Eco. Env. & Cons. 29 (January Suppl. Issue) : 2023; pp. (S369-S376)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i01s.057

Impact of climatic factors and vector population on incidence of Phyllody in Sesame under rainfed cultivation

Saritha R.[1]*, Sujatha V.[2], Sirisha Abm[3] and Haseena S.K.[3]

[1]Regional Agricultural Research Station, Anakapalle, Anakapalle District, A.P., India
[2]Agricultural Research Station, Peddapuram, East Godavari District, A.P., India
[3]Agricultural Research Station, Yellamanchili, Anakapalle District, A.P., India

(Received 3 June, 2022; Accepted 20 August, 2022)

ABSTRACT

Phyllody is a severe disease caused by a phytoplasma and transmitted by leaf hopper, *Orosius albicinctus* Distant is a major controlling factor in accomplishing full yield potential of the sesame crop. Sesame crop was grown during *kharif* season of the year 2018 and 2019 with three sowing dates to investigate the influence of vector population and climate variability on occurrence of phyllody and the pooled data was analyzed. Studies on correlation of leaf hopper population and climatic factors indicated that, the leaf hopper population evinced significant positive correlation with maximum temperature (r=0.775), minimum temperature (r=0.525) and mean temperature (r=0.7), while, non-significant negative correlation with minimum relative humidity (r=-0.3), mean relative humidity(r =-0.41) and significant negative correlation with maximum relative humidity (r=-0.524) and rainfall (r =-0.55). Among the three sowing dates, the highest population was observed in the crop sown during first fortnight of June followed by crop sown during the second fortnight of June and first fortnight of May. Correlation between the climatic factors and phyllody incidence has indicated that the phyllody exhibited significant positive correlation with maximum temperature (r=0.709), minimum temperature (r=0.535) and mean temperature (r=0.705) while, non-significant negative correlation with maximum relative humidity (r=-0.445), minimum relative humidity (r=-0.242), mean relative humidity(r=-0.338) and significant negative correlation with rainfall (r=-0.565). Phyllody incidence was highest in the crop sown in the second fortnight of May, incidence was significantly decreased with delayed sowing in both the years. It was also revealed that the vector population had significant positive correlation with the phyllody incidence (r=0.979). Variation in yield realization was also observed owing to dates of sowing. Higher yields were recorded in the crop sown during first fortnight of June (372.2 kg/ha) and second fortnight of May (365.5 kg/ha) compared the to crop sown during second fortnight of June (298.6 kg/ha).

Key words*: Sesame, Leaf hopper, Phyllody, Climate, Correlation, Economics*

Introduction

Sesame (*Sesamum indicum* L.) is one of the most prominent oilseed crops grown in tropical and subtropical countries. Sesame seeds are abundant in superior quality edible oils (50%); sesame is also called the "queen of oil seeds" because of its high production and oil quality (Weiss, 2000). The world produces 6.11 million tons out of 7.73 million hectares of cultivated area. India ranks first in area (17.5 lakh ha) and production (8.93 lakh tons) with a relatively low productivity of 368 $kgha^{-1}$, in contrast with the world average (489 $kgha^{-1}$) (Anonymous,2012). Andhra Pradesh along with West Bengal, Madhya Pradesh, Rajasthan, Uttar Pradesh, Gujarat, and Telangana contributes to more than 85 % production. The acerage of sesame in Andhra Pradesh is 0.61 lakh hectares with production of 0.2 lakh tonnes and productivity of 321 $kgha^{-1}$ (Anonymous, 2017).

The significant barriers on the potential yield of sesame comprise agronomical practices such as broadcasting seeds, inadequate management of fertilizer, ineffective weed control and protection from pests and diseases (Raikwar *et al.,* 2013). Numerous insect pests were estimated to cause around 25% yield losses to sesame crops (Weiss, 2000). Out of 30 species recorded on sesame, *Acherontia styx, Nezara viridula, Spilarctia oblique, Orosius albicinctus,* and *Bemisia tabaci* were the major pests (Rojeet *et al.,* 2018). Phyllody, Alternaria leaf blights, Phytophthora leaf spot, Cercospora leaf spot, Macrophomina root and stem rot, Powdery mildew, Bacterial leaf spot and Bacterial blight are important diseases of sesame (Gupta *et al.,* 2018). Sesame phyllody is quite a severe disease that occurs worldwide, caused by a phytoplasma and spread by a leaf hopper, *Orosius albicinctus* and is a significant limiting factor in achieving maximum yield. The losses as high as 90% have been reported (Gopal *et al.,* 2005). The leafhopper *Orosius albicintus* has been identified as a sesame phyllody phytoplasma vector (Khan *et al.,* 2007).

Abiotic factors also play a significant role in the growth and spread of insect pests and diseases in crops. Temperature, relative humidity, precipitation and other weather parameters are known to affect the occurrence, reproduction, growth, behavior and population dynamics of insect vectors that transmit these diseases. Increase or decrease in prevalence of plant disease relies not only on actual climatic conditions but also upon epidemiological and ecological influences from the local area. It was reported that, the climate variability has been shown to be a unique influence on the occurrence of vector-transmitted phyllody disease and shows the fact that climate variability influence is not always a negative impact, especially in relation to vector borne diseases, which require a better understanding of vector-host-pathogenic changes' variability effects (Kandakoor *et al.,* 2012). In the context, present research was carried out to evaluate the influence of climate variability and vector population on occurrence of phyllody in sesame under rainfed cultivation.

Materials and Methods

The research work was carried out at the Agricultural Research Station, Yellamanchili, Visakhapatnam, Andhra Pradesh during *kharif* 2018 and *kharif* 2019 to investigate the influence of vector population climate variability and on occurrence of phyllody on sesame under unprotected field conditions.

Cultivation of sesame

Untreated sesame seed of variety YLM-66 was sown in a bulk plot of size 0.2 ha, adopting 30 cm row to row and 15 cm plant spacing, during both the *kharif* seasons. All recommended agronomical practices were adopted. The seed rate of 6 $kgha^{-1}$ was used and fertilizers applied were FYM @ 10 tha^{-1} and NPK as 40:20:20 with N in two equal splits as basal and at 30 days after sowing (DAS). The *kharif* crops during 2018 and 2019 were raised as purely rainfed. Manual weeding was done twice during each of the season. No plant protection measures were taken up during the entire crop growth period during both the seasons.

Leaf hopper population

Data was noted in the early hours between 7:00 am and 9:00 am on randomly selected plants in the plot using standard sampling methods. Population data for leaf hoppers in the sesame crop was recorded at three plant canopy levels (lower, middle and top). Ten plants were selected randomly per spot from five random spots in the plot of 0.2 ha and data on leaf hopper population was collected and calculated the mean population. Leaf hopper population was recorded and presented standard week-wise from initial appearance till crop maturity.

Phyllody incidence

Five locations were randomly chosen, the total number of plants exhibiting sesame phyllody symptoms had been counted within the area and the percentage of disease occurrence was determined (Yadav *et al.,* 2012).

$$\text{Disease incidence (\%)} = \frac{\text{Total number of infected plants}}{\text{Total number of plants examined}}$$

Climatic factors

Data on climatic factors pertaining to minimum and maximum temperature, minimum and maximum percent of relative humidity and rainfall were collected following meteorological standard weeks from the observatory located at Agricultural Research Station, Yellamanchili.

Crop yield

Sesame crop yield data were collected from each plot for different dates of sowing and the total estimated yieldhectare^{-1} was computed according to the following formula (Borde *et al.*, 2017).

Yield, kg/ha = Factor × Seed yield (plot^{-1})

Where,

Where, Factor = $\frac{10000}{Net\ plot\ size}, m^2$

Benefit-cost ratio

Benefit cost ratio (B: C ratio) was calculated with respect to different dates of sowing according to following formula (Borde *et al.*, 2017).

$$B : C\ ratio = \frac{Net\ Profit}{Cost\ of\ Treatment}$$

Statistical analysis

Using Microsoft Excel software, data on insect species and climatic factors were statistically analyzed for correlation. The data collected on leaf hopper and philology incidence were correlated with the climatic factors following the standard weather week (SMW) as per Steel and Torry, 1980.

$$r_{xy} = \frac{\sum XY - \sum X \sum Y}{\sqrt{\left[\sum X^2 - \frac{\sum X^2}{n}\right] - \left[\sum Y^2 - \frac{\sum Y^2}{n}\right]}}$$

Where

r_{xy} = Simple corelation coefficient

X = Variable (abiotic component.)

Y = Variable (No. of Insects per plant)

n = Number of observations

The correlation coefficient (r) values were subjected to the test of significance using t - test

$$t = \frac{r}{\sqrt{1-r^2}} X \sqrt{n-2} \sim t_{n-2} d.f$$

The calculated t-value obtained was compared with tabulated t-value at 5% level of significance

Regression analysis

The data on insect populations and climatic factors was subjected to non linear regression analysis was carried out using Microsoft excel software and developed the regression equations (Steel and Torry, 1980).

Results

Sesame crop was grown during *kharif* season of the year 2018 and 2019 with three sowing dates *viz.* second fortnight of May (S1), first fortnight of June (S2) and second fortnight of June (S3). Two years pooled data have been used to study the incidence of leaf hopper and phyllody with respect to climatic factors and results are presented.

Incidence of leaf hopper and phyllody with respect to sowing date

The incidence of leaf hopper and phyllody varied depending on the sowing date and increased during cropping period. The leaf hopper population varied in the range of 0.9-6.15 plant^{-1} as shown in Fig. 1. Pooled leaf hopper population data revealed that, among the three showing dates, the highest population was observed in the crop sown during first fort-

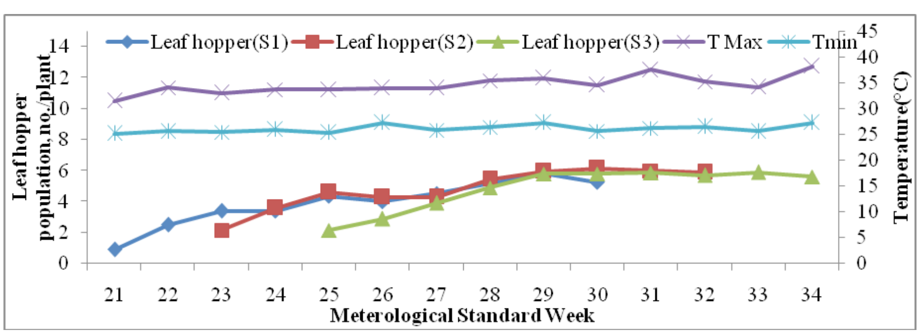

Fig. 1. Leaf hopper population as influenced by temperature

night of June followed by crop sown during second fortnight of June and first fortnight of May (Fig.1). The population leaf hopper was minimum during first week of sowing, reached peak during the 9th week of crop growth period and slightly decreased at the end for the crop grown in three sowing dates. The initial incidence was highest in S2 and S3 as compared with S1. Variation in maximum temperature might have favored the leafhopper population during S2 and S3. Highest population (6.15 plant^{-1}) was observed in S2 during 30th MSW, where as in S3 highest population was 5.9 plant^{-1} in 33th MSW. The leaf hopper population observed on 21st SMW was of 0.9 plant^{-1} and steadily increased till 30rd SMW and peaked with 5.9 plant^{-1} and at crop maturity the population recorded was 5.6 plant^{-1} on 34th SMW as shown in Fig.3. Seasonal data indicate that, among the three sowing dates, the highest population was observed in the crop sown during first fortnight of May, 2018 whereas during the year 2019, it was in the crop sown during second fortnight of June, 2019 as depicted in the Table 1.

Phyllody incidence has also shown similar trend, the phyllody population varied in the range of 0-15.1 % for the pooled data (Fig.2) and the incidence varied in between 2-14.8 % during the years 2019 and 2018 (Table 1).

Leaf hopper incidence in relation to climatic factors

Climate change could have significant effect on distinct plant insect pests and diseases. Variability in the meteorological conditions influences life-cycles of insect pest and diseases, as well as the growth of disease (Chakraborthy *et al.*, 2008). Two years pooled data of climatic factors and leaf hopper population indicated that the leaf hopper popula-

Table 1. Effect of dates of sowing on incidence of sesame phyllody and leaf hopper population

Standard week	Leaf hopper population			Phyllody,%			T_{max} (° C)	T_{min} (° C)	T_{mean} (° C)	RH_{Max} (%)	RH_{Min} (%)	RH_{mean} (%)	Rainfall (mm)
	S1	S2	S3	S1	S2	S3							
Kharif-2019													
21	0.0			0.0			31.70	25.30	28.50	91	61	76.0	39.6
22	2.5			2.4			32.70	26.70	29.70	79	55	67.0	62.8
23	3.8	2.2		6.9	4.1		32.20	25.30	28.75	83	62	72.5	5.3
24	4.2	4.6		9.2	5.3		35.50	26.50	31.00	83	60	71.5	3.9
25	4.6	5.3	1.4	10.5	7.0	3.3	32.00	25.40	28.70	80	65	72.5	18.4
26	4.0	5.0	2.3	11.3	6.8	3.8	36.40	28.00	32.20	88	75	81.5	39.4
27	4.7	4.6	3.5	11.1	8.4	4.4	35.30	26.90	31.10	90	68	79.0	65.6
28	5.3	6.2	4.4	13.7	10.2	6.4	35.20	26.80	31.00	84	62	73.0	18.8
29	5.8	6.8	5.8	14	11.6	7.2	37.30	28.40	32.85	86	66	76.0	7.0
30	5.4	6.9	6.2	15.1	12.2	8.6	35.30	26.00	30.65	80	54	67.0	0.0
31		6.5	6.4		12	9.2	38.10	27.40	32.75	70	42	56.0	5.8
32		6.3	5.9		12.1	10.3	34.60	26.10	30.35	80	58	69.0	1.4
33			6.1			10.5	34.50	26.00	30.25	88	64	76.0	7.9
34			6.0			10.4	39.40	29.10	34.25	80	56	68.0	1.2
Kharif -2018													
21	1.8			2.2			31.2	25.1	28.2	90.0	68.0	79.0	50.4
22	2.5			3.4			35.5	24.5	30.0	87.0	64.0	75.5	54.3
23	3.0	2.1		5.9	3.7		33.8	25.6	29.7	85.0	61.0	73.0	1.0
24	2.6	2.6		8.5	5.1		31.9	25.3	28.6	87.0	60.0	73.5	11.7
25	4.1	3.9	2.9	10.3	8.0	3.9	35.3	25.3	30.3	87.0	64.0	75.5	29.9
26	4.0	3.6	3.5	11.4	8.2	4.2	31.6	26.5	29.1	80.0	58.0	69.0	59.6
27	4.3	4.0	4.3	12.1	8.7	5.6	32.7	24.8	28.8	92.0	75.0	83.5	62.9
28	5.0	4.7	5.4	14	9.4	7.4	35.6	26.0	30.8	84.0	59.0	71.5	27.6
29	5.8	5.1	5.8	14.5	10.4	8.2	34.5	26.1	30.3	85.0	73.0	79.0	6.5
30	5.1	5.4	5.4	14.8	10.7	8.9	33.8	25.3	29.6	86.0	57.0	71.5	5.0
31		5.5	5.3		11.3	9.3	36.9	25.1	31.0	86.0	65.0	75.5	24.3
32		5.5	5.5		11.7	10.4	35.8	26.9	31.4	84.0	49.0	66.5	1.4
33			5.7			10.5	33.8	25.2	29.5	79.0	58.0	68.5	17.4
34			5.2			10.5	37.1	25.4	31.3	87.0	68.0	77.5	16.7

tion exhibited significant positive correlation with maximum temperature(r=0.775), minimum temperature (r=0.525) and mean temperature (r=0.7), while, non-significant negative correlation with minimum relative humidity(r=-0.3), mean relative humidity(r=-0.41) and significant negative correlation with maximum relative humidity (r=-0.524) and rainfall (r=-0.55) as shown in the Table 2. It has been confirmed that the temperature favored to the leaf hopper population and also the relative humidity controlled the leaf hopper population as depicted in Table 2.

Studies on effect of climatic factors on incidence of leaf hopper in sesame crop sown at three different dates during two years of cultivation has led to the revelation that the leaf hopper population has significant positive correlation with maximum temperature, insignificant positive correlation with minimum temperature, insignificant positive correlation maximum and minimum relative humidity and rainfall as detailed in Table 2.

Incidence of phyllody in relation to vector population and climatic parameters

Phyllody is a serious phytoplasmal disease of sesame, transmitted from infected sesame plants to healthy sesame plants by the leafhopper vector (Akhtar *et al.,* 2008 and Pathak *et al.,* 2013). Two years of pooled data revealed that, incidence of phyllody initiated with 1.1 % during the 21st MSW, linearly increased till the 24th SMW along with vector population. Rate of incidence was less till the 27th SWM then further raised with increase in vector population till the 30th SMW and reached peak incidence with 11.7 %, later incidence was decreased thought the vector population remains constant and reached 10.5 % at the crop maturity (Fig. 3). Multiple non-linear regression equation has been established between the vector population and phyllody incidence exhibited strong relationship (R^2=0.958) and the equation given below.

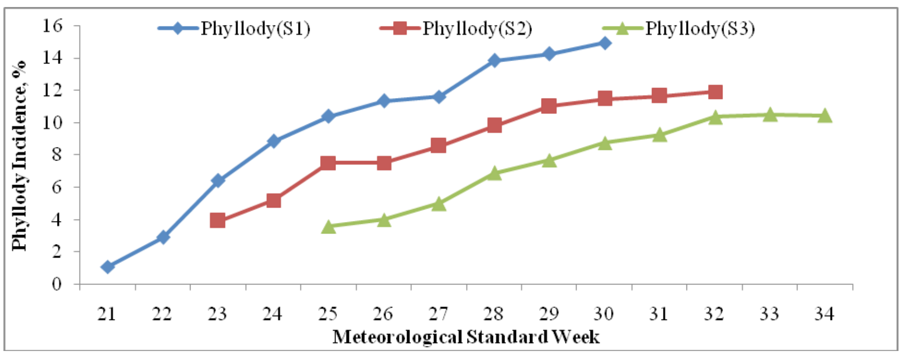

Fig. 2. Incidence of phyllody as influenced by sowing date

Table 2. Correlation between leaf hopper incidence, phyllody incidence and climatic factors

	Leaf hopper population (2019)			Phyllody incidence (2019)			Leaf hopper population (2018)			Phyllody incidence (2018)		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Tmax	0.671	0.592	0.531	0.742	0.560	0.416	0.557	0.428	0.631	0.359	0.244	0.563
Tmin	0.45	0.429	0.206	0.462	0.343	0.108	0.307	0.502	0.204	0.086	0.519	0.252
Tmean	0.614	0.552	0.422	0.666	0.499	0.311	0.621	0.592	0.647	0.374	0.421	0.601
RHMax	-0.320	-0.329	-0.356	-0.148	-0.383	-0.384	-0.383	-0.315	-0.053	-0.170	-0.315	-0.075
RHmin	-0.168	-0.353	-0.668	0.252	-0.487	-0.638	-0.195	0.087	-0.073	-0.117	-0.044	-0.065
RH mean	-0.034	-0.351	-0.559	0.098	-0.457	-0.552	-0.281	-0.055	-0.073	-0.146	-0.150	-0.074
Rainfall	-0.446	-0.238	-0.656	-0.467	-0.236	-0.739	-0.447	-0.307	-0.113	-0.678	-0.295	0.009

Two years pooled data

	T_{max}	T_{min}	T_{mean}	RH_{max}	RH_{min}	RH_{mean}	RF
Leaf hopper	0.775	0.525	0.752	-0.524	-0.298	-0.407	-0.549
Phyllody	0.709	0.535	0.705	-0.446	-0.242	-0.338	-0.566

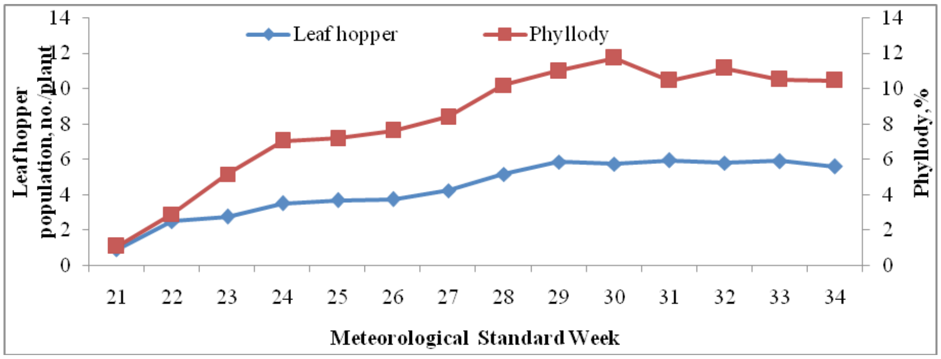

Fig. 3. Mean incidence of phyllody and leaf hopper with respect to meteorological standard week

Phyllody incidence (%) = -0.631 + 2.015× Leafhopper population (no.)

Effect of sowing date in incidence of phyllody has been analyzed. The two years mean data indicated that, the sesame crop sown on second fortnight of May recorded highest phyllody incidence of 15.0 % whereas it was 11.9 % and 10.5 % for the crop sown during first and second fortnight of June. Relatively lower incidences were recorded with advancement of date of sowing as shown in Fig. 2.

The effect of weather conditions on phyllody incidence over time was established through correlation. Two years pooled data of weather parameters and phyllody incidence has indicated that the phyllody incidence exhibited significant positive correlation with maximum temperature(r=0.709), minimum temperature (r=0.535) and mean temperature (r=0.705) while, non-significant negative correlation with maximum relative humidity(r=-0.445), minimum relative humidity(r=-0.242), mean relative humidity(r=-0.338) and significant negative correlation with rainfall (r=-0.565) as shown in Table 2.

Yield and cost economics

The impact of different dates of sowing on sesame

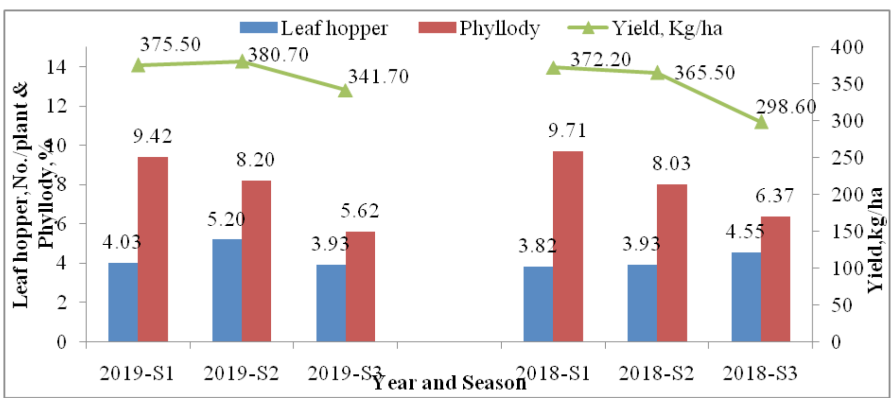

Fig. 4. Sesame yield in relation to leaf hopper and phyllody incidence

Table 3. Cost economics of sesame

Sowing window	Yield (kg/ha)	Gross returns (Rs./ha)	Cost of Cultivation (Rs./ha)	Net Returns (Rs./ha)	B : C Ratio
Second fortnight of May,18	372.2	40942	12000.00	28942	2.41
First fortnight of June,18	365.5	40205	12000.00	25431	2.12
Second fortnight of June,18	298.6	32846	12000.00	20847	1.74
Second fortnight of May,19	375.5	41305	12000.00	33166	2.76
First fortnight of June,19	380.7	41877	12000.00	29877	2.49
Second fortnight of June,19	341.7	37587	12000.00	22069	1.84

yield was studied and presented in the table 3 and Fig. 4. The study revealed that, the yield was significantly higher in the crop sown during first fortnight of June, 2018 (372.2 kgha^{-1}) and second fortnight of May, 2018 (365.5 kgha^{-1}) compared to the yield of crop sown during second fort night of June, 2018 (298.6 kgha^{-1}). Similar results were reported during the year 2019 also.

Cost economics of sesame crop sown at different sowing dates indicated that the crop sown during second fortnight of May has given highest net returns during the year 2019(Rs.33,166ha^{-1}) and 2018(Rs.28,942ha^{-1}). The net returns were decreased due to delay in sowing dates. Similarly, the benefit cost ratio was high for the crop grown during second fortnight of May in both the years 2019(BC ratio-2.8) and 2018(BC ratio-2.4).

Discussion

In the studies it was revealed that the vector population had significant positive with the phyllody incidence (r=0.979). The positive correlation between higher disease incidences with increased number of vectors was also reported (Manoj *et al.,* 2019). Pooled leaf hopper population data revealed that, among the three showing dates, the highest population was observed in the crop sown during first fortnight of June followed by crop sown during second fortnight of June and first fortnight of May. Mishra *et al.,* (2015 have also reported similar trends in population dynamics of leaf hoppers in sesame. It was also observed that the leaf hopper population was increased till the crop maturation stage and almost remains constant during final stage of crop growth.

Phyllody incidence was highest when the crop sown in the second fortnight of May (S1), incidence was significantly decreased with delayed sowing in both the years. Leaf hopper population has to trigger the spread of phyllody indicating that phytoplasma load might be available in vectors. These results are in agreement with the results of other researchers (Sandhu *et al.,* 2009; Al-Sakeiti *et al.,* 2005 and Akhtar *et al.,* 2008). It has been confirmed that the temperature favored to the leaf hopper population and also the relative humidity controlled the leaf hopper population. These results are in accordance with other findings (Yadav *et al.,* 2012 and Kandakoor *et al.,* 2012). Studies on effect of climatic factors on incidence of leaf hopper in sesame crop sown at three different dates during two years of cultivation has lead to the revelation that the leaf hopper population has significant positive correlation with maximum temperature, insignificant positive correlation with minimum temperature, insignificant positive correlation maximum and minimum relative humidity and rainfall.

Though the highest vector population observed on the crop sown during first fortnight of June, the phyllody incidence was highest on the crop sown during second fortnight of May. It may be inferred that combined effect of weather variables and vector population favored occurrence and further spread of phyllody disease. Similar report by Harrison (1983) states that, the weather variables and vector population highly influences the vector borne virus diseases.

Climate change and variability could have a substantial effect on vector-borne plant diseases. Rainfall, humidity and temperature, among other climatic parameters, are known to influence the incidence of disease and population dynamics of insect vectors. Two years pooled data of weather parameters and phyllody incidence has indicated that the phyllody incidence exhibited significant positive correlation with maximum temperature and non-significant negative correlation with maximum relative humidity. It was reported that a significant positive correlation exists between phyllody incidence and maximum temperature and negative correlation with relative humidity (Sellamal *et al.,* 1983).

It was also observed that, in spite of high incidence of phyllody and leaf hopper population, higher yield was reported from the crop sown during second fortnight of May and first fortnight of June. Delayed sowing beyond first fortnight of June adversely affected the yield though the insect and pest incidence was less and this may be owing to photosensitive nature of sesame crop.

Based on the data on returns and cost benefit ratio, it can be concluded that, it is economical the sow the sesame crop during second fortnight of May both in terms of high return and high benefit cost ratio in spite of high incidence of phyllody and leaf hopper. However, in areas endemic to phyllody it can be suggested to opt for delayed sowing in first fortnight of June without having adverse reduction in crop yield.

Conclusion

It is concluded from two years pooled data that, the incidence of leaf hopper population exhibited significant positive correlation with temperature (r=0.705), non-significant negative correlation with mean relative humidity (r =-0.41) and significant negative correlation with rainfall (r=-0.55). Correlation between the climatic factors and phyllody incidence has indicated that, the phyllody exhibited significant positive correlation with temperature (r=0.705) while, non-significant negative correlation with relative humidity(r=-0.338) and significant negative correlation with rainfall (r=-0.565). The leafhopper population, which acts as vector exhibited significant positive correlation with the phyllody incidence (r=0.979).

Acknowledgements

The author is highly thankful for the resources provided by Acharya NG Ranga Agricultural University, Andhra Pradesh to conduct the present study.

References

Akhtar, K.P., Dickinson, M., Sarwar, G., Jamil, F.F. and Haq, M.A. 2008. First report on the association of a 16SrII phytoplasma with sesame phyllody in Pakistan. *Plant Pathol*ogy. 57 : 771.

Al-Sakeiti, M.A., Al-Subhi, A.M., Al-Saady, N.A. and Deadman, M.L. 2005. First report of witches' broom disease of sesame (*Sesamum indicum*) in Oman. *Plant Diseases*. 89: 530.

Anonymous, 2017. Annual Report of Oilseeds Division, Department of Agriculture, Cooperation & Farmers' welfare, Krishi Bhawan, New Delhi.

Anonymous, 2012. Third Advance Estimates of Production of Oilseeds & Other Commercial Crops for 2011-12, Directorate of Economics & Statistics, Department of Agriculture & Cooperation, Agricultural Statistics Division (India).

Borde, C.M., Pande, A.K. and Thomos, M. 2017. Study the effect of seed treatments and foliar spray against major insect pests of sesame. *Ecology, Environment and Conservation*. 23(3) : 344-349.

Chakraborthy, G. S., Sharma, G. and Kaushik, K. N. 2008. *Sesamum indicum*: A review. J. *Her. Med. and Toxi*. 2 (2): 15-19.

Gopal, K., Jagadeswar, R. and Prasad Babu, G. 2005. Evaluation of sesame genotypes for their reactions topowdery mildew and phyltody diseases. *Plant Disease Research.* 20(2) : 126-130.

Gupta, K.N., Naik, K.R. and Rajni, B. 2018. Status of sesame diseases and their integrated management using indigenous practices. *International Journal of Chemical Studies*. 6(2): 1945-1952.

Harrison, B.D. 1983. Epidemiology of plant virus diseases. In: Plant virus epidemiology. The spread and the control of insect borne diseases (ed. R.T. Plumb and M. Thresh). Oxford, London, Black Well Scientific Pub. VII. pp. 377.

Khan, M.S., Raj, S.K., and Snehi, S.K. 2007. First report of molecular identification of 'Candidatus Phytoplasma asteris' affecting sesame (*Sesamum indicum*) cultivation in India. *Journal of Plant Pathology*. 89 : 301-305.

Kandakoor S.B., Khan, H.K, Gowda, G.B., Chakravarthy, A.K., Kumar, C.T.A. and Venkataravana, P. 2012. The incidence and abundance of sucking insect pest on groundnut. *Current Biotica*. 6 : 342-348.

Manoj. K.K., Ashok, K. G., Shankar, H. G., Jutimala, P., Palash,N., Prasanta, N., Pranjal, P. N. and Buddha, B. 2019. *Phytopathogenic Mollicutes.* 9(1): 173-174.

Mishra, M. K., Gupta, M. P., Thakur, S. R. and Raikwar, R. S. 2015. Seasonal incidence of major insect pests of sesame in relation to weather parameters in Bundelkhand zone of Madhya Pradesh. *Journal of Agrometeorology.* 17(2) : 263-264.

Pathak, D.M., Joshi, N.S., Dulawat, M.S. and Patel, N.V. 2013. Control of sesame phyllody caused by PLO's. *Intern. J. Green Herbal Chem*. 2 : 164-165.

Raikwar, R. S. and Srivastva, P. 2013. Productivity enhancement of sesame (*Sesamum indicum* L.) through improved production technologies. African *Journal of Agricultural Research.* 8(47) : 6073-6078.

Roojeet Thangjam, and Vastrad A.S. 2018. Studies on pest complex of sesame and their natural enemies in North Karnataka, India. *Journal of Entomology and Zoology Studies*. 6(6) : 57-60.

Sandhu, P.S. Sarbjeet, K., Sheoran, P. and Sarwan, K. 2009. Influence of sowing dates on development of phyllody on sesame, *Sesarnum indicum L. J. O/seeds Res*. 26: 495-498.

Sellamal, M., Ramakrishnan, C., Kandasamy, T.K. and Murugesan, M. 1973. Forecasting phyllody disease' of Sesamum. *Madras Agric. J.* 60: 492-495.

Sridhar, D., Patil, M.S. and Palakshappa, M.G. 2013. Survey for sesamum phyllody disease in Northern Karnataka. *Karnataka Journal of Agricultural Science*. 26(2): 320-321.

Steel, R.G.D. and Torry, J.H. 1980. *Principles and Procedures of Statistics.* Publ. Mcgraw HillBook Company, New York.

Yadav., P.C., Sharma, U.S., Ameta, O.P., Padiwal, N.K. 2012. Seasonal incidence of major sucking insect pests of groundnut (*Arachis hypogaea* L.). *Indian Journal of Applied Entomology*. 26 : 57-59.

Weiss, E. A. 1971. Castor, Sesame and Safflower, Leonard Hill Books, London, pp. 311-355.

Weiss, E. A. 2000. *Oil Seed Crop.* 2nd ed Blackwell Science, Inc. Malden, MA, 2000.