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Population dynamics and effect of abiotic factors on spider *Oxyopes kohaensis* (Araneae: Oxyopidae) in an organic mango orchard

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Abstract
Spiders are potential biological control agents in agricultural ecosystems and are major integral part of IPM. Understanding the biology and the factors like biotic and abiotic components influencing the occurrence and diversification of spiders are required for exploiting them to the full extent. In the past few decades global warming is a hot topic where it not only affects the physiological activity of the predator/prey but also the survival to different temperatures. Hence the present study was aimed at determining the abundance of spiders in organic mango orchard and to study the impact of abiotic factors on their occurrence. The peak population of *Oxyopes kohaensis* was found during the months of September during vegetative phase and March - April during flowering and fruiting phase of mango. The peak population of *O. kohaensis* was found during the first week of April 2015 where the total number of spiders was found to be 4.21/tree. Correlation matrix showed that there was a significant positive correlation with the maximum and minimum temperature and negative correlation with relative humidity. Further the significant variables were regressed, the highest coefficient of determination was found in maximum temperature (R^2 =0.64). The present study suggested that the spider can thrive up to a maximum temperature of 33.50ºC. The highest spider density was found in the optimum temperature range between 29.75-33.50ºC.

Keywords: Mango, spider, *O. kohaensis*, population dynamics, abiotic factors

1. Introduction
Mango is one of the most important tropical fruits and is known as ‘king of fruits’. Among various constraints in the production of mango, the loss incurred by pests play a vital role. The current management practices like, the use of synthetic pesticides have caused various hazards such as pest resurgence, pesticide-resistance and influx of various other species. Recent trends in agriculture towards organic agriculture use and ecological sustainability have led to increased interest in utilizing biological control agents for eco-friendly IPM programs.
It is a well- known fact that spiders are considered to be a potential biological control that can significantly reduce prey densities in agricultural fields[1]. Spiders are important mortality agents of horticultural/agricultural pests such as aphids, leafhoppers, planthoppers, fleahoppers, mites and other soft bodies insect like lepidopterous larvae as well as some flying insect [2]. For a predator to effectively and economically control an insect pest, the predator must be capable of reducing pest densities to levels below an economic threshold. Many studies have shown that spiders can significantly reduce prey densities in agricultural fields and can be used as important biological control agents of insect pests [3]. Sahito [4] found that all stages of spiders prey on all stages of sucking insect pests in Brassica and play important role in reducing prey densities.
Understanding the biology, biotic and abiotic factors influencing the occurrence and diversification of spiders are required for exploiting them to the full extent. The potential of spiders as natural control agents of insect pests in different agro ecosystems has been studied by a number of workers [5, 6]. Literature perusal has shown that there are no much studies on the spiders in mango. Hence the present study was carried out to study the population dynamics of the commonest spider *Oxyopes kohaensis* and to determine the effect of various abiotic factors in vegetative and flowering and fruiting phases in an organic mango orchard.

2. Materials and Methods
A detailed study was conducted at ICAR-Indian Institute of Horticultural Research

(12^0 58'N; $77^0$35'E) Hesaraghatta, Bangalore, Karnataka in an organic mango orchard of *cv* Totapuri aged 20 years in an area of one acre. Organic orchard was chosen to ensure the presence of *O. kohaensis* and its prey in the ecosystem and to preclude the negative effects of chemical sprays as in organic orchard chemical sprays are avoided. It was also ensured by regular sampling that sufficient soft bodied insects like leafhoppers *(Idioscopus nitidulus*, *I. niveosparsus*, *I. clypealis*, *Amritodus atkinsoni*), aphids, mealybugs, caterpillars (*Orthaga euadrusalis*) etc were available as food for the predator. This was one of the reasons to choose organically maintained mango orchard. The spider numbers were estimated by visual counts. For each sampling five random panicles/fresh shoots were selected from the tree. Twenty eight trees were sampled at weekly interval from 1st week of Jan 2014 to 4th week of Jun 2016 constituting 140 sampling units/day. The total number of observations (n=260) comprised of 36,400 sampling units for three consecutive years. These trees were maintained organically without the use of any pesticides. Data were tabulated and average spider/tree was documented.

The weather parameters *viz.*, maximum and minimum temperature (°C), relative humidity I (morning) and II (evening) (%), total rainfall (mm) and wind speed (km/h) of selected site were collected every day from the meteorological section of ICAR-IIHR from Jan 2014 to Jun 2016. This was subsequently utilized to correlate with the occurrence of predator in the two study years. Data were analyzed using correlation and regression[7] to know the extent of variability by weather parameters that influence the abundance of spiders in an organic mango orchard.

3. Results and Discussion

3.1 Population dynamics of *O. kohaensis* in an organic mango orchard (Jan 2014 – Jun 2016)

Population dynamics of *O. kohaensis* in an organic mango orchard was studied from Jan 2014 - Jun 2016. During flowering and fruiting phase of mango the peak population of spiders was found to be 2.54, 3.43 and 2.25 per tree in 2014, 2015 and 2016 respectively. During the vegetative phase of mango the peak population of spider was found to be 1.93 and 2.0 per tree in 2014 and 2015 respectively. The mean number of spiders ranged between 0.00 to 4.21 per tree for the entire three year study period. The peak population of *O. kohaensis* was found during the first week of April 2015 where the total number of spiders was found to be 4.21/tree Fig.1.

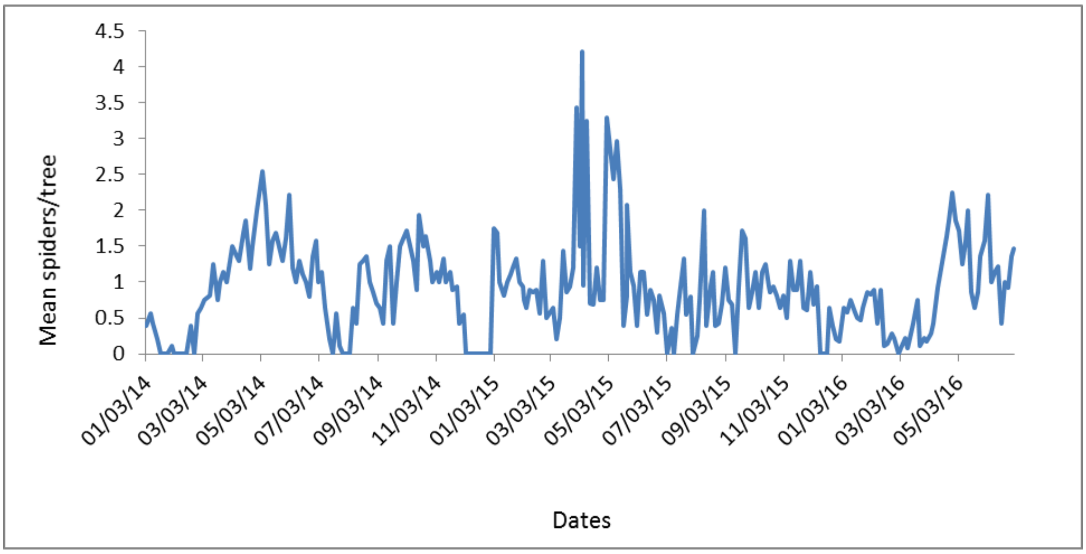

Fig 1: Abundance of spider *Oxyopes kohaensis* in an organic mango orchard (Jan 2014 – Jun 2016)

3.2 Effect of abiotic factor on population of *O. kohaensis* in an organic mango orchard

Flowering and fruiting phase

During flowering and fruiting phase of mango, there was a significant positive correlation between spiders and maximum temperature and minimum temperature. A significant negative correlation was noticed with relative humidity- I during first and second year of the study period (2014 and 2015). Similarly, in 2016 there was a significant positive correlation between spider population and maximum and minimum temperature whereas all other weather parameters were non-significant. In the pooled data, similar results were obtained where there was a significant positive correlation between spider population and maximum and minimum temperature and a significant negative correlation with relative humidity-I (Table 1).

Vegetative Phase

The correlation analysis of *O. kohaensis* and weather parameters suggested that in the first year of the study (2014) during vegetative phase of mango there was a significant positive correlation between spider and maximum temperature, RH-I and windspeed. Similarly during the second year (2015) of vegetative phase there was a significant positive correlation between maximum and minimum temperature whereas all other variables had a non-significant correlation with spiders. In pooled data (2014 and 2015), similar results were obtained where there was a significant positive correlation with maximum and mininmum temperature and relative humidity-I. However, spiders did not show any significnat correlation with relative humidity II, wind speed and rainfall in the pooled data (Table 1)

In overall pooled data (Jan 2014 – Jun 2016) of both vegetative and fruiting phases of mango only maximum and minimum temperature had a significant positive correlation with spider population and all other weather variables were non-significant.

Table 1: Correlation matrix of *Oxyopes kohaensis* and weather parameters in an organic mango orchard

Weather	Flowering and fruiting phase (Jan-Jul)				Vegetative phase (Jul-Dec)			Overall Pooled
	2014	2015	2016	Pooled	2014	2015	Pooled	
Maximum temp (°C)	0.79*	0.44*	0.49*	0.38*	0.57*	0.50*	0.38*	0.43*
Minimum temp (°C)	0.66*	0.25*	0.46*	0.42*	0.22	0.28*	0.27*	0.34*
RH- I (%)	-0.31*	-0.30*	-0.25	-0.31*	-0.35*	-0.16	0.28*	-0.31
RH- II (%)	-0.31*	-0.10	-0.05	-0.12	-0.15	-0.03	-0.10	-0.17
Wind speed (km/h)	0.10	-0.20	0.12	-0.04	-0.34*	-0.02	-0.10	-0.07
Rainfall (mm)	0.11	-0.03	-0.01	0.02	0.37	0.01	0.17	0.04
*Significant at p= 0.05								

The correlation analysis of spiders and abiotic factors during flowering and vegetative phase of mango suggested that maximum and minimum temperature were found consistent in influencing the population of *O. kohaensis* in mango orchard. Hence, these two weather variables were further regressed to know the extent of variability in influencing the occurrence of spiders in mango orchard.

The regression analysis in different years of the study period during flowering and fruiting phase of mango showed that the maximum temperature had a positive impact on the occurrence of spiders compared to the minimum temperature. The highest co-efficient of determination was found in maximum temperature during the third year of the study period (2016) with R^2= 0.64 followed by 0.61 in 2014. However the minimum temperature could explain the variability of occurrence of spiders to an extent of 28% and 34% in 2015 and 2016 respectively (Table 2). In pooled analysis of flowering and fruiting phase of mango the highest co-efficient of determination was found in maximum temperature with R^2= 0.34 (Fig. 2). Similarly, the occurrence of spiders based on minimum temperature could explain the variability to an extent of 31% (Fig. 3).

Table 2: Linear regression equations of *O. kohaensis* population based on weather parameters in flowering and fruiting phase of mango

Weather parameters	Flowering and fruiting phase of mango (Jan-Jun)							
	2014		2015		2016		Pooled (2014-16)	
	Model	R^2	Model	R^2	Model	R^2	Model	R^2
Maximum Temperature °C	y=0.394x-10.47	0.61	y=0.2672x-6.84	0.41	y=0.101x-2.10	0.64	y=0.1411x-3.20	0.34
Minimum Temperature °C	-	-	y = 0.3045x - 4.96	0.28	y = 0.1166x - 1.27	0.34	y = 0.1703x - 2.24	0.31

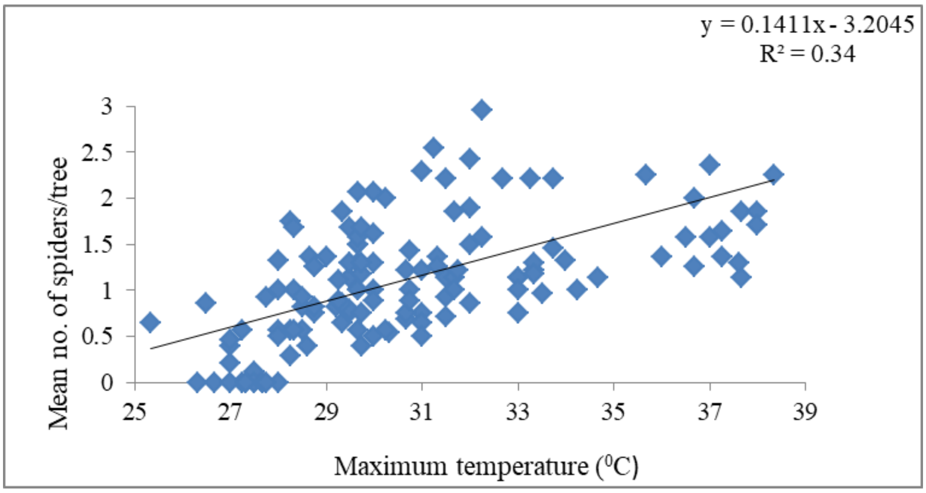

Fig 2: Effect of maximum temperature on population of *O. kohaensis* in pooled flowering and fruiting phase Jan 2014

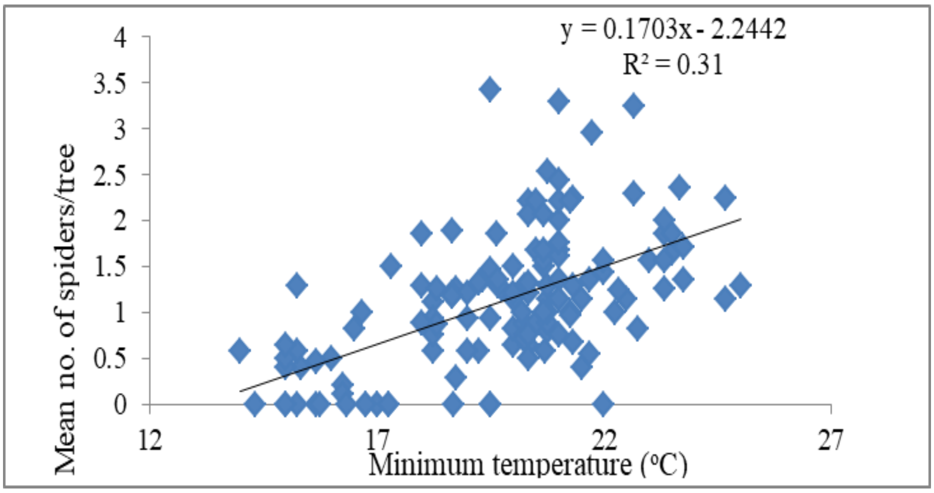

Fig 3: Effect of minimum temperature on population of *O. kohaensis* in pooled flowering and fruiting phase of mango

The regression analysis during the vegetative phase of mango showed that population of spiders in mango orchard is more influenced by maximum temperature compared to minimum temperature, the highest co-efficient of determination was found in the first year of the study period (2014) with R^2 = 0.50 followed by R^2 = 0.41 in 2015. However minimum temperature could influence the occurrence of spiders only to an extent of 32%. In the pooled analysis maximum temperature could influence the occurrence of spiders to an extent of 37% followed by 30% in minimum temperature.

In the overall pooled data, of both vegetative and flowering and fruiting phase, the extent of variability in the occurrence of spiders by maximum and minimum temperature was accounted to 33% and 30% respectively (Table 3).

Table 3: Linear regression equations of *O. kohaensis* population based on weather parameters in vegetative phase of mango

Weather parameters	Vegetative phase of mango (Jul- Dec)						Overall Pooled (2014-15)	
	2014		2015		Pooled (2014-15)			
	Model	R^2	Model	R^2	Model	R^2	Model	R^2
Maximum Temperature (°C)	y = 0.284x-7.21	0.50	y = 0.2178x-5.64	0.41	y = 0.2922x-7.51	0.37	y = 0.1549x-3.6196	0.33
Minimum Temperature (°C)	y = 0.1689x - 2.42	0.32	y = 0.2014x -3.20	0.29	y = 0.2047x - 3.07	0.30	y = 0.197x - 2.90	0.30

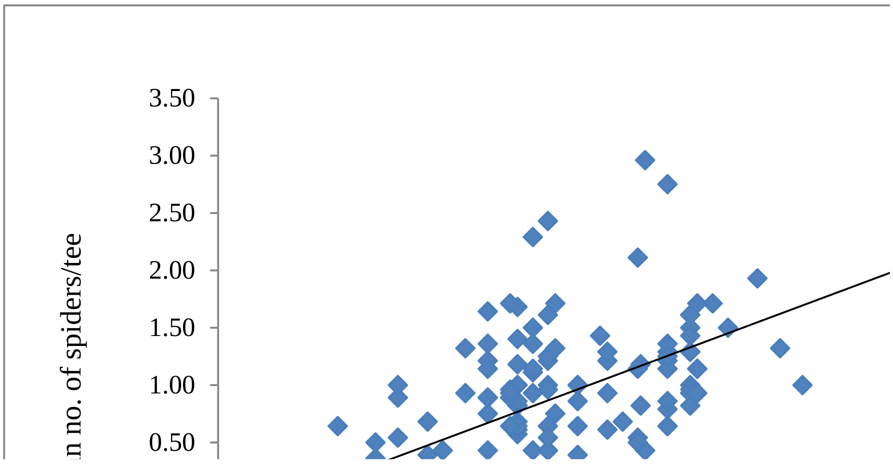

Fig 4: Effect of maximum temperature on population of *O. kohaensis* in pooled vegetative phase of mango

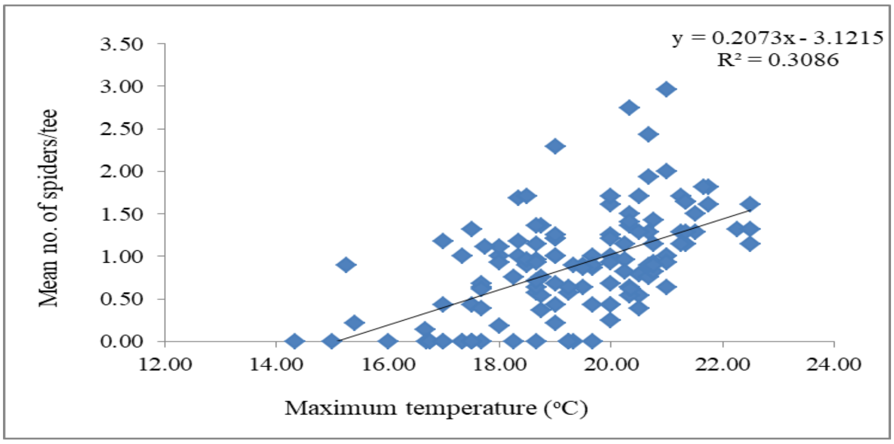

Fig 5: Effect of minimum temperature on population of *O. kohaensis* in pooled vegetative phase of mango

Multiple regression analysis by using both maximum and minimum temperatures as independent variables showed that the highest co-efficient of determination was found in 2014 of flowering and fruiting phase of mango with R^2=0.61. In pooled analysis, the occurrence of spider based on both maximum and minimum temperature during flowering and fruiting phase of mango could explain the variability to an extent of 18% and 16% respectively. However in overall pooled of both vegetative and fruiting phase could explain the variability to an extent of only 19%.

Table 4: Multiple regression equation for *O. kohaensis* based on weather parameters

Period	Year	Model	R^2
Vegetative phase (Jul- Dec)	2014	$y = -4.172+0.134x_1+0.058x_2$	0.27
	2015	$y = -5.823+0.170x_1+0.074x_2$	0.22
	Pooled	$y = -3.65+0.120x_1+0.051x_2$	0.16
Flowering and fruiting phase (Jan-Jun)	2014	$y = -9.888+0.351x_1+0.033x_2$	0.61
	2015	$y = -6.159+0.176x_1+0.095x_2$	0.21
	2016	$y = -1.145+0.061x_1+0.009x_2$	0.23
	Pooled	$y = -1.833+0.037x_1+0.088x_2$	0.18
	Over all pooled	$y = -2.40+0.081x_1+0.046x_2$	0.19

x_1= Maximum temperature and x_2=Minimum temperature

4. Discussion

Spiders being one of the important biocontrol agents play a vital role in management of insect pests in an agricultural ecosystem [8]. In the present study the peak population of *Oxyopes kohaensis* was found during the month of September in vegetative phase and March - April in fruiting phase of mango this is probably due to the peak population of sucking pests (prey) present during the vegetative and fruiting phases of mango. However, changing climatic conditions also lead to altered community composition. Regardless of the production system, IPM will have an important role to play and the use of biological controls like spiders can be an integral part of IPM.

The correlation analysis of spider population and weather parameters suggested that the maximum and minimum temperature had a significant positive correlation and relative humidity –I had a significant negative correlation with spiders. This is in accordance with Patel [9], who reported that there was a significant positive correlation with maximum temperature and average relative humidity had a significant negative correlation with spiders in rice. Dhaka [10] reported that maximum and minimum temperature had a significant positive correlation with spiders. However, relative humidity was also had a significant positive correlation with spiders in cotton. Since maximum and minimum temperature was found consistent in influencing the population of *O. kohaensis* only these two variables were regressed to know the extent of variability influencing the population of spiders. In vegetative phase the highest coefficient of determination was found in the year 2014 with $R^2 = 0.50$. However in the pooled analysis maximum temperature alone influenced the occurrence of spiders to an extent of 33% this is due to the other biotic and abiotic factors such as prey densities, crop stage, microhabitat etc., Both light and temperature levels may also affect foraging decisions indirectly by causing changes in the behaviour and abundance of the prey and the predator species [11].

The role of temperature on its survival, reproduction and rate of development is studied by Li [12]. Jackson and Pollard[13] have reviewed that the life history of spider species and they have reported that the thermal adaptations play an important role in adaptation to the surrounding environmental habitat. They also reported that the spiders living in warmer climates can withstand higher temperature and spiders living in colder climates can adapt to cooler climate. These features are an index of their adaptation to climate change. The present study suggested that the spider can thrive up to a maximum temperature of 33.50 ºC. The highest spider density was found in the optimum temperature range between 29.75-33.50 ºC.

Spiders have been found useful in serving as biological agents for pest management in china. In a pest management program the two conditions are required to be fulfilled that the pest population is maintained under check with time and the pest stabilization is also maintained for the sustained population of spiders [14]. In the present study the spider population has been found stabilized during the occurrence of pests such as leafhopper, aphids and other sucking pests which are in conformity with the published literature. Several other studies have also suggested that spiders can reduce pest infestation by virtue of their top down effects that is microhabitat use, prey selection, polyphagy nature, functional responses and numerical responses and obligate predatory behaviour [2, 15].

5. Conclusion

Spiders are important component of the ecological food web and a generalist predator. It serves as effective biocontrol agents to reduce the pest population such as aphid, leafhopper in an organically managed mango orchard *cv* Totapuri. Among abiotic factors, maximum and minimum temperature influences the spider population significantly during vegetative and flowering phases of crop phenology. The optimum temperature range for the spider population is 29.75 – 33.50 ºC. The other weather parameters such as relative humidity-I and II, wind speed and rainfall had no significant influence on occurrence of *O. kohaensis*. However in Indian agriculture situation the spiders are not effectively utilized as potential biological agents in mango pest management under organic practices. There is a need for further research to determine the extent of spider predation in the multitude of crops and climate under a variety of management practices.

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