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T Vijaya Lakshmi
Senior Scientist (Pathology), Horticultural Research Station, Lam Farm, Guntur, Andhra Pradesh, India

VL Pathipati
Associate Professor, (Entomology) & Principal, HPC, Dr YSR Horticultural University, Nuzvid, Krishna District, Andhra Pradesh, India

Rajani
Scientist (Horticulture), Horticultural Research Station, Lam Farm, Guntur, Andhra Pradesh, India

CV Ramana
Senior Scientist (Horticulture), Horticultural Research Station, Lam Farm, Guntur, Andhra Pradesh, India

L Naram Naidu
Principal Scientist (Horticulture) & Head, Horticultural Research Station, Lam Farm, Guntur, Andhra Pradesh, India

Corresponding Author:
VL Pathipati
Associate Professor, (Entomology) & Principal, HPC, Dr YSR Horticultural University, Nuzvid, Krishna District, Andhra Pradesh, India

Impact of weather parameters on incidence of whitefly, *Bemisia tabaci* (Gennadius) on chilli in Andhra Pradesh

T Vijaya Lakshmi, VL Pathipati, Rajani, CV Ramana and L Naram Naidu

Abstract
To know the initial occurrence and subsequent build up of whitefly population on chilli crop in relation to weather parameters, the field experiments were carried out from 2014-16 at Horticultural Research station, Lam, Guntur, Andhra Pradesh. Seasonal incidence of whitefly was recorded from leaves and fruits at weekly intervals during the crop growth period. In 2014-15, Correlation coefficients worked out between whitefly population and weather parameters of preceding one week indicated that among the various weather parameters, significant positive correlation was observed between morning relative humidity (0.25**), evening relative humidity (0.33*) and minimum temperature (0.04**) whereas significant negative correlation was observed with maximum temperature (-0.22**) and non significant negative impact of rain fall (-0.27) with whitefly population. Similar trend was observed at preceding two weeks and also in 2015-16 year. The combined effect of weather parameters ranged from 22 to 62 per cent.

Keywords: Chilli (*Capsicum annum* L.), whitefly, impact of weather parameters, Andhra Pradesh

Introduction
Chilli (*Capsicum annum* L.) s an important spice grown for its fruits, which are used in green as well as ripe dried form for its pungency. Chilli belongs to the genus Capsicum, family Solanaceae. It has originated in Mexico, Southern Peru and Bolivia. It was first introduced in India by Portuguese towards the end of 15th century. The top ten chilli producing countries India, China, Ethiopia, Myanmar, Mexico, Vietnam, Peru, Pakistan, Ghana and Bangladesh accounted for more than 85% of the world production in 2009; lion‟s share is taken by India with 36% share in global production, followed by China (11%), Bangladesh (8%), Peru (8%) and Pakistan (6%). In India Chilli is cultivated in all the states including Andhra Pradesh, Karnataka, Maharashtra, Orissa, Rajasthan, Tamil Nadu, West Bengal and Punjab. India contributes one-fourth of the total quantity of chilli exported in the world. Tremendous foreign exchange is being earned through export of chilli powder, oleoresin of low, medium or high pungency [20]

It is an important commercial and export-oriented crop in Andhra Pradesh which has got both domestic and export market as vegetable and a condiment. Andhra Pradesh occupies a prime place in chilli cultivation (116,578 hectares) accounting for 49% of the total cultivated area in the country [4] The cultivation and yield of chillies are frequently hampered in tropical and subtropical regions of India by the occurrence of pests and diseases. Besides several factors responsible for low productivity and quality deterioration of chilli the damage caused by insect pests is the most important. The crop is infested by more than 35 insect and non-insect pests and forty five viruses [5]

Among the insect pests harbouring chillies, the whitefly, *Bemisia tabaci* Genn. (Aleyrodidae: Hemiptera) has become a serious threat to crop production in recent years not only by causing direct feeding damage but also by vectoring and transmission of Begomoviruses and Criniviruses that cause serious problems [9, 10] Particularly, the epidemics of chilli leaf curl disease (ChiLCuD), caused by Chilli leaf curl virus (ChiLCV) and transmitted by *B. tabacii* a serious challenge to yield of chillies in South India [18]. It causes 90% yield loss in chilli, 30% in sweet pepper [16] and acts as vector for chilli leaf curl virus. Direct crop damage occurs when feed in plant phloem removes plant sap and reduce plant vigour.

It also excrete honeydew, which promotes sooty mold that interferes with photosynthesis and may lower harvest quality [17]. Both nymphs and adults suck the sap from developing plant tissue with their mouth parts. In response, young leaves curl upward and appear distorted, buds and fruits become brittle and drop. Infested plants become stunted, leaves with petioles detached from the stem, causing defoliation. It is very difficult to control as it had broad host range, rapid life cycle, small size and mobility [11]. Viruliferous whitefly causes heavy losses are caused due to viruses such as induce mild to severe mosaic, yellow mosaic, mosaic mottle, leaf curl, leaf roll, bushy stunt and necrosis symptoms. During the last two decades insecticidal control of chilli pests in general and especially in irrigated crop characterised by high pesticides usage, has posed problems of residues in the fruits [6]. The several insecticides are being used to manage chilli whiteflies but because of development of many fold resistance to existing insecticides, it has become difficult to manage the pests effectively [8] Considering the seriousness of *Bemisia tabici* infesting chilli in Andhra Pradesh, some new molecules are evaluating time to time to save the crop. Chemical management is the only way to control this pest. To avoid more pesticide usage in chilli ecosystem, there is a need of pest prediction method.

Due to variation in the agro climatic conditions of different regions, the nature and extent of damage caused by whitefly varies. Environmental factors play an important role in determining the seasonal abundance and damage caused by the insect pests. Hence it is necessary to study the influence of various abiotic factors effecting the population fluctuation of whitefly species in chilli crop. These studies would give an idea about the peak period of their activity which in turn may be helpful in developing better pest management strategies. To know the initial occurrence and subsequent build up of whitefly population in both open and poly house conditions, to prevent the spread of viral diseases and timely management of the whitefly population is the need of the day, keeping this in view the present study was done in chilli ecosystem of Andhra Pradesh.

2. Materials and Methods

The experiment was carried out under open field conditions at Horticultural Research Station, Lam Farm, Guntur, Andhra Pradesh from 2010 to 2014. The popularly grown chilli variety LCA-334 was used for the study. The experiment was laid out in 500 m^2plot. The plot was divided into 5 quadrates with a gap of 1m between each quadrate. Seeds of chilli variety LCA 334 were sown in the raised seed beds and one month old healthy seedlings were transplanted in the main field with a row to row and plant to plant distance of 60 cm x 60 cm. All the recommended agronomic practices like fertilizer application, weeding, hoeing, irrigation etc., were taken up at regular intervals. The crop was raised under unprotected conditions. Observations on whitefly species (nymphs) inhabiting the leaves and fruits were recorded at weekly intervals in the chilli crop after noticing the whitefly incidence and continued till the harvest of the crop. For recording the pest incidence, 10 healthy plants were selected randomly from each quadrate and tagged. It is very difficult to take the population counts of the whitefly species in the field as they are very minute, very active and inhabit the young terminal leaves. Hence for taking the whitefly counts and identifying different species inhabiting the leaves, young terminals were collected from ten plants of each quadrate. The whitefly species inhabiting the terminal leaves were collected in 250 ml plastic containers and counted with hand lence. Thus 10 samples from each quadrate were collected at weekly intervals. After collecting the samples, the labels containing the information about the date of observation and the quadrate from which the samples were collected were written and pasted on the container. The whitefly species feeding on the chilli fruits were collected by gently tapping ten fruits from each quadrate in zip lock polythene bags and labelled for counting in the lab.

The weather data was collected from the weather station located at Regional Agricultural Research Station (RARS), Lam, Guntur. Maximum temperature (T. max), Minimum temperature (T. min), Morning Relative humidity (RH I), Evening Relative humidity (RH II) and Rainfall were recorded and represented by Standard Week wise. To find out the effect of various weather parameters on whitefly population simple correlation coefficients were worked out between whitefly population and observatory weather data of preceding one and two weeks. The correlation coefficients obtained were tested at five per cent and one per cent level of significance. To find out the combined influence of all the weather parameters on whitefly population the data were subjected to simple correlation and regression.

3. Result and Discussions

To find out the effect of individual abiotic factors on the population dynamics of whitefly species infesting chilli leaves, flowers and fruits, the correlation coefficients were worked out between whitefly population and weather parameters. While working out the correlation coefficients, whitefly population of each standard week was correlated with preceding one and two weeks weather data which gave better correlation coefficients than with the present week weather data. The incidence of *B. tabaci* in chillies was initiated from 47^{th} STW week (2.1/leaf) and it continued up to the harvest of the crop 12^{th} STW(6.00) with a peak activity at 48^{th} STW (10.5) during 2014-15 (Table-1). The prevailed weather parameters viz., maximum temperature ranged from 29-37.5 ^{0}C, minimum temperature 12.9 -25.6 ^{0}C, morning relative humidity 88.14 -97.86%, evening relative humidity 44.6 -67.9%, rainfall 9-36.2 mm and white fly population ranged from 1.00 to 10.5 per leaf. Correlation coefficients worked out between whitefly population and weather parameters of preceding one week (Table 3) indicated that among the various weather parameters, significant positive correlation was observed between morning relative humidity (0.25**), evening relative humidity (0.33*) and minimum temperature (0.04**) whereas negative significant correlation was observed with maximum temperature (-0.22**) and non significant negative impact of rain fall (-0.27**) with whitefly population. Similar trend was observed at preceding two weeks weather parameters and whitefly population. Significant positive correlation was observed between morning relative humidity (0.12**), evening relative humidity (0.47*) and minimum temperature (0.29**) whereas negative significant correlation was observed with maximum temperature (-0.38**) and non significant negative impact of rain fall (-0.30**) with whitefly population.

The incidence of *B. tabaci* in chillies was initiated from 47^{th} STW week (0.5/leaf) and it continued up to the harvest of the crop 9^{th} STW(4.5) with a peak activity at 6^{th} STW (7.5) during 2015-16 (Table-2). The prevailed weather parameters viz., maximum temperature ranged from 30.79 to 33.75 ^{0}C, minimum temperature 17 -23.21 ^{0}C, morning relative humidity 90.43 -100%, evening relative humidity 43.28 -82%, rainfall 0.1-60.8 mm and white fly population ranged from 0.5 to 6.2 per leaf. Correlation coefficients worked out between whitefly population and weather parameters of preceding one week (Table 3) indicated that among the various weather parameters, significant positive correlation was observed between morning relative humidity (0.14**), evening relative humidity (0.68*) and minimum temperature (0.07**) whereas negative significant correlation was observed with maximum temperature (-0.33**) and non significant negative impact of rain fall (-0.43**) with whitefly population. Similar trend was observed at preceding two weeks weather parameters and whitefly population. Significant positive correlation was observed between morning relative humidity (0.37**), evening relative humidity (0.63*) and minimum temperature (0.28**) whereas negative significant correlation was observed with maximum temperature (-0.21**) and non significant negative impact of rain fall (-0.4**) with whitefly population.

The combined effect of weather parameters on incidence of white fly was worked out (Table-4), the variation in the incidence (20 to 60%) was contributed by the weather parameters. Similar findings by [13, 2] as 81% incidence was contributed by weather parameters.

The variation in the peak activity of whitefly observed in different regions could be attributed to the variation in ecological conditions, date of transplantation and the chilli varieties used in the study. The results strongly support the significant negative correlation with maximum temperature and rain fall where as positive correlation with minimum temperature, morning and evening relative humidity of prevailed weather parameters. As per [20] reported that among the weather parameters, morning relative humidity has significant positive impact on whitefly incidence. Similar results were reported by [1] found that white fly population has positive correlation with minimum temperature, morning and evening relative humidity as in the present study. [12] reported that there was significant negative correlation with maximum temperature and rain fall where as positive correlation with minimum temperature, morning and evening relative humidity with whitefly incidence. From the findings it was evident that population build-up of white fly population on leaves was mainly influenced by relative humidity and minimum temperature. From the result every unit of decreasing temperature three units increasing white fly population similarly every unit of increasing relative humidity, there is eight units increase in population levels. [19] were confirm the present findings. The population levels also vary with year to year because of variations in the weather parameters.

The overall results obtained from the seasonal incidence of chilli whitefly and its relation with weather parameters clearly indicated that the relative humidity has significant impact on peak period of activity of whitefly species inhabiting the plant parts of chilli crop The information obtained from these studies used in developing weather based pest prediction models which in turn are helpful in taking up timely control measures.

Tables 1: Seasonal incidence of Chilli whitefly, *Bemisia tabaci* during 2014-15

Standard week	Date & Month	Max	Min	Morn	Eve	Rainfall (mm)	No. of white fly per leaf
45	5-11,Nov	30.4	12.9	94.29	63.4	9	0
46	12-18,Nov	30.6	15.3	98.29	74	36.2	0
47	19-25,Nov	30.7	17.1	97.14	60.3	0	2.1
48	26-2,Dec	31.6	18.5	87.29	47.6	0	10.5
49	3-9,Dec	30.8	17.7	92.57	53.4	0	0.9
50	10-16,Dec	29.8	22.1	93.86	67.9	0	1.4
51	17-23,Dec	29	17.1	88.14	56.6	0	1.8
52	24-31,Dec	33.1	17.5	91.88	59.8	0	6.2
1	1-7,Jan	30.1	21.9	95.14	58.4	0	2.4
2	8-14,Jan	29.6	14.6	86.43	53.6	0	2.2
3	15-21,Jan	29.7	16.4	94.29	54	0	0.3
4	22-28,Jan	30.3	16.4	93.57	54.6	0	1.4
5	29-4,Feb	30.6	18.1	97.14	56	0	5.5
6	5-11,Feb	30.7	19	96.71	49.4	0	4.6
7	12-18,Feb	32.7	20.6	96.43	50.6	0	1
8	19-25,Feb	33.6	19.8	92	44.6	0	1.5
9	26-4,Mar	32.7	21.6	86.57	60	0	1.6
10	5-11, Mar	34.6	24.3	88.14	48	0	2.5
11	12-18, Mar	36.1	22.6	94.71	44	0	5
12	19-25, Mar	37.5	25.6	97.86	39.1	0	6

Tables 2: Seasonal incidence of Chilli whitefly, *Bemisia tabaci* during 2015-16

Influence of weather factors on White fly, *Bemisia tabaci* during 2015-16							
Standard week	**Date & Month**	**Max**	**Min**	**Morn**	**Eve**	**Rainfall (mm)**	**No. of white fly per leaf**
45	5-11,Nov	33.5	23.21	90.43	57.43	7.2	0
46	12-18,Nov	31.57	20	96.29	63.43	60.8	0
47	19-25,Nov	30.76	20.07	98.29	69.43	5	0.5
48	26-2,Dec	30.93	18.29	98.29	76.29	0.1	1.1
49	3-9,Dec	31.86	18.29	99.43	82	0	3
50	10-16,Dec	32.36	17.5	96.57	63.43	0	1
51	17-23,Dec	32.71	18.29	98.86	64	0	1.8
52	24-31,Dec	32	16.58	97.5	58.38	0	2.2

1	1-7,Jan	31.57	16.43	98.86	55.57	0	5.7
2	8-14,Jan	31.92	15.64	99.42	50.71	0	3.2
3	15-21,Jan	30.79	17	98.86	57.29	0	4.6
4	22-28,Jan	30.7	18.21	96	55	0	6.2
5	29-4,Feb	32.99	17.79	99.43	44.14	0	7
6	5-11,Feb	32.71	19.36	97.14	49.14	0	7.5
7	12-18,Feb	33.71	18.36	100	43.28	0	5.1
8	19-25,Feb	35	19.57	96.57	48	0	5
9	26-4,Mar	33.75	21.5	99	46	0	4.5

Table 3: Correlation co-efficient between Chilli whitefly, *Bemisia tabaci* incidence and weather parameters (preceding one and two weeks from 2014-15)

Observatory Weather Parameters	2014-15		2015-16	
	Preceding 1 Week	Preceding 2 Week	Preceding 1 Week	Preceding 2 Week
Maximum Temperature	-0.22**	-0.38**	-0.33**	-0.21**
Minimum Temperature	0.04**	0.29**	0.07**	0.28**
Morning Relative Humidity (RH-1%)	0.25**	0.12**	0.14**	0.37**
Evening Relative Humidity (RH-II%)	0.33*	0.47*	0.68*	0.63*
Rain fall (mm)	-0.27	-0.30	-0.43	-0.42

*Significant at 5 per cent level (r =0.30)
** Significant at 1 per cent level (r =0.02)

Table 4: Multiple regression equation developed for Chilli whitefly, *Bemisia tabaci* incidence on chilli and weather parameters from 2010 to 2014

Observation	Step down multiple linear equation	Co-efficient of determination (R^2)
2014-15 Preceding 1 week	Y=101.0-0.41* Tmax- 1.15T min +0.03*RH-I+0.06 RH-II-0.04RF	0.24
2014-15 Preceding 2 week	Y=44.75-0.26* Tmax- 0.025T min +0.05*RH-I+0.08 RH-II-0.03RF	0.22
2015-16 Preceding 1 week	Y=25.79-0.36* Tmax- 0.14T min +0.03*RH-I+0.15RH-II-0.09RF	0.44
2015-16 Preceding 2 week	Y=35.99-0.39* Tmax- 0.03T min +0.28*RH-I+0.15RH-II-0.04RF	0.60

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