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Seasonal population dynamics of whitefly (*Bemisia tabaci* Gennadius) in soybean

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Abstract
A trial was conducted to know the seasonal population dynamics of whitefly, *Bemisia tabaci* in soybean (*cv.* JS-335) and their relation to weather parameters during three consecutive seasons viz., *Rabi* (2014-15), summer (2015-16) and *Kharif* (2015-16). The population of adults whitefly were exhibited significantly positive correlation with maximum and minimum temperature (r= 54 and r= 0.58), morning and evening vapour pressure (r= 0.59 and r= 0.58) and evaporation (r= 0.56) whereas, negative correlation was expressed with morning RH% during *Rabi* season. Similarly during the summer season of soybean the maximum and minimum temperature (r= 0.74 and r= 0.65) and evaporation (r= 0.64) were showed significantly positive correlation with whitefly population while, morning RH% was exhibited negative. On the other hand, in *Kharif* season maximum temperature (r= 0.56), sunshine (r= 0.59) and evaporation (r= 0.59) were expressed significantly positive correlation whereas, wind speed and rainfall were negative on influence of whitefly population. Overall results revealed that weather parameters like temperature, RH%, sunshine and rainfall were played limiting factors for the buildup of whitefly population in soybean agro-ecosystem.

Keywords: Whitefly, *Bemisia tabaci*, soybean, population dynamics

1. Introduction
Soybean (*Glycine max* L.) is the main *Kharif* crop of the Madhya Pradesh state of India. The present area under soybean in the state is 6.31 million ha with production of 5.24 million tonnes and productivity 831 kg/ha [1]. It is world's most useful and cheapest sources of protein, vitamins, minerals, salts, carbohydrates and other ingredients which result it is known as Miracle bean and Golden bean. Its protein is rich in the valuable amino acid lycine (5%) which is generally deficient in most of the cereals. In Indian scenario, Madhya Pradesh alone contributes about 67 per cent area in which producing half of the total production of the India. Productivity of soybean is less than the potential yield of recommended varieties due to attack of different pests. About more than 150 insect pests have been reported on soybean crop in various parts of Madhya Pradesh [2]. Among them the whitefly, *Bemisia tabaci* Gennadius has became devastating insect pest which suck the phloem sap from the lower surface of leaves and also play as a vector for transmission of mungbean yellow mosaic virus disease in soybean, blackgram and greengram [3]. In Central India, yellow mosaic disease (YMD) of soybean, blackgram and greengram is caused by Mungbean Yellow Mosaic India Virus (MYMIV) [4-6]. It may cause 85–100% yield loss depending upon the susceptibility of the cultivar, time of infection, population of vector (*Bemisia tabaci*) and other favourable conditions [3]. In India, the annual monetary losses in legumes (soybean blackgram and mungbean) caused by YMD have been estimated to be approximately US $300 million per year [7]. Keeping the above facts it was planned to comprehensive study the influence of weather parameters on seasonal incidence of whitefly in soybean crop.

2. Materials and Methods
An investigation was carried out to study the seasonal population dynamics of whitefly in soybean crop (*cv.* JS-335) and their relation to weather parameters during three consecutive seasons viz., *Rabi* (2014-15), summer (2015-16) and *Kharif* (2015-16) at Breeding seed Production unit, Live Stock Farm, JNKVV, Jabalpur (MP), India. Soybean crop was grown as a test crops in *Rabi* and summer seasons only for experimental purpose to assess the seasonal fluctuations of whitefly population while this crop is usually grown in *Kharif* season.

2.1 Experimental layout
The plot size was kept 40x30m with the spacing of 45x10cm between the rows and plants. All the recommended agronomical practices like fertilizer, weeding operations were followed except the insect pest management.

2.2 Observation recorded
Observations on population of adult whiteflies were recorded weekly intervals on randomly ten selected plants of soybean by caging the individual plant with the help of cage till the availability of the insect or maturity of the crop whichever is earlier and their mean was calculated.

2.3 Statistical analysis
Statistical analysis of obtained data was studied through multiple correlation to find the seasonal population dynamics of whitefly on soybean with different weather parameters viz., temperature, Relative humidity, wind speed, sunshine hours, vapor pressure, evaporation and rainfall. Relationship between whitefly and different meteorological variables were subject to studied using simple correlation and regression.

3. Results and Discussion
3.1 Influence of weather parameters on activity of whitefly on *Rabi* soybean 2014-15
The results of seasonal population dynamics of whitefly in soybean field in *Rabi,* 2014-15 is presented in Table 1. Soybean crop was grown in *Rabi* season for experimental purpose to assess the population dynamics of whitefly. The population of whitefly was first observed from 49th SW (0.27 whiteflies/plant) which was gradually increased and reached at its peak on 8th SW (5 whiteflies/plant). During the peak period the maximum and minimum temperature were 30.6 ^{0}C and 12.0 ^{0}C, while morning and evening RH, wind speed, sunshine, morning and evening vapour pressure, evaporation and rainfall were 86% and 33%, 1.9km/h, 9.70 hrs, and 10.40 mm, 10.70mm, 3.30mm and 0.00mm, respectively. After that activity of whitefly population was somewhat gradually declined on 9th SW (2.5 whiteflies/plant) and again gradually increased on 10th SW (3.00whiteflies/plant), 11th SW (4.00 whiteflies/plant), 12th SW (4.47/plant) and declined with the increasing age of crop on 13th SW (2.50whiteflies/plant), respectively. Present results revealed that among the abiotic factors the temperature plays important role for oscillation of whitefly population and this was corroborated with the previous workers [8].

Table 1: Influence of weather parameters on activity of whitefly on *Rabi* soybean (2014-15)

SW	Whitefly/plant	Weather parameters									
		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
49	0.27	28.7	8.0	88	24	2.5	8.7	7.8	6.3	3.1	0.0
50	0.50	29.0	11.8	89	52	2.6	6.2	10.3	8.0	1.7	3.2
51	0.60	25.3	5.6	86	32	2.2	7.6	6.4	6.4	1.8	0.0
52	0.70	23.8	4.8	87	32	2.1	8.5	6.4	6.1	2.0	0.0
1	0.60	20.5	11.7	90	61	3.8	6.5	10.4	10.4	1.1	37.7
2	0.93	22.1	5.3	87	38	2.1	8.5	6.8	7.4	1.4	0.0
3	1.30	22.2	5.3	91	37	2.6	8.3	7.3	7.3	1.7	0.0
4	0.90	21.0	12.1	89	75	3.3	3.7	11.1	12.6	0.9	10.2
5	1.77	22.5	8.7	85	44	2.7	9.8	8.3	9.0	1.7	10.8
6	2.40	24.2	10.2	88	52	4.5	7.1	9.5	11.6	2.7	14.4
7	3.00	26.8	10.4	88	40	2.8	9.1	9.4	10.7	2.7	6.2
8	5.00	30.6	12.0	86	33	1.9	9.7	10.4	10.7	3.3	0.0
9	2.50	26.7	14.5	85	54	3.2	6.8	12.0	12.6	2.4	64.8
10	3.00	28.0	12.0	85	39	2.9	9.5	10.4	11.2	3.3	0.0
11	4.00	26.8	15.2	87	54	3.6	6.0	13.2	13.3	1.7	23.6
12	4.47	31.8	13.8	80	26	2.2	10.3	11.4	9.5	4.0	0.0
13	2.50	35.1	17.4	78	23	3.3	8.5	13.2	9.3	4.9	0.0
Correlation (r)		0.54*	0.58*	-0.49*	-0.18	0.01	0.39	0.59*	0.58*	0.56*	0.04

*Significant (P=0.05), X_1-Maximum temp.(^{0}C), X_2-Minimum temp.(^{0}C), X_3-Morning RH%, X_4-Evening RH %, X_5-Wind speed (km/h), X_6-Sunshine (hrs), X_7-Morning vapour pressure (mm), X_8- Evening vapour pressure (mm), X_9 -Evaporation (mm) and X_{10}-Rainfall (mm).

Further correlation was studied between the mean whitefly population and weather parameters in which maximum and minimum temperature (r= 54 and r= 0.58), morning and evening vapour pressure (r= 0.59 and r= 0.58) and evaporation (r= 0.56) which were expressed significantly positive correlation, respectively, whereas morning RH% (r= -0.49) was exhibited negative correlation on influence of whitefly population. Regression equation of whitefly population with weather parameters viz., maximum temperature and minimum temperature, morning RH%, morning vapour pressure, evening vapour pressure and evaporation were exhibited as Y= -3.13+0.20x (R^2 =0.29), Y= - 0.37+0.23x (R^2 =0.33), Y= 20.97 - 0.22x (R^2 =0.24), Y= -1.74+0.39x (R^2 =0.33), Y= -1.47+ 0.37x (R^2 =0.33) and Y= 0.20+0.77x (R^2 =0.31), respectively. The equations of R^2 values were revealed that weather parameters which played role as density independent factors for fluctuation of whitefly population. Lapidot Moshe reported the life cycle progression of whitefly from egg to nymph and adult emergence is inevitably governed by temperature as a result the adult emergence does not occur when the temperature reached below 17 ^{0}C [9].

3.2 Influence of weather parameters on activity of whitefly on summer soybean 2015-16
Seasonal population dynamics of whitefly in summer soybean field during 2015-16 is shown in Table 2. The appearance of incremental adult whiteflies populations were ranged from 2.30 to 14.50 whiteflies/plant. The lowest mean population of whitefly was recorded 2.30 whiteflies/plant in 14th SW. During this week maximum and minimum temperature were 35.4 ^{0}C and 19 ^{0}C, whereas morning and evening RH, wind speed, sunshine, morning and evening vapour pressure, evaporation and rainfall were 55% and 23%, 5.3 km/h, 9.3 hrs, 11.3mm, 9.6mm, 6.9mm and 0.00mm, respectively. After that activity of whitefly population was somewhat gradually increased and reached at peak on 21st SW (14.50whiteflies/plant) when received favourable weather conditions.

Table 2: Influence of weather parameters on activity of whitefly on summer soybean (2015-16)

SW	Whitefly/plant	Weather parameters									
		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
14	2.30	35.4	19.0	55	23	5.3	9.3	11.3	9.6	6.9	0.0
15	4.80	33.6	18.9	75	35	5.1	8.1	14.3	11.6	5.3	12.4
16	6.20	37.4	20.5	64	18	3.9	9.2	15.5	8.9	6.6	1.0
17	9.00	39.2	23.9	42	17	6.3	9.4	11.5	8.9	8.1	0.0
18	12.20	40.4	23.5	44	14	4.7	8.3	12.0	7.4	7.4	0.0
19	10.50	41.9	24.0	37	14	4.9	9.0	11.4	7.9	8.4	4.4
20	12.00	40.2	25.8	51	23	5.8	7.5	15.8	11.5	7.7	0.0
21	14.50	42.8	27.5	37	16	6.9	9.4	13.2	10.2	10.9	6.2
22	8.60	43.0	27.0	40	17	5.4	8.9	13.1	10.2	9.5	0.0
23	7.00	41.6	28.7	46	20	6.2	8.3	16.6	12.4	8.9	0.0
Correlation (r)		0.74*	0.65*	-0.66*	-0.56	0.32	-0.12	-0.05	-0.22	0.64*	-0.05

*Significant (P=0.05), X_1-Maximum temp.(^{0}C), X_2-Minimum temp.(^{0}C), X_3-Morning RH%, X_4-Evening RH %, X_5-Wind speed (km/h), X_6-Sunshine (hrs), X_7-Morning vapour pressure (mm), X_8- Evening vapour pressure (mm), X_9 -Evaporation (mm) and X_{10}-Rainfall (mm)

During this week the maximum and minimum temperature were 42.8 ^{0}C and 27.5 ^{0}C, whereas morning and evening RH, wind speed, sunshine, morning and evening vapour pressure, evaporation and rainfall were 37% and 16%, 6.9 km/h, 9.4 hrs, 13.2mm, 10.2mm 10.9mm and 6.2mm, respectively. The whitefly population was started declined with increasing age of the crops on 22nd (8.60whiteflies/plant) and 23rd SW (7.00whiteflies/plant), respectively. The correlation between the mean whitefly population and weather parameters in which maximum and minimum temperature (r= 0.74 and r= 0.65), and evaporation (r= 0.64) were expressed significantly positive, while morning RH has exhibited negative correlation (r= -0.66) and other parameters were found statistically non-significant. Regression equation of whitefly population with weather parameters viz., maximum temperature, minimum temperature and evaporation were observed as Y= -25.91+0.88x (R^2=0.55), Y= -7.97+0.70x (R^2=0.43) and Y = -3.27+1.50x (R^2=0.41), respectively, while morning RH% was Y =18.42-0.20x (R^2 =0.43). The R^2 values revealed that fluctuation of whitefly were governed by weather parameters. Gupta *et al.* also stated that temperature was expressed positive correlation, while relative humidity and rainfall influenced negative correlation on population of whitefly on cotton [10]

3.3 Influence of weather parameters on activity of whitefly on *Kharif* soybean 2015-16

Seasonal population dynamics of whitefly in soybean field in *Kharif* 2015 is shown in Table 3. Population of adult whitefly was ranged from 1.77 to 13.40whiteflies/plant. The lowest population of whiteflies (1.77/plant) was recorded on 29th SW. During this SW the maximum and minimum temperature were 31.3 ^{0}C and 24.2 ^{0}C, whereas morning and evening RH, wind speed, sunshine, morning and evening vapour pressure, evaporation and rainfall were 89% and 70%, 5.1km/h, 2.8 hrs, 22.5mm, 22.9mm, 3.6mm and rainfall 72.8mm, respectively. After that activity of whitefly population was gradually increased and reached at peak on 32nd SW when the favourable weather parameters were occurred. During this SW the maximum population of whiteflies (6.00/plant) was recorded. During this SW the maximum and minimum temperature were 31.2 ^{0}C and 24.2 ^{0}C, whereas morning and evening RH, wind speed, sunshine, morning and evening vapour pressure, evaporation and rainfall were 91% and 69%, 3.7 km/h, 4.6 hrs, 23. 1mm, 23.7mm, 3.6mm and 14mm, respectively. After that the population of whitefly was again little bit declined and reached at peak on 37th SW (13.40whiteflies/plant). During this highest peak the maximum and minimum temperature were 33.5 ^{0}C and 23.1 ^{0}C, while morning and evening RH, wind speed, sunshine, morning and evening vapour pressure, evaporation and rainfall were 91% and 55%, 3.1 km/h, 8.4hrs, 23.3mm, 21.2mm, 4.0mm and 3.4mm, respectively. After that it was gradually declined as the increased the age of crop and remained up to 41st SW (6.4 whiteflies/plant) although temperature and relative humidity was increased. During this week the maximum and minimum temperature were 35.1 ^{0}C and 17.9 ^{0}C, whereas morning and evening RH, wind speed, sunshine, morning and evening vapour pressure, evaporation and rainfall were 88% and 31%, 2.2 km/h, 9.5hrs, 16.3mm, 12.2mm, 3.8mm and 0.0mm, respectively.

Table 3: Influence of weather parameters on activity of whitefly on *Kharif* soybean (2015-16)

SW	Whitefly/plant	Weather parameters									
		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
29	1.77	31.5	24.2	89	70	5.1	2.8	22.5	22.9	3.6	72.8
30	2.50	30.6	23.5	87	67	5.4	4.5	21.5	20.8	3.0	84.7
31	2.40	29.8	23.6	90	70	8.3	4.7	21.3	20.2	3.4	149.4
32	6.00	31.2	24.2	91	69	3.7	4.6	23.1	23.7	3.6	14
33	3.40	31.2	24.5	91	73	6.1	3.0	22.8	23.3	2.9	116.8
34	5.20	31.3	23.6	88	64	6.5	7.4	21.6	21.3	3.6	9.4
35	6.60	30.4	22.9	93	76	4.9	3.0	21.8	22.7	3.8	104.6
36	11.20	32.2	24.2	87	57	3.5	6.7	21.5	20.8	3.4	8.2
37	13.40	33.5	23.1	91	55	3.1	8.4	22.3	21.2	4.0	3.4
38	9.00	32	23.7	92	64	5.5	5.6	22.7	21.7	4.4	70.2
39	8.5	32.6	21.1	84	45	4.2	9.2	18.4	16.6	3.8	0.0
40	7.50	33.1	19.5	88	35	2.1	9.3	18.3	14.3	3.7	0.0
41	6.4	35.1	17.9	88	31	2.2	9.5	16.3	12.2	3.8	0.0
Correlation (r)		0.56*	-0.18	-0.005	-0.42	-0.59*	0.59*	-0.11	-0.18	0.59*	-0.63*

*Significant (P=0.05), X_1-Maximum temp.(^{0}C), X_2-Minimum temp.(^{0}C), X_3-Morning RH%, X_4-Evening RH%, X_5-Wind speed (km/h), X_6-Sunshine (hrs), X_7-Morning vapour pressure (mm), X_8- Evening vapour pressure (mm), X_9 -Evaporation (mm) and X_{10}-Rainfall (mm)

Whitefly prefers to suck the phloem sap from the succulent part of the plant and as the plant become older its dry matter accumulation is increased with the age of the plant and thus reduces population of whitefly and its infestation as well [11-12].
Selvaraj and Ramesh observed maximum temperature ranging from 26-35 ^{0}C, RH 67 to 84%, wind velocity 6.3km/h, sunshine 9.4 hrs and evaporation 52.20 mm were found to be congenial for the built up of whitefly population on cotton [13]. Though, this result may vary with the findings of other workers because of ecological and different weather conditions, cropping pattern and season, occurrence of natural enemies of the whitefly.
The correlation coefficient was expressed significantly positive between the mean whitefly population and maximum temperature (r= 0.56), sunshine (r= 0.59) and evaporation (r= 0.59), whereas wind speed (r= -0.58) and rainfall (r= -0.63) were significantly negative influenced to the activity of whitefly. Although, minimum temperature, both morning and evening RH were exhibited negative correlation (r=0.005 and r= 0.420) but statistically non-significant. Mean temperature around 26^{0}C was most conducive for the population build-up of whitefly, *B. tabaci* soybean.
Regression equation of whitefly population with weather parameters viz., maximum, temperature, wind speed, sunshine and evaporation were calculated as Y = - 37.25+1.37x (R^2 =0.31), Y = 11.85-1.16x (R^2 =0.34) and Y = 1.46+0.83x (R^2 =0.35), Y = - 12.47+5.23x (R^2 =0.34), respectively, while rainfall was Y = 8.47+-0.04x (R^2 =0.39). All R^2 values indicated that population of whitefly actively fluctuate due to the contribution of environmental factors. Earlier researchers reported the population of adult whiteflies showed a significant positive association with temperature and sunshine while negative correlation with rainfall [14]. Shrivastva and Prajapati reported that maximum temperature was exhibited significantly positive (r= 0.82), whereas mean RH (r= -0.83) and rainfall (r= -0.56) showed negative influence on whitefly population in blackgram (*Vigna mungo*) [15], whereas, temperature (r= 0.57) and relative humidity (r=0.77) exhibited significant positive correlation whereas rainfall (r=0.29) did not show significant correlation with whitefly population on cotton [16]. Similar results was also reported that maximum temperature and evaporation exhibited significantly positive correlation while, evening relative humidity and rainfall were expressed negative correlation on influence of whitefly population of soybean[17].

4. Conclusion
The present experiment in which soybean was grown in three consecutive seasons to assess the seasonal population dynamics of whitefly. It provides basic information for population dynamics of whitefly during *Rabi,* summer and *Kharif* seasons. Seasonal population fluctuations of whitefly on legume crops particularly soybean, blackgram and greengram are greatly influenced by abiotic factors and peak population levels are observed during consecutively grown crop of soybean. The statistically significant correlation values indicated that occurrence of whitefly population as its outbreak on soybean crop was due to the prevailing ecological conditions and impact of climate change. This experiment will support in the formulation of insect pest monitoring system and sustainable integrated pest management module.

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