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Temperature Predicts the Population of *Aceria cajani* Chan. (Acari: Eriophyidae) and Efficacy of Insecticides and Acaricides in its Control on Pigeonpea [*Cajanus cajan* (L) Millsp.]

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ABSTRACT

Background: The pigeonpea eriophyid mite, *Aceria cajani* Chan., vector of sterility mosaic disease in pigeonpea, causes economic damage of up to 90% during the early stages of crop growth. The major element in deploying management practice is to know the population dynamics of the pest. Generally, the vectors of disease causing agents were managed with the synthetic chemical. So we have taken studies to know efficacy of insecticides and acaricides in its control on pigeonpea.

Methods: The population dynamics of *A. cajani* Chan. was monitored in field plots from January 2021 to December 2021. For efficacy of insecticides and acaricides studies in control of *A. cajani* a completely randomized design was organized. Twelve treatments (insecticides/acaricides) were tested against *A. cajani* on pigeonpea [*var.* ICP 8863 (Shree Maruti].

Result: This study found that mite population reached a peak in the summer (March) and another peak in the post-monsoon period (October), whereas the lowest populations were recorded in winter (January). Correlation studies exhibited a significant positive correlation with both maximum and minimum temperature. The insecticide and acaricide trials on *A. cajani* found that all chemicals used were effective and entomopathogenic formulations were comparatively less effective.

Key words: Entomopathogenic fungi, Eriophyid mite, Pigeonpea sterility mosaic virus.

INTRODUCTION

Pigeonpea (*Cajanus cajan* L. Millsp.) is an important tropical legume crop. It is also known as red gram, arhar and tur dal and belongs to the Leguminosae family (Ghadge *et al.*, 2008). It is the world's sixth most important pulse crop, with India contributing more than 70% of the total production (Jorrin *et al.,* 2021).

Fusarium wilt and sterility mosaic disease are two diseases that cause significant yield losses in India (Kaushik *et al.,* 2013). Sterility mosaic disease (SMD) is caused by the pigeonpea sterility mosaic virus (PPSMV), belonging to the emaravirus family and is semi-persistently transmitted by the eriophyid mite, *Aceria cajani* Chan. (Acari: Eriophyidae) (Seth, 1962; Ghanekar *et al.,* 1992). The SMD-infected plants become stunted and bushy in appearance. Infected plants become partial or completely sterile. Both the disease and the vector are host specific and are also found in a few of its wild relatives (Patil and Kumar, 2015). The infected perennials (perennial grown pigeonpea crops) and volunteer plants (self-sown pigeonpea) both serve as potential sources of the inoculum (Kumar *et al.*, 2007). The mite does not transfer the virus transovarially.

The population of mites, their life cycle and the incidence of disease were observed to be affected by seasonal temperature fluctuations, relative humidity, wind direction, speed and rainfall, *etc.* (Hill *et al.*, 2014). In the case of viral diseases transmitted by insects and mites, management practices are primarily focused on vectors**.** So, the aim of the study was to determine the incidence pattern of mites across the different seasons to find the peaks and lows in population of mites. Secondly, we evaluated the efficacy of chemical acaricides, insecticides and entomo-pathogenic fungi formulations against *A. cajani.*

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MATERIALS AND METHODS

The population dynamics of *A. cajani* was monitored in field plots from January 2021 to December 2021. Sampling of mites was done in two field plots. The field studies include one winter crop and one summer crop. The field study experiments were conducted at Tamil Nadu Agriculture University, Coimbatore, India.

Population dynamics of *A cajani* in field

Experiments were conducted on the susceptible cultivar ICP 8863 (Shree Maruti). The seeds were sown in a 100 m^2 plot by adopting a spacing of 150 × 30 cm. The infected hedgerow method was chosen for the artificial inoculation of disease. The 100 m^2 plot was divided into five sub plots (20 m^2) and a buffer zone of 0.3 meter maintained between subplots. Each sub plot was treated as replication and from each subplot ten plants were selected for data collection. At two-week intervals, mites were sampled and at each sampling, random five trifoliate leaves at different canopy levels were collected in each plant. The leaves were collected and brought back to the laboratory and viewed under a stereo zoom microscope (Magnus 40x) to take a mite count. All stages of mites except (egg) were counted. The weather parameters data collected from the TNAU meteorological observatory located at 2 km from the experimental site.

In the first study plot, sampling was started in January 2021 sown in October 2020 at a pulses research farm in Coimbatore. The sampling of mites was done at fortnightly intervals and continued until the harvest of the crop (up to April 2021). The second study plot was pigeon pea grown in the month of April 2021. In second field study plot infected leaf stapling was adopted as artificial inoculation of disease. Sampling of mites was done at fortnightly intervals in this plot from May 2021 and continued up to December 2021.

Acaricides and insecticide efficacy trial on *A. cajani*

Aceria cajani mite colony was established on ICP 8863 (Shree Maruthi), a susceptible cultivar grown in pots (25 × 25 cm) in a greenhouse (plot size 5 × 5 m) by stapling the infected leaves having mites more than ten in number. These mite populations were used for infestation of the new plants. A completely randomized design was organized, having three replications per treatment. Twelve treatments were tested against *A. cajani* on pigeonpea (*var.* ICP 8863 (Shree Maruti). At 14 DAP (days after planting), all the seedlings (12 seedlings/ treatment) were infested with *A. cajani* by attaching leaflets (3 × 3 cm) with 30 mites (all stages except eggs) to the adaxial surface of the young leaves using paper clips. Mites were allowed to develop on these experimental plants for up to 30 days after infestation.

Foliar sprays of various treatments were applied after 30 days after infestation (DAI) using a hand-held pump pressure garden sprayer of 2L capacity (Kishan Kraft). All the pesticide chemicals (commercial products) in the recommended dosage (Table 3) were mixed and made up to 1000 ml of water. For control treatment, only water was applied as spray. Three to four days after treatment, mites were counted using a stereo zoom microscope on the entire plant (Magnus, 40x). The entire plants from the pots were plucked out and counting of mites was done from each trifoliate by detaching it from the plant.

Data analysis

The basic statistical measures, such as mean, standard deviation and standard error of mean and ANOVA were calculated. Associations between climate variables and mite populations were investigated by using the Pearson correlation coefficient, multiple linear regression and principal component analysis (PCA). In the acaricides and insecticide efficacy trail on *A. cajani,* the mean mite data per plant was calculated from three replications. The values were converted into arcsine transformation. A Tukey test was conducted to determine significance among means at the 5% probability level. The mean comparison alphabets were generated. All statistical analyses were conducted using SPSS 26.0.

RESULTS AND DISCUSSION

Population dynamics of *Aceria cajani*

The mite populations per trifoliate was varied in all experimental studies, ranging from 15 to 160 mites/ trifoliate. The lowest mean mite populations/trifoliate was recorded in the winter (during December) and the population reached its peak in the summer (March) and in the post monsoon period (October) (Fig 1). In the first study plot from January to April (2021), the lowest mean number of mites was

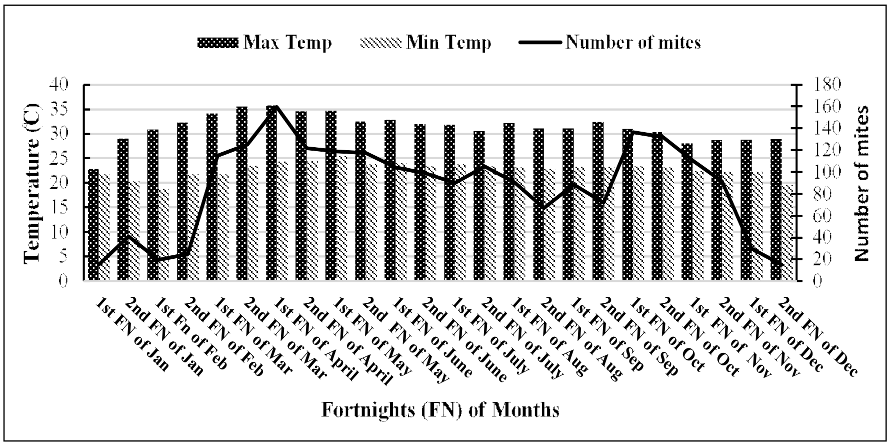

Fig 1: Population dynamics of *Aceria cajani* in field and its relation to the temperature.

recorded in the first two weeks of January (15.3 mites/trifoliate) and the peak number of mites was found in the last two weeks of April (159.6 mites/trifoliate) (Fig 1). In the second experimental plot from May to December 2021, the peak population was found in the first two weeks of October (136.0 mites/trifoliate), whereas the low population was recorded in the last two weeks of December (15.0 mites/trifoliate) (Fig 1).

The degree of linear association between mite populations and weather parameters (T_{max}-Maximum temperature, T_{min}-Minimum temperature, Rh_1-Morning Relative humidity and Rh_2-Evening relative humidity), rainfall (mm) and wind speed (km/hr) were explained by correlation. (Table 1).

The mite population exhibited a significant positive correlation with both maximum (r= 0.610, p= 0.002) and minimum temperature (r= 0.762, p<0.001), respectively. The population exhibited a non-significant positive correlation with rainfall (r= 0.028, p= 0.896) and wind speed (r= 0.009, p=0.96) and a non-significant negative correlation with both Rh1 (r= -0.383, p=0.65) and Rh2 (r= -0.033, p=0.87) (Table 1). The significant positive correlation with both maximum and minimum temperature explains that temperature plays a role in the dynamics of the mite population. It was found that mite numbers were too low during the winters and mite numbers were high in the summers.

The correlation between weather parameters also existed, so here principal component analysis (PCA) was used to group the correlated variables into data subsets called principal components, which are uncorrelated to each other. The principal components (PC_1, PC_2 and PC_3) explain the maximum variation (92.67%). PC_1 captures 47.04% variability, whereas PC_2 and PC_3 capture 26.75% and 18.26% variability, respectively. The variables T_{max}, T_{min} and wind speed are positioned on the same side axis, whereas least correlated variables like Rh_1, Rh_2 and rainfall lie on the opposite quadrants of the mite density axis. T_{max} and T_{min} variables contribute significant variation to the mite population. The length of the vector explains the variance due to that vector, *i.e.,* the longer the vector length, the more the variation is caused by the vector (Fig 2). According to PC_1, maximum and minimum temperature are important variables that influence mite density (Fig 2).

The multiple regression equation developed between the mite and weather variables was mite density/per trifoliate = 0.99 (T_{max}) + 0.40 (T_{min})-0.44 (Rh_1) + 0.36 (Rh_2) + 0.70 (rainfall) - 0.074 (wind speed) and the coefficient of determination (at p<0.001 R_2= 0.80, R = 0.90)

The analysis of variance suggests that individual impact variables on the mite population. The effect of maximum temperature (R^2=37.3, F=13.06, p=0.002), minimum temperature (R^2 =58.1, F=30.49, p=<0.001), morning relative humidity (R^2=14.6, F=3.77, p=0.065) evening relative humidity (R^2=0.01, F=0.024, p=0.878), rainfall (R^2=0.001, F=0.018, p=0.896) and wind speed (R^2=0.09, F=0.002, p=0.965) (Table 2). The minimum temperature was the most important factor, followed by the maximum temperature, were the most significant factors contributing to the variability.

In this study, it was found that the mite *A. cajani* population varied throughout the experimental period. Mite population density peaked in the summer (March and April), then declined and again reached a second peak in the post-monsoon season (August to October). The decline in mite population density during the winter may have been caused by low temperatures. The mean temperature during this period was 20°C. Based on this study, climate variables such as temperature (both maximum and minimum) were important variables in contributing to significant variability in mite populations.

The seasonal variation of mean mite densities was consistent with results supported by (Kaushik *et al.*, 2013), who noted that the peak population of *A. cajani* was observed in April and March whereas (Pallavi *et al.*, 2019) found the highest mite population in May and August. These findings indicate that management is required in the summer and in the post-monsoon period where mite populations reach their peak.

In *Kharif* crop pest management practices should be done in the post monsoon period (August-October). In *Rabi* crop, pest management practices should be done in summer. More than 90 per cent of the crop would be lost if infection occurs at the early stage of the crop's growth (Bhaskaran and Muthiah, 2005). Infection before flowering causes yield losses of up to 95% to 100%; late infections can lead to a yield loss of between 26% and 97% (Kannaiyan

Table 1: Correlation (Pearson) matrix of weather parameters and *Aceria cajani*.

Variables	Mite	Max T	Min T	RH1	RH2	Rainfall	Wind speed
Mite	1	0.611**	0.763**	-0.382	-0.033	0.028	0.008
Max T	0.611**	1	0.514*	-0.662**	-0.663**	-0.655**	-0.083
Min T	0.763**	0.514**	1	-0.378	0.212	-0.021	0.164
RH1	-0.382	-0.662**	-0.378	1	0.573**	0.693**	-0.479*
RH2	-0.033	-0.663**	0.212	0.573**	1	0.746**	0.194
Rainfall	0.028	-0.655**	-0.021	0.693**	0.746**	1	-0.171
Wind speed	0.008	-0.083	0.164	-0.479*	0.194	-0.171	1

Note 1: Max T= Maximum temperature, Min T- Minimum temperature, RH1-Morning relative humidity, RH2- Evening relative humidity.
Note 2: '*' Indicates their significant correlation at P<0.05 and data followed by '**' indicate their significant correlation at P<0.01.

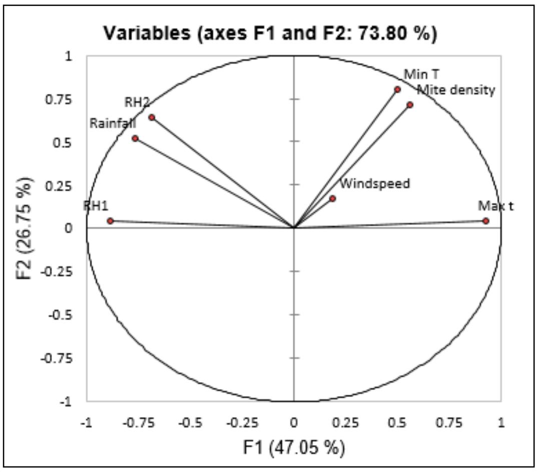

Fig 2: Principal component analysis of the *Aceria cajani* mite populations with the weather parameters during 2021.

Table 2: Linear models describing the effects of the individual weather parameters on *Aceria cajani.*

Weather parameters	Mite number/trifoliate		
	t stat	F	P
Maximum temperature (°C)	3.61	13.06	0.002*
Minimum temperature (°C)	5.52	30.49	<0.001**
Morning relative humidity (%)	-1.94	3.77	0.065
Evening relative humidity (%)	-0.155	0.024	0.878
Wind speed (km/hr)	0.133	0.018	0.896
Rainfall (mm)	0.045	0.02	0.965

Note 1: '*' Indicates their significant correlation at P<0.05 and data followed by '**' indicate their significant correlation at P<0.01.

et al., 1984). So, management practices should be taken at early stages of crop growth if infection has been established, to prevent further spread of SMD disease and economic damage. The left-over stubbles and ratooning of the crop should be avoided, which acts as a source of infection.

Acaricides and insecticides efficacy trial on *Aceria cajani*

The insecticide and acaricide trials on *A. cajani* found that spiromesifen, propargite, combination of (fenpyroximate + profenophos), fipronil and etoxazole (96%) are effective in reducing the number of mites, followed by diafenthurion, profenophos and dimethoate (86-89%). The entomopathogenic fungi formulations such as *H. thompsonii* and *B. bassiana* were comparatively less effective compared to the chemical formulations. The *B. bassiana* formulation was least effective compared to other formulations (Table 3).

Acaricides and insecticides are commonly used for the management of vectors transmitting viral diseases (Van *et al*., 2010; Hoy, 2011; Marcic, 2012). It was found that all synthetic chemicals were effective in reducing mite numbers (80-98 per cent reduction over the control). The EPFs (entomopathogenic fungi products) such as *B. basssiana* and *H. thompsonii* were not effective as chemicals.

The chemicals were tested against the mite *A. cajani* and found that all chemicals reduced the mite up to 71 per cent, increasing the yield (Manjunatha *et al.,* 2012). Rajeshwari *et al.* (2016) found that fenazaquin (0.1%) spray reduced the population by 81.9 per cent.

Application of synthetic chemicals for management of vectors will be beneficial when it is grown as the sole crop on large farms. The timing of management is also an important factor for managing the vector. Regular monitoring

Table 3: Evaluation of various acaricides/insecticides on *Aceria cajani* populations.

Treatment details	Trade name/ Manufacturer name	Dosage	Number of mites/ per plant (3-4 DAS)	Percent reduction of mites over control
T1-*Hirsutella thompsoni*-2% AS	Almite/Intrnl.Panaacea ltd.	3 ml/l	1628.3±122.2 (3.21)^{j}	81.5 (64.75)^{b}
T2-*Beauveria bassiana*	Greenlife Biotech Laboratory	5 ml/l	1929.2±96.1 (3.28)^{jk}	78.1 (62.49)^{a}
T3-Diafenthurion 50% W/W	Pegasus/Syngenta	2 gm/l	575.6±20.2 (2.81)^{i}	93.4 (75.53)^{c}
T4-Profenophos 50% EC	Progold/Alpha bio Products	2 ml/l	257.1±6.3 (2.41)^{f}	97.0 (81.30)^{f}
T5-Dimethoate 30% EC	Rogorin/FMC India Pvt.Ltd	2 ml/l	374.2±5.2 (2.58)^{g}	95.7 (77.16)^{d}
T6-Fenazaquin 10% EC	Magister/Dupont	3 ml/l	390.6±14.1 (2.59)^{gh}	95.5 (78.04)^{de}
T7-Profenophos 40% + Fen pyroximate 2.5% EC	Etna/ Excel Crop Care Ltd.	0.5 ml/l	111.4±5.6 (2.05)^{e}	98.7 (82.71)^{f}
T8-Etoxazole 10% EC	Borneo/Sumitomo chemical. Co. Ltd.	1 ml/l	78.2±2.9 (1.89)^{cd}	99.1 (85.24)^{g}
T9-Spiromesifen 22.9% EC	Oberon/Bayer Crop science Ltd	1 ml/l	1.0±0.0 (0.00)^{a}	99.9 (89.20)^{i}
T10-Propargite 57% EC	Omite/Agrostar	2 ml/l	40.6±1.6 (1.61)^{b}	99.5 (86.31)^{gh}
T11-Fipronil 5% SC	Regent Gold/Bayer	1.5 ml/l	91.0±7.0 (1.88)^{c}	98.9 (82.70)^{f}
T12-Control	-	-	8818.67±440.2 (3.93)^{l}	-
CD (5%)	-	-	0.20	3.08
SE(m)	-	-	0.07	1.06
CV	-	-	5.02	2.34

Note 1: Values in parenthesis are arcsine transformed.

Note 2: Means followed by same letter are not significantly different Tukey's HSD, (p = 0.05).

Note 3: DAS- Days after spraying.

of fields is essential to detect the SMD disease and timely spraying of the chemicals is required, which is unrealistic for the farmers in India.

Multiple sprays at 30, 45 and 60 DAS (Days after sowing) are required to manage the disease. Generally, pigeonpea is grown in marginal lands under rainfed conditions, in such situations, application of synthetic chemicals to manage vector is not economical (Singh *et al.,* 2021).

Finding host plant resistance genes from the diverse germplasm is the most practical way to lessen the losses brought on by disease. To identify the cultivars that yield large yields and have long-lasting resistance to the sterility mosaic disease, a thorough screening of the germplasm should be conducted.

CONCLUSION

The results from the studies indicate that populations are active throughout the year and reach their peak when environmental factors are conducive. Frequent field scouts should be done from initial stages of the crop growth to detect the disease and timely management practices will reduce the further spread of the disease in the field. All the chemicals tested for the management of mites were effective, whereas entomo pathogenic formulations were not as effective as chemicals.

Conflict of interest: None.

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