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Influence of weather parameters on population of whitefly, *Bemisia tabaci* in Sunflower

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Abstract
Whitefly *Bemisia tabaci* is a polyphagous insect pest infesting many host species throughout the entire geographical range. Study was carried to determine the population dynamics of whiteflies and establish the correlation with abiotic factors in Sunflower. Activity of whiteflies was observed throughout the year in sunflower ecosystem with population ranging from 0.40 to 60.56 / 6 leaves per plant across the study years (2011-2019) and mean population of leafhopper ranged from 4.62 to 15.89/6 leaves/plant and was at its peak during 3rd MSW (January) and declined thereafter but remained active till harvest of the crop. The significant and negative correlation was observed between nymphal population and minimum temperature. There existed a non-significant and positive correlation between whitefly population and Rainfall, morning relative humidity and evening relative humidity. Whereas, the relation was negative and non-significant with maximum temperature and bright sunshine hours. The simple linear regression model showed that the BSS, evening relative humidity, minimum temperature and maximum temperature had maximum influence on the development of leafhopper population. Multiple regression indicated that weather factors collectively influenced the population of whiteflies to the extent of 92.0 per cent. This Information may be utilized in targeting suitable pest management techniques for respective zones.

Keywords: whiteflies, seasonal abundance, sunflower, abiotic parameters

Introduction
Sunflower is an important short duration crop grown for its edible oils. It is a crop of choice for farmers due to its wider adaptability, high yield potential shorter duration and profitability (Lavanya *et al*., 2005) [1]. In India, sunflower is being grown over an area of 0.52 m ha with a production of 0.34 million tonnes and the productivity of 643 kg per ha. In Karnataka sunflower is being grown over an area of 0.35 m ha with a production of 0.20 million tonnes and the productivity of 579 kg per ha (Anon., 2016) [2]. Amongst the sap sucking insect pests damaging this crop, whitefly, *B. tabaci* (Hemiptera: Aleyrodidae), a highly polyphagous insect-pest, has become serious, causing heavy losses during certain years. High population of the pest has the potential to remove significant amounts of phloem sap resulting in the reduction of plant vigour. Damage by this pest is caused in two ways: (a) the vitality of the plant is lowered through the loss of cell sap, and (b) normal photosynthesis is interfering with the growth of sooty mould on the honeydew excreted by the insect. The pest is also known to transmit cotton leaf curl virus causing significant yield losses if the infection is in the early stages of crop growth. Recently, whitefly has emerged as the new potential sucking insect pest of sunflower and also acting as the vector of leaf curl begomovirus in Northern Karnataka, India. This has attracted lot of attention of the Entomologists and pathologists, as it affects the productivity of sunflower an important oilseed crop in the country (Katti Pramod, 2007) [3]. Sunflower leaf curl disease vectored by whitefly was noticed for the first time in the country and the disease was recorded on sunflower hybrid 'Sun breed-275' up to 40 per cent disease incidence in the fields of Main Agricultural Research Station, University of Agricultural Sciences, Raichur, Northern Karnataka, during rabi season of 2009 (Govindappa *et al*., 2011) [4]. Since then, the whitefly infestation has been noticed in an endemic form consecutively for the last two years in sunflower growing areas of northern districts of Karnataka. Sunflower is an important oil seed of the country. Due to variation in the agro climatic conditions of different seasons insect show varying trends in their incidence also in nature and extent of damage to the crops. Besides, some known and unknown factors also play a key role in determining the incidence and dominance of a pest.

Therefore, the present study was to understand the behaviour of whitefly with the weather parameter of the environment.

Materials and Methods

Sunflower hybrid DRSH-1 was sown at Main Agricultural Research Station, Raichur from 2011 to 2019 during rabi season. Experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The row to row and plant to plant distance was kept at 0.60 and 0.30 meters, respectively. Fertilizer applications and agronomic practices were used according to standard recommendations of the university. After fifteen days of germinations, data for the leafhoppers and predators were recorded on weekly basis till harvest of the crop. Population was recorded from upper, middle and lower leaves of the plants. Total of 50 plants were observed. All natural enemies were recorded on whole plant basis. No pesticides were applied on the crops during the study period.

Meteorological Data: The weather data was obtained from the Department of Agricultural Meteorology, Main Agricultural research Station, University of Agricultural Sciences, Raichur for the crop period from October to February during 2011 to 2019. The daily weather data *viz*. minimum and maximum temperature, the morning and evening relative humidity, the rainfall, and the bright sunshine hours were recorded by the weather station, installed in the research area. Correlation and regression analyses were used to find out the influence of climatic factors –on the population dynamics of leafhopper.

Statistical Analysis: The weekly averaged data of population dynamics of leafhopper were subjected to correlation and regression analysis with weather parameters following standard procedure. Simple Regression was worked out between insect pests and weather factors. The significance level was set at $P < 0.05$.

Results and Discussion

Weather based pest forewarning systems can act as an effective tool in developing suitable control measures against pest incidence in crops. Information on abundance and distribution of pest in relation to meteorological parameters is the basic requirement for developing pest management program for a specific agro ecosystem. Both maximum and minimum temperatures, total rainfall, and relative humidity are the major weather parameters that largely control the dynamics of a given insect species (Jayewar *et al*., 2019) [5].

Activity of whitefly was observed throughout the year in sunflower ecosystem with population ranging from 0.40 to 60.56 / 6 leaves per plant across the study years (2011-2019) and mean population of leafhopper ranged from 4.62 to 15.89/6 leaves/plant and was at its peak during 3rd MSW (January) and declined thereafter but remained active till harvest of the crop (Table 1 and Fig 1).

Peak whitefly population ranged from 10.34 – 60.56 adults/6leaves/plant during 2011-2019, with the maximum population having been recorded during 2011 and the minimum in 2017. On the other hand T_{max}, T_{min}, Rainfall, RH1, RH2 and BSS varied from 24.7 - 35.1 ºC, 10.1- 20.4 ºC, 0.00 – 8.20 mm, 62-93%, 20-52% and 1.9-9.6 respectively. Peak activity of whiteflies across the season was not uniform and more than one peaks were observed. Peak activity was observed during 49th MSW (46.80/6 leaves/plant) for the year 2011, 52nd MSW during the year 2018 (20.02/6 leaves/plant) and 2019(21.22/6 leaves/plant), 1st MSW during the year 2014 (14.60/6 leaves/plant) and 2017 (10.34/6 leaves/plant), 2nd MSW during the year 2013 (19.46/6 leaves/plant) and 2016 (13.10/6 leaves/plant). For the year 2012 and 2015 the peak population was observed during 3rd MSW with a population of 60.56 and 21.93/6 leaves/plant respectively. These differences in the peak incidence of whiteflies were may be due to the difference in climatic conditions (Table 1).

The present findings are in conformity with the findings reported by Biswas and Patel (2015) [6] who reported that the initial incidence of whitefly on field pea was observed during 49th SW (2nd week of December 2011). The peak period for whitefly incidence was observed during 6th SW (2nd week of February 2012) and available up to 11th SW (2nd week of March 2012). Geetha and Hegde (2018) [7] reported mean maximum and minimum incidence of 1.65 and 0.25 per six leaves per plant respectively during 43rd and 45th SMW in sunflower at Dharwad. The finding was more or less similar with the finding of Chavan *et al*. (2013) [8] who reported that whitefly population commenced from transplanting with 0.37 whiteflies/leaf and reached to peak level 6.01whiteflies/leaf at 11th standard meteorological week on tomato. Such study on sunflower had been taken by Men *et al*. (1997) [9] from India, but the study was at kharif season. Latif and Akthar (2013) [10] also peak reported that population of whitefly gradually increased with the increased environmental factors (*viz*., temperature, relative humidity) up to certain age of the cultivated crops then declined with increasing age of the crops. Similarly, Konar and Paul (2006) [11] found that whitefly became active from October to March-April in gangatic plains of West Bengal, India. Solanki and Jha (2018) [12] reported that among the three different dates of sowing, the population of whitefly (*Bemisia tabaci* Gennadius) (Homoptera: Aleyrodidae) was always higher on first date of sowing followed by intermediate and late sown crop. During first year the whitefly population reached its peak with population load of 5.08, 3.52 and 3.05/leaf at CRF and 6.49, 5.44 and 4.63/leaf at Madandanga farm on second week of February, first week of March and fourth week of March respectively. During second year the whitefly on sunflower, reached its peak with population load of 5.27, 4.45 and 3.71/leaf at CRF and 8.79, 7.29 and 5.21/leaf at Madandanga field on second week of February, first week of March and fourth week of March respectively.

The coefficient of correlation between whitefly population and weather parameters are presented in Table 1. The significant and negative correlation was observed between nymphal population and minimum temperature (r = -0.571).There existed a non-significant and positive correlation between whitefly population and Rainfall(r = 0.17), morning relative humidity(r = 0.197) and evening relative humidity(r = 0.165). Whereas, the relation was negative and non-significant with maximum temperature (r = -0.368) and bright sunshine hours (r = -0.100) (Table 2).

Geetha and Hegde (2018) [7] reported non-significant correlation between whiteflies population and weather parameters during the years 2015 and 2016. Correlation studies revealed that all abiotic factors showed non-significant correlation with whitefly population (Piyali Bhowmik *et al*., 2018) [13]. The present findings are in conformity with Meena and Bairwa (2014) [14] and they reported that evening relative humidity and rainfall showed negative and non-significant relationship with whitefly population. The present findings also support the findings of Yadav and Singh (2015) [15] who reported that minimum temperature, rainfall and wind velocity showed non-significant negative correlation with whitefly population. The present findings are in contradiction with Berragani *et al*. (2015) [16] who reported that morning relative humidity, evening relative humidity and evaporation showed significant positive correlation with whitefly population. However Ghosh (2014) [17] also reported that maximum temperature and minimum relative humidity showed non-significant positive correlation with whitefly population. These differences may be due to different ecological condition and difference crop on which the experiment was conducted.

Weather variables act as a limiting factor in the development of the insect pest. In order to understand the relative importance of selected weather parameters in explaining the fluctuation of the population of leafhopper, the Simple regression coefficients of pest population on weather parameters were computed taking the population of leafhopper as dependent variable and maximum & minimum temperature, morning & evening relative humidity, rainfall and sunshine hours as independent variables. In a simple regression analysis (table 1) the impact of weather factors on the population of whitefly in Sunflower during 2011-2019 showed that the contribution of weather parameters to the tune of 2.70 to 51.10 per cent on the incidence of whiteflies in Sunflower. BSS exerted 51.10 per cent role in the whitefly population variation which was the highest than any other factors and which was followed by evening relative humidity (45.00 per cent)minimum temperature (33.00 per cent), maximum temperature (30.00 per cent),morning relative humidity (4.20 per cent) and Rainfall (2.70 per cent) (Table 3 & Fig 2). The simple linear regression analysis reported by Arun Janu *et al*., (2017) [18] indicated that morning relative humidity was most important factor which contributed maximum i.e. 44.90 per cent in the fluctuation of whitefly population followed by maximum temperature (31.30 per cent) and evening relative humidity (30.90 per cent). The impact of morning & evening relative humidity were positive while maximum temperature had a negative impact on the whitefly population during both the years. The results of Arif *et al*., (2006) [19] who reported that rainfall showed 8.5 per cent influence in the population of whitefly, increased up to 33.5 per cent when the influence of temperature and if relative humidity influence added than the impact was 66.4 per cent on the variation of whitefly population favours the present study. Similarly, weather factors showed a significant role in population fluctuation of pest (Rote and Puri, 1991; Gupta *et al*., 1998; Murugan and Uthamasamy, 2001) [20-22]. These results are also partially similar to the findings of (Akram *et al*., 2013) [23] who reported that the minimum temperature exerted maximum role 31.2 and 11.3 per cent during 2010 and 2011, respectively.

The multiple linear regression equation Y= -94.70+4.02T_{max} - 5.85T_{min}+3.54RF - 0.36RH_1+ 1.86RH_2 + 5.88BS indicated one unit increase in minimum temperature and morning relative humidity caused increase whitefly population by 5.85 and 0.36 units. However, a unit increase in maximum temperature, Rainfall, evening relative humidity and BSS caused decrease in their population by 4.02, 3.54, 1.86 and 5.88 units. The weather factors collectively influenced the population of whiteflies to the extent of 92.0 per cent.

The multiple linear regression analysis reported by Arun Janu *et al*., (2017) [18] indicated that the total influence of all the weather parameters was high in the population of whitefly. It was upto 64.90, per cent on the population of whitefly during the 2014 and upto 79.50 per cent during 2015. In pooled an analysis, all weather parameters exerted 79.60 per cent of variation in the whitefly population. Prasad *et al*., (2008) [24] Evaluated multiple linear regression analysis and found that the total influence of all the weather parameters was up to 60.26 per cent variation of whitefly population. Thus, the various meteorological parameters had a profound influence on the incidence and population build up of whitefly in Bt cotton and the findings will indicate the importance of weather factors in pest forecasting. Geetha and Hegde (2018) [7] through multiple linear regression analysis reported that all the weather factors put together influence the *B. tabaci* incidence to an extent of 72.6 and 91.2 per cent respectively in 2015 and 2016. The multiple linear regression equation of pooled data Y= -2.199- 0.025X1 + 0.487X2 - 0.057X3 - 0.030X4 + 0.002X5 + 0.014X6 indicated one unit increase in maximum temperature, morning relative humidity, evening relative humidity caused increase *B. tabaci* population by 0.025, 0.057 and 0.030 units. However, a unit increase in minimum temperature, rainfall and wind velocity caused decrease in their population by 0.487, 0.002 and 0.014 units. The weather factors collectively influenced the population of *B. tabaci* to the extent of 88.6 per cent.

Table 1: Mean population of Whiteflies during 2011-2019

SMW	Mean Leafhopper Population/6 leaves/plant									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
48	8.00	3.40	0.40	3.40	2.80	3.64	10.32	13.38	10.88	6.25
49	46.80	4.20	2.34	5.40	1.97	5.32	9.70	19.90	17.40	12.56
50	42.00	3.90	13.40	7.47	0.73	7.20	10.12	8.38	12.12	11.70
51	16.20	6.50	14.20	8.90	5.57	5.56	10.30	11.22	14.62	10.34
52	4.80	9.46	12.90	11.56	17.00	5.48	6.90	20.02	21.22	12.15
1	19.20	16.90	16.50	14.60	16.67	11.88	10.34	16.10	12.16	14.93
2	14.00	24.38	19.46	8.60	13.03	13.10	10.34	0.80	9.48	12.58
3	21.60	60.56	16.90	8.60	21.93	5.20	2.34	1.20	4.68	15.89
4	13.60	30.25	4.50	3.80	13.07	3.50	1.50	0.64	1.90	8.08
5	11.20	8.90	3.20	6.40	6.50	2.50	1.20	0.50	1.20	4.62

Table 2: Mean weather parameters and Whitefly population of sunflower (mean of 2011 to 2019) along with correlation coefficient

SMW	Whiteflies/plant	T_{max} (ºC)	T_{min}(ºC)	RF (mm)	RH-I (%)	RH-II (%)	BSS (Hrs)
48	6.25	30.7	17.8	0.1	80.7	42.6	5.6
49	12.56	30.6	17.4	0.2	84.9	42.5	6.0
50	11.70	31.3	16.9	1.1	82.5	38.7	5.9
51	10.34	30.0	15.6	0.0	81.4	37.8	6.4
52	12.15	29.6	15.5	0.0	77.4	37.1	6.3
1	14.93	31.1	17.4	1.1	81.6	39.3	6.6
2	12.58	30.7	16.0	0.0	77.0	34.7	6.6
3	15.89	30.7	15.9	0.2	76.5	35.5	7.2

4	8.08	31.1	17.9	1.1	75.9	35.0	7.0
5	4.62	31.8	17.9	0.0	76.6	32.2	7.7
Mean	-	30.76	16.83	0.38	79.45	37.54	6.53
Correlation coefficient	-	-0.368	-0.571	0.167	0.197	0.165	-0.100

Table 3: Simple regression models along with coefficient of determination of individual weather variables on leafhopper population fluctuation on Sunflower

Weather variable	Simple Regression Equation	R^2 Value
Maximum temperature (°C)	$y = -2.977x^2 + 180.7x - 2730.$	0.295
Minimum temperature (°C)	$y = -2.111x + 46.42$	0.326
Rainfall (mm)	$y = 1.195x + 10.44$	0.027
Morning relative humidity (%)	$y = 0.028x^2 - 4.276x + 172.6$	0.042
Evening relative humidity (%)	$y = -0.208x^2 + 15.94x - 291.6$	0.450
Bright Sunshine hours	$y = -6.245x^2 + 82.08x - 256.4$	0.511

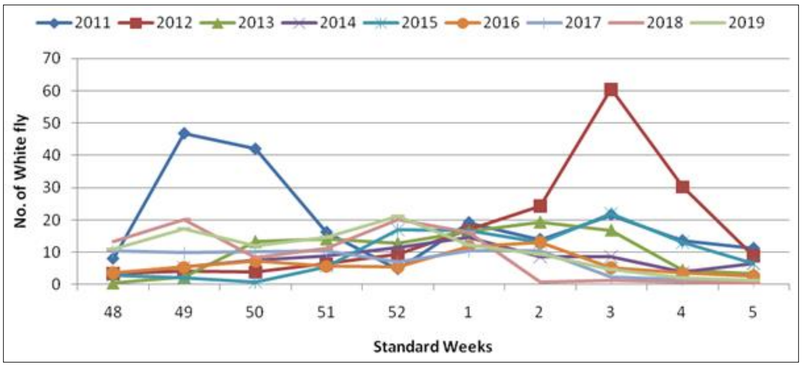

Fig 1: Weekly whitefly population in sunflower ecosystem during 2011-2019

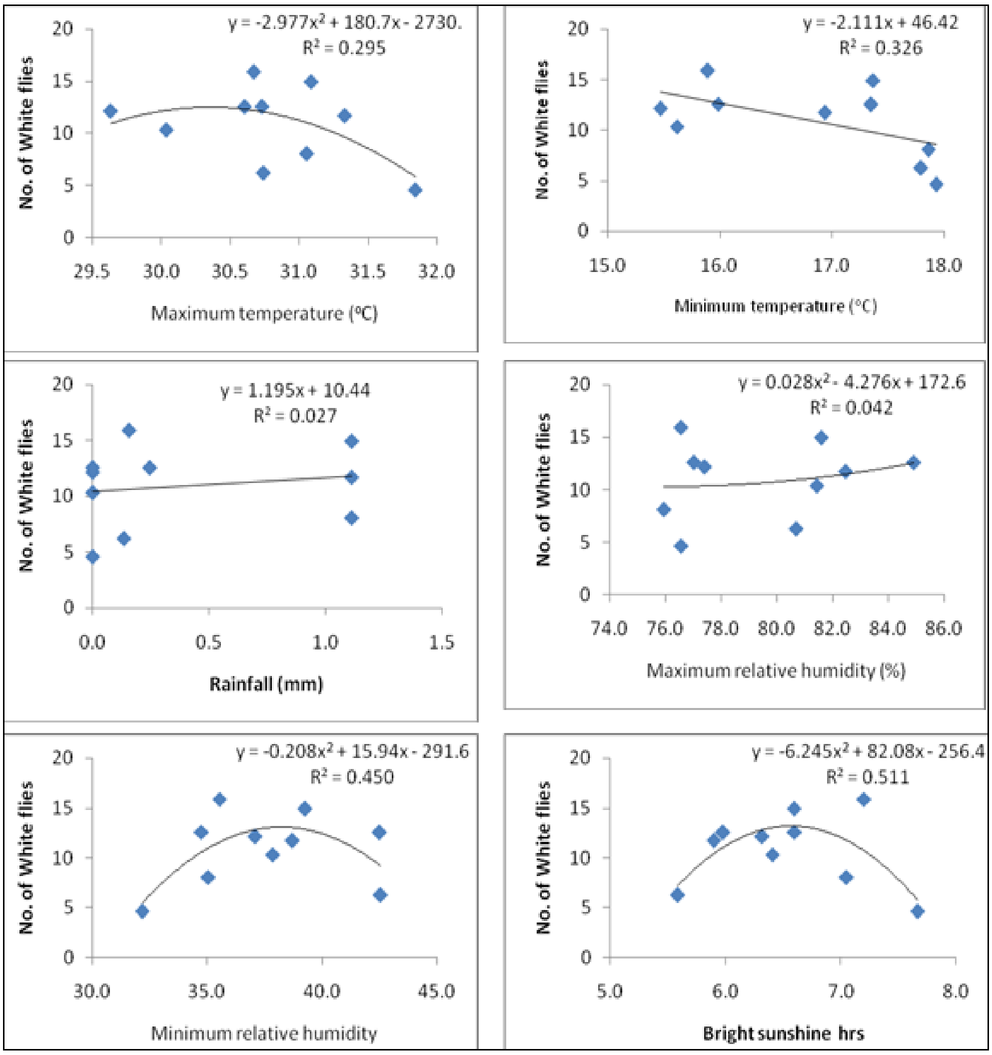

Fig 2: Relationship between different weather parameters and number of white fly population in sunflower

Conclusions

Whitefly *Bemisia tabaci* is a polyphagous insect species infesting many host species throughout the entire geographical range. The results on present study revealed that the population build up of the whitefly was found as to be significantly influenced by weather variables in Sunflower. The significant and negative correlation was observed between nymphal population and minimum temperature. There existed a non-significant and positive correlation between whitefly population and Rainfall, morning relative humidity and evening relative humidity. Whereas, the relation was negative and non-significant with maximum temperature and bright sunshine hours.

The simple linear regression model showed that the BSS, evening relative humidity, minimum temperature and maximum temperature had maximum influence on the development of leafhopper population. Multiple regressions indicated that weather factors collectively influenced the population of whiteflies to the extent of 92.0 per cent. Although empirical pest-weather models have significantly contributed in understanding pest population dynamics but these are influenced by local conditions and thus behave in a location-specific manner (Pinnschmidt *et al*., 1995 and Teng *et al*., 1998) [25-26]. The pest population is thus shown to be affected by different factors at various locations. Pest weather regression models were developed for the pest population explained which would be helpful in gauging likely build up of the pest population, thereby aiding in forewarning and timely action before infestation in conducive weather. Information may be utilized in targeting suitable pest management techniques for respective zones.

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