three IDM modules comprising combination of seven treatments was tested using Randomised Block Design (RBD) using susceptible cultivar Sindhuri and each module was replicated five times including control. Spacing of 30 × 30 cm was followed.

Disease incidence was recorded by taking counts of twenty randomly selected and tagged plants, leaving the borders, seven days after imposing the treatment. Percent disease incidence and reduction in disease incidence were calculated by following formula.

$$\text{Disease Incidence (\%)} = \frac{\text{No. of diseased plants}}{\text{Total no. of assessed plants}} \times 100$$

Estimation of vector population

The method given by Bhattiprolu and Rahman (2006) was used to estimate white fly population in the field. According to which, five plants per treatment and three terminal leaves per plant were randomly selected and tagged. White fly populations were recorded directly on leaves early in the morning when they were less active. Observations were recorded at seven days interval starting from 14 days after transplanting (DAT) till last harvesting of fruits.

Yield and yield component

Fruit yield of each plot and number of fruit/ plant were taken separately for each module and calculated by cumulating the successive plucking from respective field and then converted to quintal per hectare. The data were tabulated, pooled and ranked on the basis of their yield performance.

Estimation of cost-benefit ratio

The Cost Benefit Ratio (CBR) of different modules was calculated by estimating cost of cultivation and gross income received from the produce per hectare land. Average market price of green chilli was Rs. 15.0 per kg during experimental period. Cost benefit ratio was calculated by using following formula:

$$CBR = \frac{\text{Gross income}}{\text{Total cost of cultivation}}$$

The field data were analyzed in Randomized Block Design by F test for significance and critical difference of values were calculated at 5 per cent significance level.

Results and Discussion:

At Warangal:

The effect of different IDMs on the incidence of viral complex disease and population of whiteflies in chilli during *Rabi* 2019-20 were recorded and presented in Table 2 revealed that all the treatments resulted in significant reduction in disease incidence. The disease appeared in all the modules at 4 weeks after transplanting (WAT). In general, the disease incidence increased with the age of the plants and recorded maximum incidence at 10 WAT. The disease progress was gradual in all the modules and at all the periods of observation. However, per cent disease incidence (PDI) was highest at 10 WAT and least at 4 WAT. Leaf curl was the major disease in the complex that was observed during the field trials. The perusal of data revealed that there were significant differences among the modules in respect to viral complex incidence.

The population of whiteflies was recorded at weekly intervals upto 9 weeks after transplanting (WAT) (Table 3). The first count of the whiteflies was recorded on 2 WAT. The results revealed that there was a remarkable difference in the vector population from 2 WAT to 9 WAT. The mean population was least (2.2/ plant) in module-2 at 2 WAT and followed by module-1 (3.1/plant) and module-3 (3.3/ plant) and maximum population was recorded at 9 WAT in control plot (9.2 / plant) followed by module-1 (5.7/ plant), module-3 (5.9/ plant) and the least population was recorded in module-2 (5.1/ plant) during *Rabi* 2019-20.

The effect of weather parameters during different weeks of crop growth in *Rabi* 2019-20 at Warangal was presented in Table 4. The population of whiteflies in chilli cv. Sindhuri was recorded at weekly intervals from 11^{th} standard week to 19^{th} standard week. The first count of whitefly/plant was recorded in the crop in all the modules from 2 WAT onwards. During the peak infestation of whiteflies, the crop was in active growth stage (45-60 DAT). The average maximum and minimum temperatures recorded were 37.8 and 23.6^{0} C, respectively and the average relative humidity forenoon and afternoon were 89.6 and 56.3 per cent respectively. The whitefly population declined as the crop reached senescence.

Population of whiteflies at various intervals was found to be affected by climatic conditions. The overall correlation matrices drawn for whitefly population with weather is given in Table 5.

At Rajendranagar:

The effect of various modules on the incidence of viral complex disease in chilli during *Rabi* 2020-21 conducted at Rajendranagar were recorded and presented in Table 6 disclosed that all the treatments resulted in significant reduction in disease incidence. The disease appeared in all the modules at 4 weeks after transplanting (WAT). In general, the disease incidence increased with the age of the plants and recorded maximum incidence at 10 WAT.

The disease progress was gradual in all the modules and at all the periods of observation. However, per cent disease incidence (PDI) was maximum at 10 WAT and least at 4 WAT. The perusal of data revealed that there were significant differences among the modules in respect to viral complex incidence.

The first count of the whiteflies was recorded on 2 WAT. The results revealed that there was a significant difference in the vector population from 2 WAT to 9 WAT. In *Rabi* 2020-21, similar pattern was observed where least incidence was recorded in module-2 (2.0/ plant) during 2 WAT followed by module-3 (2.2/ plant), module-1 (2.3/ plant) and in control it was 3.3/plant. Whereas, peak population was recorded during 9 WAT in control (8.1/plant) followed by module-3 (5.6/ plant), module-1 (5.5/ plant) and the least among the modules being recorded in module-2 (5.0/ plant) (Table 7)

The mean whitefly population during *Rabi* 2020-21 ranged from 1.2 whiteflies/plant with peak incidence during 4th standard week (2021) followed by 5th standard week (2021). The average minimum and maximum temperatures recorded were 31.6 and 15.6^{0}C respectively and the average relative humidity forenoon and afternoon were 95 and 43 per cent. Further whitefly population was at its peak during 45-60 DAT. The population gradually decreased with age of the plant (Table 8).

There was positive correlation of whitefly population with minimum temperature and wind velocity and negative correlation with morning, evening relative humidity and sunshine hours. Of these weather parameters, significant positive correlation existed between whitefly population and minimum temperature (0.7031) and wind velocity (0.9347) (Table 9).

Bhagat *et al.* (2019) also have documented the efficacy of imidacloprid on the significant reduction of mosaic in chilli. Daunde and Khandare (2020) have also confirmed these findings in their report. Sprays of thiomethoxam also had significant effect in the reduction of the population and these results are in line with Pandey *et al.* (2010) also studied the management of leaf curl of chilli and observed that thiomethoxam was most effective than other insecticides used in chilli.

The studies clearly indicated that involvement of different weather parameters in fluctuation of the population of whiteflies during different growing seasons. A similar study by Lakshmi *et al.* (2020) explained successful correlation between weather parameters and whitefly population. Further, positive correlation between whitefly population and minimum temperature, rainfall and relative humidity and negative correlation with maximum temperature.

Effect on yield and yield attributes:

The results indicated that with the increase in the severity of the disease viral complex there was corresponding decrease in the yield and yield attributes of the chilli crop to certain extent. The effect was more when the plants were infected in the early stages compared to those that were infected in later stages (Table 10 and 11). The results suggest that it’s important to initiate the management tactics at the early stages of the crop to prevent vectors and the spread of the virus.

Similar results were given by Sarkar *et al.* (2018) who reported that all the growth and yield parameters were significantly affected due to viral complex resulting in yield loss of 60 per cent at 75 per cent disease incidence. These results were in accordance with Kumar and Kumar (2017) who also reported that there was yield reduction due to the viral complex infection.

The results claimed that there was significant difference between the CBR of different modules in correspondence with the disease incidence which had remarkable influence on the yield and yield attributes hence on the CBR (Table 11 and 12). The present study markedly reported that module-2 reduced the number of application of pesticides to cut down the cost of production and enhanced the yield of fruits with improved benefit cost ratio.

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Treatment	Details
T1	Seed treatment with Imidacloprid @5g/kg
T2	Application of Fipronil @8g/cent in the nursery at 8 day age
T3	Application of neem oil @10DAT
T4	Trap crop (Marigold) (16:1 ratio) and barrier crop (fodder maize, 3 rows)
T5	Foliar application of Imidacloprid @ 0.3ml/l at 30, 45, 60 days
T6	Foliar application of Thiomethoxam @0.2g/l at 30, 45 and 60 days
T7	Sticky traps @12/acre

Module	Treatments
Module 1	Seed treatment with imidacloprid @5g/kg + Application of fipronil @8g/cent+ Application of neem oil@ 10DAT + Foliar application of imidacloprid @ 0.3ml/l at 30, 45, 60 days
Module 2	Seed treatment with imidacloprid @5g/kg + Application of fipronil @8g/cent in the nursery at 8 day age + Application of neem oil @10DAT + Trap crop (Marigold) (16:1 ratio) and barrier crop (fodder maize, 3 rows) + Foliar application of thiomethoxam @0.2g/l at 30, 45 and 60 days + Sticky traps @12/acre
Module 3	Seed treatment with imidacloprid @5g/kg + Foliar application of imidacloprid @ 0.3ml/l at

	30, 45, 60 days

Table 1. Treatment details followed for different modules

Treatment	Number of whiteflies/plant* at							
	2 WAT	**3 WAT**	**4 WAT**	**5 WAT**	**6 WAT**	**7 WAT**	**8 WAT**	**9 WAT**
Module 1	3.1 (10.14)*	3.2 (10.30)	3.5 (10.78)	4.2 (11.82)	4.4 (12.10)	4.9 (12.78)	5.5 (13.56)	5.7 (13.76)

Module 2	2.2 (8.52)	2.5 (9.09)	2.8 (10.78)	3.3 (10.46)	3.5 (10.78)	4.0 (11.35)	4.4 (12.10)	5.1 (13.05)
Module 3	3.3 (10.46)	3.5 (10.78)	3.7 (11.09)	3.9 (11.38)	4.2 (11.82)	5.2 (13.18)	5.6 (13.68)	5.9 (14.05)
Control	4.1 (11.50)	4.2 (11.82)	5.2 (10.78)	5.4 (13.43)	5.9 (14.05)	6.4 (14.65)	7.9 (16.32)	9.2 (17.59)
SEm±	1.12	1.85	1.23	1.15	1.25	1.65	1.89	1.56
C.D (P=0.05)	2.51	2.32	2.23	2.45	2.12	3.54	2.36	2.45

Table 2. Effect of different modules on the population of whiteflies during *Rabi* 2019-20 at Warangal.

Table 3. **Effect of weather parameters on whitefly population during *Rabi* 2019-20**

Standard meterolog-ical week	**Period**	**Temperature**		**Relative humidity**		**Sun shine hours**	**Wind speed**	**Whitefly population**
		Max	**Min**	**RH I**	**RH II**			
11	12-18 MAR	33.1	20.7	90.4	55.6	7.7	2.6	3.1
12	19-25 MAR	36.6	23.9	92.3	47.7	9	2.8	3.2
13	26 MAR-01 APR	36.1	22.6	89	53.1	8	3	3.5
14	02-08 APR	35.6	23.6	90.6	55.1	9	3.1	4.2
15	09-15 APR	37.8	23.6	89.6	53.3	9.5	2.5	4.4
16	16-22 APR	37.3	24.7	84	46.8	9.5	3.1	4.9
17	23-29 APR	37.7	24.3	91.9	50.8	5.9	3.3	5.5
19	30 APR -06 MAY	39.2	25.3	83.7	47.9	9	2.7	6

Step No.	**Variable detected**	**Coefficient of determination (R^2)**
1	Nil	0.4624^{**}
2	X_5	0.4622^{**}
3	X_5 and X_2	0.456
4	X_5,X_1 and X_4	0.433^{**}
5	X_5, X_1, X_4 and X_3	0.411^{**}
Regression equation $Y= -33.85 + 1.197 X_2 + 0.515 X_6$		

X_1 – Maximum temperature; X_2 – Minimum temperature; X_3 – Relative humidity I
X_4 – Relative humidity II; X_5 – Sunshine; X_6 – Wind velocity
* Significant at 5% level ** Significant at 1% level

Table 4. Regression analysis of weather parameters with whitefly population in chilli cv. Sindhuri during *Rabi* 2019-20.

	Temp ^{0}C (max)	Temp ^{0}C (min)	RH I (%)	RH II (%)	Sunshine hours (h)	Wind velocity (km/h)	Whitefly population
Temp ^{0}C	1.0000	0.9160	-0.46695	-0.6699	0.1875	0.1082	-0.8153*

(max)							
Temp ^{0}C (min)		1.0000	0.2580	0.6119	-0.32323	0.3232	0.9180**
RH I (%)			1.0000	0.4990	-0.0835	-0.2110	0.8667*
RH II (%)				1.0000	-0.2402	0.2289	-0.6889
Sunshine hours (h)					1.0000	-0.4630	0.0372
Wind velocity (km/h)						1.0000	0.9007**
Whitefly population							1.0000

* Significant at 5% level ** Significant at 1% level

Table 5. Overall correlation matrix of whitefly population/plant with weather parameters in chilli cv. Sindhuri during *Rabi* 2019-20 at Warangal.

Treatment	Per cent disease incidence of chilli viral complex						
	4 WAT	5 WAT	6 WAT	7 WAT	8 WAT	9 WAT	10 WAT
Module 1	12.0 (20.26)	15.1 (22.86)	18.0 (24.44)	25.1 (35.7)	32.2 (35.78)	34.3 (37.04)	35.2 (37.58)
Module 2	11.2 (19.55)	13.1 (21.21)	17.2 (24.50)	20.0 (26.56)	21.3 (27.48)	24.3 (29.53)	25.2 (30.13)
Module 3	13.1 (21.21)	16.2 (23.73)	18.2 (25.25)	26.2 (30.78)	33.6 (35.42)	35.8 (36.63)	36.5 (36.92)
Control	20.4 (27.87)	35.5 (36.02)	47.2 (43.39)	49.3 (46.31)	50.3 (57.12)	52.3 (53.30)	53.6 (48.46)
SEm±	1.18	1.05	1.56	1.02	1.85	1.72	1.45
C.D (P=0.05)	2.51	2.91	3.52	2.45	2.12	3.21	2.75

Table 6. Effect of different IDM modules on chilli viral complex incidence during *Rabi* 2020-21 at Rajendranagar.

Treatment	Number of whiteflies/plant* at							
	2 WAT	3 WAT	4 WAT	5 WAT	6 WAT	7 WAT	8 WAT	9 WAT
Module 1	2.3 (8.73)	3.1 (10.14)	3.5 (10.78)	4.2 (11.82)	4.4 (12.10)	4.9 (12.78)	5.2 (13.18)	5.5 (14.05)
Module 2	2.0 (8.52)	2.5 (9.09)	2.7 (9.45)	3.1 (10.14)	3.5 (10.78)	3.9 (11.38)	4.0 (11.53)	5.0 (12.92)
Module 3	2.2 (8.52)	3.2 (10.14)	3.9 (11.22)	4.5 (12.24)	4.6 (12.38)	4.9 (12.79)	5.3 (13.30)	5.6 (13.64)
Control	3.3 (10.46)	4.2 (11.82)	5.4 (13.43)	5.6 (13.68)	5.9 (14.05)	6.4 (14.65)	7.9 (16.32)	8.1 (16.48)
SEm±	1.15	1.32	1.58	1.26	1.51	1.12	1.05	1.08
C.D (P=0.05)	2.51	2.23	2.32	3.21	2.85	2.95	2.20	2.45

Table 7. Effect of different modules on the population of whiteflies during *Rabi* 2020-21 at Rajendranagar.

Standard meterolog-ical week	Period	Temperature		Relative humidity		Sun shine hours	Wind speed	Whitefly population
		Max	Min	RH I	RH II			
11	12-18 MAR	33.1	20.7	90.4	55.6	7.7	2.6	3.1
12	19-25 MAR	36.6	23.9	92.3	47.7	9	2.8	3.2
13	26 MAR-01 APR	36.1	22.6	89	53.1	8	3	3.5
14	02-08 APR	35.6	23.6	90.6	55.1	9	3.1	4.2
15	09-15 APR	37.8	23.6	89.6	53.3	9.5	2.5	4.4
16	16-22 APR	37.3	24.7	84	46.8	9.5	3.1	4.9
17	23-29 APR	37.7	24.3	91.9	50.8	5.9	3.3	5.5
19	30 APR -06 MAY	39.2	25.3	83.7	47.9	9	2.7	6

Table 8. Effect of weather parameters on whitefly population during *Rabi* 2020-21.

Step No.	Variable detected	Coefficient of determination (R^2)
1	Nil	0.4844**
2	X_5	0.4162**
3	X_5 and X_1	0.484
4	X_5, X_2 and X_4	0.423**
5	X_5, X_1, X_4 and X_3	0.479**
Regression equation $Y = -31.85 + 1.187 X_2 + 0.505 X_6$		

X_1 – Maximum temperature; X_2 – Minimum temperature; X_3 – Relative humidty I
X_4 – Relative humidity II ; X_5 – Sunshine; X_6 – Wind velocity
* Significant at 5% level ** Significant at 1% level

Table 9. Regression analysis of weather parameters with whitefly population in chilli cv. Sindhuri during *Rabi* 2020-21.

	Temp ^{0}C (max)	**Temp ^{0}C (min)**	**RH I (%)**	**RH II (%)**	**Sunshine hours (h)**	**Wind velocity (km/h)**	**Whitefly population**
Temp ^{0}C (max)	1.0000	0.0320	-0.6150	-0.6504	0.6450	0.3766	-0.1632
Temp ^{0}C (min)		1.0000	0.3952	0.3952	-0.6551	0.4992	0.7301*
RH I (%)			1.0000	0.5260	-0.6075	-0.3741	-0.8938**
RH II (%)				1.0000	-0.5673	0.3137	-0.7709*
Sunshine hours (h)					1.0000	-0.5673	0.5543
Wind velocity (km/h)						1.0000	0.9347**
Whitefly population							1.0000

Table 10. Overall correlation matrix of whitefly population/plant with weather parameters in chilli cv. Sindhuri during Rabi 2020-21 at Rajendranagar.

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Treatment	Plant height*(cm)	Number of pods/plant	Length of the pods (cm)	Yield (q/ha)
Treatment	**Plant height*(cm)**	**Number of pods/plant**	**Length of the pods (cm)**	**Yield (q/ha)**
Module 1	85	90	8.2	61.9
Module 2	89	95	8.5	62.3
Module 3	80	75	7.9	59.6
Control	67	62	5.6	41.9

Table 11. Effect of different modules on yield and yield attributes during Rabi 2019-20.

* Mean of 10 plants

Treatment	Plant height*(cm)	Number of pods/plant	Length of the pods (cm)	Yield (q/ha)
Module 1	82.3	92	8.1	62.3
Module 2	90	98	8.75	63.4
Module 3	79.3	73	7.5	60.3
Control	62.3	65	5.3	45.6

Table 12. Effect of different modules on yield and yield attributes during *Rabi* 2019-20.

* Mean of 10 plants

Table 13. Effect of different modules on yield and yield attributes during *Rabi* 2020-21.

Treatment	Cost of cultivation (Rs./ha)	Gross income (Rs./ha)	Net income (Rs./ha)	Cost benefit ratio (CBR)
Module 1	20169.50	106740.0	86570.50	4.29
Module 2	26605.40	154520.0	128014.60	4.82
Module 3	18905.40	92560.0	73654.6	3.89

* Cost of chilli 4000/q; cost of cultivation included cost of chemicals and labour wages @ Rs. 350

Table 14. Effect of different modules on economics of the chilli crop during *Rabi* 2019-20.

Treatment	Cost of cultivation (Rs./ha)	Gross income (Rs./ha)	Net income (Rs./ha)	Cost benefit ratio (CBR)

Module 1	20269.50	109740.0	89470.5	4.41
Module 2	27605.40	159520.0	131915.0	4.77
Module 3	19905.40	93920.0	73355.0	3.68

* Cost of chilli 4100/q; cost of cultivation included cost of chemicals and labour wages

Table 15. Effect of different modules on economics of the chilli crop during *Rabi* 2020-21

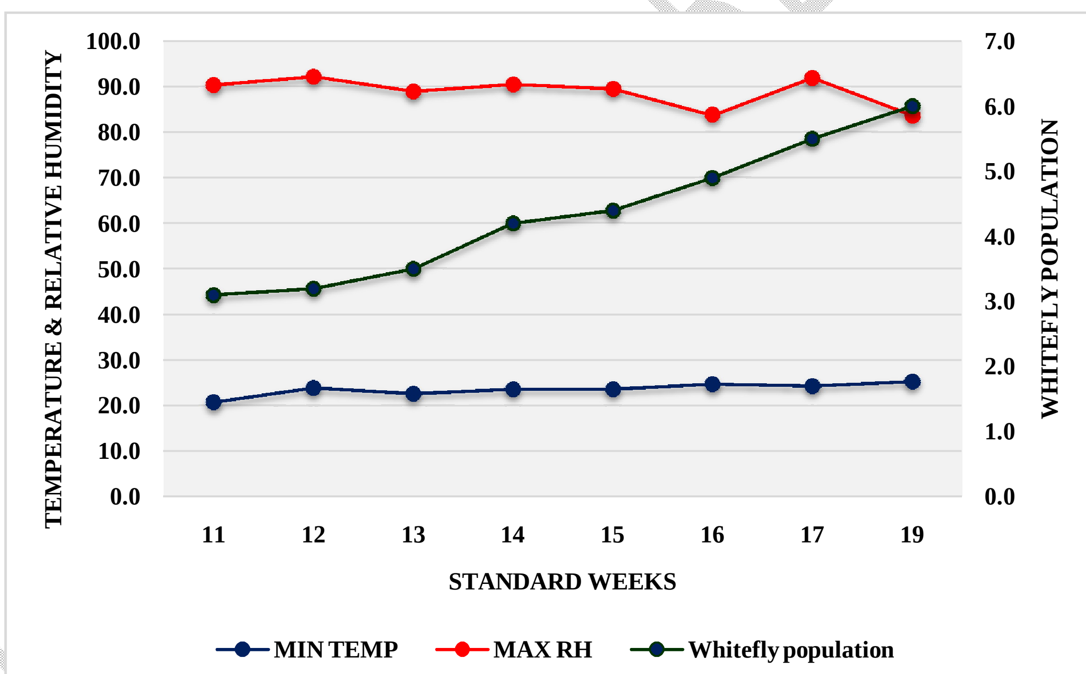

Figure 1. Effect of minimum temperature and relative humidity on whitefly population during *Rabi* 2019-20.

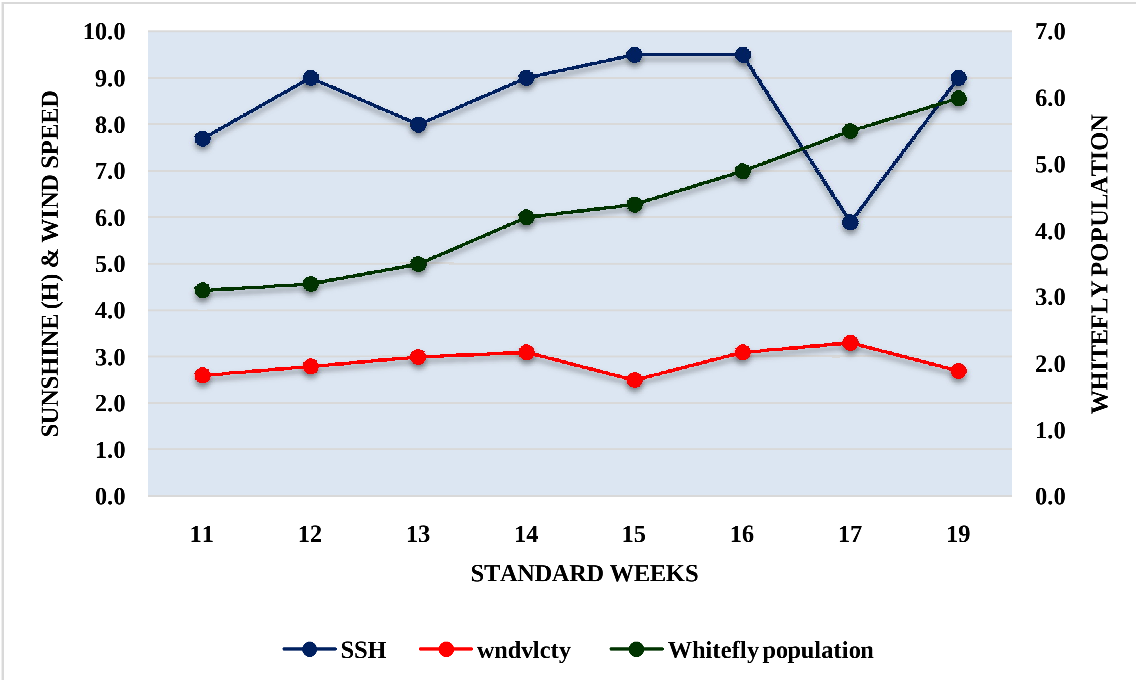

Figure 2. Effect of sunshine hours and wind velocity on whitefly population during *Rabi* 2019-20.

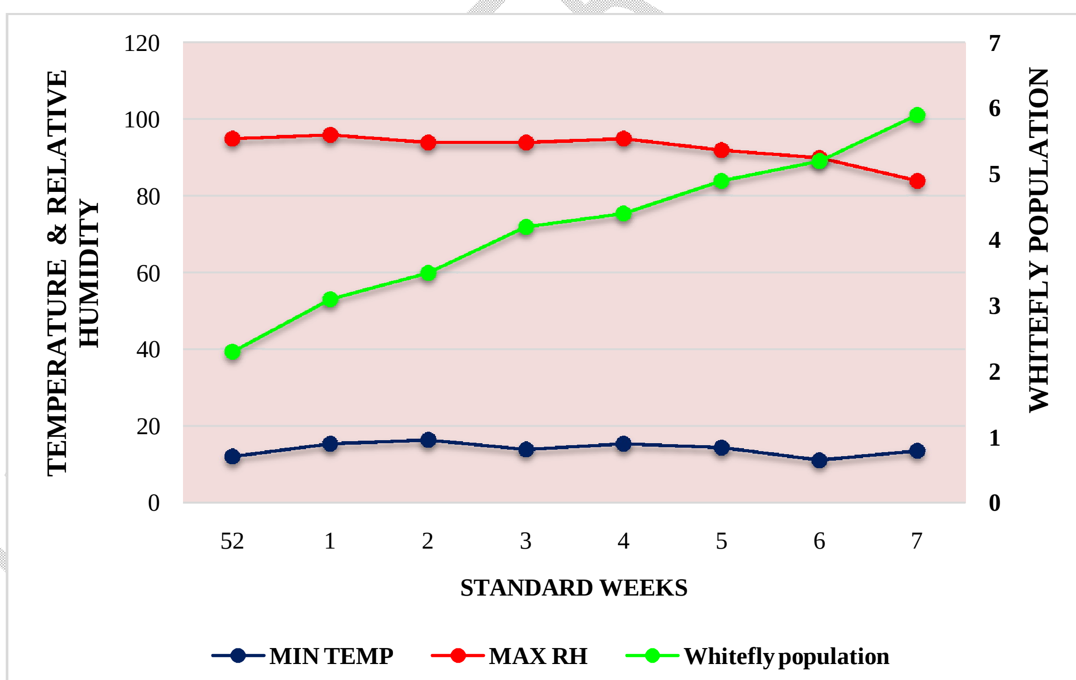

Figure 3. Effect of minimum temperature and relative humidity on whitefly population during *Rabi* 2020-21.

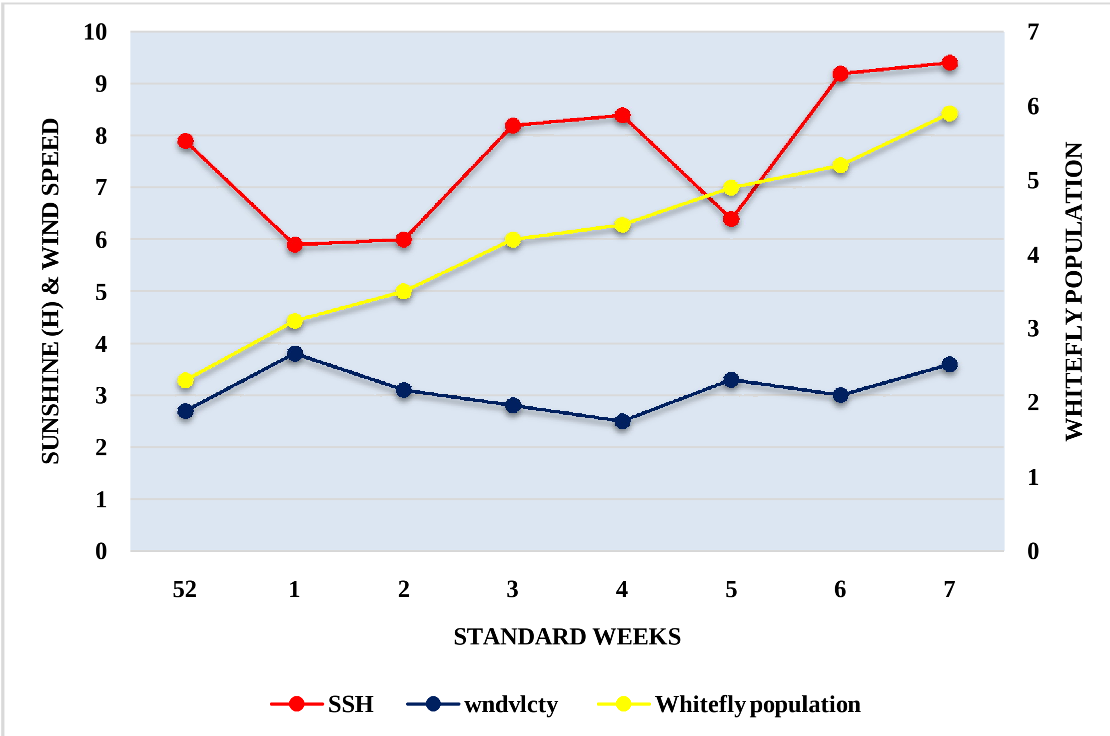

Figure 4. Effect of sunshine hours and wind velocity on whitefly population during *Rabi* 2020-21.