Influence of environmental variables on plant mite assemblages: implications on bio-control strategies in Tropical scenario

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Abstract

The seasonal variation in mite populations on four selected plants, namely *Justicia adhatoda* L., *Wissadula periplocifolia* (L.) Thwaites, *Citrus maxima* (Burm.) Merr. and *Syzygium jambolanum* (Lam.) DC from tropical agro-climatic zone in India has been studied. Temperature (°C), rainfall (24 hrs in mm), relative humidity (at 08:30 hrs and 17:30 hrs) were considered as predictor variables to analyze various ecological attributes of the mite populations. A consecutive two years (September 2015 to 2017) study at three different time points, viz pre-monsoon, Monsoon and Post-monsoon succeeded to sample 13,210 mites speciemens from these four host plants. The study revealed that the occurrence of mite species was strongly correlated with habitats, temperature, rainfall and humidity across the seasons. Pre-monsoon, Monsoon and Post-monsoon times were shown to have significant influence on the dynamics of mite communities. The result suggested that the mite assemblages are correlated with their host plant types, environmental variables and seasonal factors. This finding helps us in designing mite control strategies in different seasons in Southern West Bengal, India. Depending of the result of our study and of other, one can design strategy of the biological control of pest mite using the predatory mites at different seasons and can obtain more economic benefit in term of greater crop production in Tropical scenario.

Introduction

Mites (Acari) are one of the most abundant invertebrate groups which are economically important. Interactions among phytophagous mites (pest mites), their natural predators (predacious mites) and ecological parameters are of special interest in order to understand niche of mite and its implication in mite control strategy. Seasonal variations of ecological factors affect mite population dynamics in crop field and associated with increase in pest mite populations or reduction in the predatory mite populations. Several studies have been conducted in India and other continents to evaluate the population fluctuation of plant mites (Manjunath and Puttaswami 1992; Yanar and Ecevit 2008; Fadamiro et al., 2008, 2009; Banerjee and Gupta 2011; Kumar et al., 2015; Silva et al., 2012; Manu et al., 2016; Michal et al., 2018). However, little is known regarding the parameters that explain occurrence of phytophagous mite, seasonal fluctuation of their populations and interactions between phytophagous and fungivorous mites (Tixier, 2018).

The objective of the present study is to determine the seasonal occurrence, population dynamics and potential impact of the predacious mites on the phytophagous mites populations from different agri-horticultural crops in southern West Bengal. The study is focused on seasonal occurrence of and population fluctuations of phytophagous mites in interaction with changing ecological factors and host plant types.

Materials and Methods

Study site

The study was conducted in Medicinal Plant Garden and fruit plantation area located at Ramakrishna Mission Ashrama [22.4385° N, 88.4002° E], Narendrapur about 26 km south of Kolkata from September, 2015 to September, 2017.

Meteorological data collection: Meteorological data were collected from the Regional Meteorological Centre, Alipore (Station ID- 42807) Kolkata, Meteorological Department (Ministry of Earth Sciences, Government of India) to determine seasonal occurrence of mite population with abiotic ecological factors i.e. maximum and minimum temperature (°C), rainfall (24 hrs in mm), relative humidity (at 08:30 hrs) and relative humidity (at 17:30 hrs).

Sample collection

The leaf samples of *Justicia adhatoda* L. [Malabar nut], *Wissadula periplocifolia* (L.) Thwaites [White velvet leaf], *Citrus maxima* (Burm.) Merr. [Sweet Lime/Pomelo] and *Syzygium jambolanum* (Lam.) DC [Water apple] were collected monthly at each sampling date during pre-monsoon, monsoon and post-monsoon from the selected plants. Among these selected plants two are medicinally important i.e. *Justicia adhatoda* L. and *Wissadula periplocifolia* (L.) Thwaites and other two plants are important fruit yielding type i.e. *Citrus maxima* (Burm.) Merr. and *Syzygium jambolanum* (Lam.) DC. Altogether, 12 plants were selected from study site, 3 for each selected plant types. Sampling was done by randomly collecting 5 leaves from each plant; therefore total 15 leaves were collected from each selected plant types at each sampling date. For *Citrus maxima* and *Syzygium jambolanum* leaf samples were taken from each of the four sides of the tree's canopy, as well as from the interior and exterior part of the tree canopy. In addition to leaf samples, fruit samples and associated weeds were collected from under the canopy of the selected trees during sampling date. This was done to compare abundance of predacious mites on leaves, fruit and associated weeds and to determine whether the understory weeds could provide potential alternative food sources in overwintering period and monsoon times for predacious mites. The fruit samples (when available) were collected randomly (3–5 in number) from the plants which provided the leaf samples at each location. Ground cover plants i.e. weeds were randomly collected from beneath the canopy of the same selected 3 trees per location and sampled for mites. For other two selected medicinal plants i.e. *Justicia adhatoda* and *Wissadula periplocifolia* leaf samples were taken randomly each time from the upper, middle and lower level of the plant. Sampling for fruits, twigs or other parts of the plant did not performed for these medicinal plants. The selected plant leaves were examined by using a 10X hand lens [Opticron 10X 23mm]. The collected fresh leaf samples were kept separately in labeled zipper bags and then were brought to the laboratory and were examined under a stereoscopic research microscope [Leica-EZ4 and Motic SMZ-168 Stereo Zoom Microscope]. Mites were picked or collected from each randomly selected areas (2.5×2.5 cm) over the 15 leaves with a fine needle moistened camel "0" sized hair brush dipped in alcohol or Hoyer's medium (Walter and Krantz, 2009) and counted. Population density of mites was measured by using the formula of population density (D) = number of individuals (N)/ area (units^2) in sampling area. For monthly sampling we have recorded population density of mite/month/6.25 sqcm area of leaf. Sampling areas that were free of any insecticide contamination were selected for study.

Host/Habitat: Observation on occurrence of plant mites were assessed on selected host/habitat. The entire field site was subdivided into 4 sub-plots (plants/habitats: MP1, MP2, FP1 and FP2) and the plants were tagged with label (Table 1, Table 3).

Medicinal Plant 1(MP1) - *Justicia adhatoda* L. [Malabar nut]
Medicinal Plant 2 (MP2) - *Wissadula periplocifolia* (L.) Thwaites [White velvet leaf]
Fruit plant 1(FP1) - *Citrus maxima* (Burm.) Merr. [Sweet Lime/Pomelo]
Fruit plant 2 (FP2) - *Syzygium jambolanum* (Lam.) DC [Water apple]

Physical factors: Three parameters *viz.*, temperature (MAX T = Maximum temperature and MIN T = Minimum temperature), relative humidity (RH1 = Relative humidity at 08:30 hrs and RH2 = Relative humidity at 17:30 hrs) and rainfall (RF) have been considered for studying the environment of the experimental field. The climatic factors were considered and recorded according to the three apparently distinct seasons — Pre-monsoon (March-April-May-June), Monsoon (July-August-September-October) and Post-monsoon (November-December-January-February).

Statistical analyses

We have used the Analysis of variance (ANOVA), Analysis of similarity (ANOSIM), Non-metric multidimensional scaling (NMDS), Correlation analysis and Multiple linear regression (MLR) analyses for statistical interpretation of our ecological study. We performed Kolmogorov-Smirnov and Shapiro-Wilk normality test for evaluating sample distribution. The level of significance was evaluated by ANOVA followed by Tukey HSD test at $p < 0.05$ using SPSS version 16.0. The influence of the environmental parameters and seasonal variables on mite assemblage was investigated with CCA (Canonical Correspondence Analysis) using PAST (Paleontological Statistics software, version 3.26) with forward selection of environmental and seasonal factors. The factors were included as centroids in the CCA bi-plot. The CCA demonstrates in best way how community composition varies with the environmental variables and species-environment relationships.

Result

Mite population dynamics have been portrayed considering population attributes and their interactions with environmental factors i.e. maximum and minimum temperature (°C), rainfall (24 hrs in mm), relative humidity (at 08:30 hrs) and relative humidity (at 17:30 hrs) from September, 2015 to September, 2017. The record on seasonal occurrence of mite is presented in the Table 1. A total of 13,210 mite specimens were collected between 2015 and 2017 and the specimens includes 13 families and 24 genera. Total 36 different species were recorded from MP1, MP2, FP1 and FP2 (Table 3). The interrelationship between environmental variables and species occurrence was analyzed using correlation analysis and canonical correspondence analysis (CCA). CCA was applied to examine the relationship between species assemblages and their distribution of associated environmental factors.

Effects of host, habitat and seasons on mite population

We have recorded population variations of the studied phytophagous mites on the four selected host plants (MP1, MP2, FP1 and FP2). Analysis of variance (ANOVA) revealed that population of phytophagous mites were depended on the host plant types. ($F_{(3, 96)} = 13.70$, $p < 0.05$; Table 1). The post hoc analysis with Tukey HSD also confirmed this inference ($p < 0.05$). In analyzing the effects of habitats on the population fluctuation of fungivorous and soil mites, we employed the ANOVA analysis and obtained no significant effects of habitat variation on mite population density($F_{(3, 96)} = 1.43$, $p > 0.05$; Table 1). This observation was further confirmed by post hoc analysis with Tukey HSD test ($p > 0.05$). The Spearman correlation coefficient, R^S indicates a perfect association of three seasons in two consecutive years of the study with population fluctuations of phytophagous mites. It suggests strong relationship (very close to + 1) with premonsoon, monsoon and postmonsoon sampling time with mite abundance. We obtained significant correlation between host plant types and mite population density $p < 0.01$ (Table 1). We used Kolmogorov-Smirnov and Shapiro-Wilk normality test for evaluating distribution; the result confirmed the strong association between seasonal variables.

Effects of environmental variables, seasonal variables and inhabiting plants on population densities of mite

The canonical correspondence analysis (CCA) was used to study mite community responses to the environmental variables. The outcomes of analyses are represented in the Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5.

In CCA ordination diagram, families of mite with their population densities are represented by points and environmental variables are represented by arrows for different habitat (MP1, MP2, FP1 and FP2) at different season (Pr.M, M and Pt.M) against horizontal (CCA1) and vertical (CCA2) axis.. The first two canonical axes (Axis1/CCA1and Axis 2 /CCA2) accounted for 94.99% (CCA1 = 50.10%; CCA2 = 44.89%) of the total variation in the original matrix (Table 2; Fig. 1). The first canonical axis was highly correlated with temperature (MAX T and MIN T), whereas the second canonical axis was correlated with RH1, RH2 and RF (Table 4.5; Fig. 4.12). In the CCA analysis on Medicinal Plant 1 (MP1), the first two canonical axes (Axis1/CCA1and Axis 2 /CCA2) accounted for 93.77% (CCA1 = 77.75%; CCA2 = 16.02%) of the total variation in the original matrix (Table 2). The population densities of Tenuipalpidae and Tarsonemidae are highly correlated with temperature (MAX T and MIN T) and rainfall (RF) on MP1 (Fig. 2). The members of the family Tydeidae, Stigmaeidae and other predatory mites exhibited positive correlation with relative humidity (RH1 and RH2) and hence their population density reached peak during monsoon (M) season. The population densities of fungivorous and soil inhabiting mites are also correlated with monsoon season and rainfall. The population densities of Tetranychidae, Cunaxidae and Phytoseiidae are strongly correlated with post-monsoon period, though we observed the population of Tetranychidae sometimes increases in monsoon in compare to other plant mites groups. From CCA analysis on Medicinal Plant 2 (MP2), the first two canonical axes (Axis1/CCA1and Axis 2 /CCA2) accounted for 98.74% (CCA1 = 87.47%; CCA2 = 11.27%) of the total variation in the original matrix (Table 2). The population densities of Phytoseiidae, Cunaxidae, fungivorous and soil inhabiting mites exhibited strong correlation with relative humidity (RH1 and RH2) and rainfall (RF) on MP2 (Fig. 3). Therefore their population densities have significant positive relation with the occurrence monsoon season. Tetranychidae have positive correlation with temperature (MAX T and MIN T) during monsoon and post-monsoon times. Similarly Tenuipalpidae, Tarsonemidae, Tydeidae, Stigmaeidae and other predatory mites also exhibited positive correlation with monsoon and post-monsoon seasons. In the CCA analysis on Fruit Plant 1 (FP1), the first two canonical axes (Axis1/CCA1and Axis 2 /CCA2) accounted for 75.48% (CCA1 = 46.23%; CCA2 = 29.25%) of the total variation in the original matrix (Table 2). On FP1 (Fig. 4) Tetranychidae population shown positive correlation with temperature (MAX T and MIN T) and Phytoseiidae shown positive correlation with relative humidity. During monsoon population densities of fungivorous and soil inhabiting mites reaches very high with heavy rainfall. The members of Tarsonemidae and Tenuipalpidae exhibited elevated densities during pre-monsoon and post-monsoon seasons, respectively. Cunaxidae have no definite correlation with seasonal variables on FP1 as we observed similar abundance across all the seasons. In the CCA analysis on Fruit Plant 2 (FP2), the first two canonical axes (Axis1/CCA1and Axis 2 /CCA2) accounted for 95.19% (CCA1 = 71.77%; CCA2 = 23.42%) of the total variation in the original matrix (Table 2). On FP2 (Fig. 5) Cunaxidae exhibited strong correlation with maximum temperature during pre-monsoon. During monsoon Tetranychidae showed positive correlation with relative humidity and rainfall. Population densities of predatory mites i.e. Phytoseiidae, Tydeidae, Stigmaeidae and other predatory familiesare positively correlated with post-monsoon season. We observed positive abundance of phytophagous mites such as Tenuipalpidae and Tarsonemidae across all the seasons except monsoon.

Table 2
Result of Canonical correspondence analysis (CCA) with eigenvalues for first two canonical axes (Axis1/CCA1and Axis 2 /CCA2)

CCA	**Habitat/Host Plant**				
Eigenvalues	**MP1**	**MP2**	**FP1**	**FP2**	**MP1 + MP2 + FP1 + FP2**
Axis1/CCA1	0.048 (77.75%)	0.234 (87.47%)	0.13 (46.23%)	0.172 71.77%)	0.044 (50.1%)
Axis2/CCA2	0.009 (16.02%)	0.03 (11.27%)	0.082 (29.25%)	0.056 (23.42%)	0.039 (44.89%)
Total variation in matrix = CCA1 + CCA2	**93.77%**	**98.74%**	**75.48%**	**95.79%**	**94.99%**

(CCA ordination diagram on population density of all mites with environmental variables and different seasons on four habitats: MP1 = Medicinal plant 1, MP2 = Medicinal plant 2, FP1 = Fruit plant 1, FP2 = Fruit plant 2, Environmental variables: MAX T = Maximum temperature, MIN T = Minimum temperature, RH1 = Relative humidity at 08:30 hrs, RH2 = Relative humidity at 17:30 hrs, RF = Rainfall, Seasonal variables: Pr M = Pre-monsoon, M = Monsoon, Pt M = Post-monsoon)

Table 3
Name of the mite species identified from the habitat/inhabiting plants (MP1, MP2, FP1 and FP2) of studied ecological site

No.	Family	Species	MP1	MP2	FP1	FP2
1.	Tetranychidae	*Tetranychus ludeni*	+	+	−	−
2.	Tetranychidae	*Tetranychus urticae*	+	+	−	+
3.	Tetranychidae	*Eotetranychus syzygii*	−	+	+	+
4.	Tetranychidae	*Panonychus citri*	−	−	+	−
5.	Tetranychidae	*Oligonychus indicus*	+	+	−	−
6.	Tetranychidae	*Oligonychus mangiferus*	−	−	−	+
7.	Tetranychidae	*Schizotetranychus baltazari*	−	−	+	−
8.	Tenuipalpidae	*Brevipalpus californicus*	+	+	−	+
9.	Tenuipalpidae	*Brevipalpus lewisi*	+	+	−	−
10.	Tenuipalpidae	*Brevipalpus obovatus*	+	−	−	−
11.	Tenuipalpidae	*Brevipalpus phoenicis*	+	−	+	+
12.	Tarsonemidae	*Tarsonemus* sp.1	+	−	−	−
13.	Tarsonemidae	*Tarsonemus* sp.2	−	−	−	+
14.	Eriophyidae	*Aceria justiciae*	+	−	−	−
15.	Cunaxidae	*Cunaxa mangiferae*	−	−	+	+
16.	Cunaxidae	*Dactyloscirus bengalensis*	+	+	−	−
17.	Stigmaeidae	*Agistemus fleschneri*	−	−	+	+
18.	Stigmaeidae	*Agistemus terminalis*	−	−	+	−
19.	Anystidae	*Anystis baccarum*	+	−	−	−
20.	Tydeidae	*Lorryia stricta*	−	−	+	+
21.	Tydeidae	*Tydeus* sp.1	+	−	−	−
22.	Tydeidae	*Tydeus* sp.2	−	−	+	−
23.	Bdellidae	*Bdella* sp.1	−	+	−	−
24.	Bdellidae	*Bdella* sp.2	−	−	+	−
25.	Ascidae	*Lasioseius bengalensis*	−	−	+	+
26.	Phytoseiidae	*Amblyseius adhatodae*	+	−	−	−

No.	Family	Species	MP1	MP2	FP1	FP2
27.	Phytoseiidae	*Amblyseius herbicolus*	–	–	–	–
28.	Phytoseiidae	*Amblyseius largoensis*	+	+	+	+
29.	Phytoseiidae	*Euseius alstoniae*	–	+	+	+
30.	Phytoseiidae	*Neoseiulus longispinosus*	+	–	–	–
31.	Phytoseiidae	*Paraphytoseius orientalis*	+	+	–	+
32.	Phytoseiidae	*Phytoseius* sp.	–	–	+	–
33.	Phytoseiidae	*Typhlodromips syzygii*	–	–	–	+
34.	Acaridae	*Acarus* sp.	+	–	–	–
35.	Acaridae	*Tyrophagus longior*	+	–	–	–
36.	Oribatidae	Oribatid mites	+	+	+	–

(+) indicating the presence of mite and (–) indicating the absence of mite

Discussion

The study recorded the plant mite population dynamics as a function of climatic factors across the seasonal changes on selected host plant species. The canonical correlation analysis (CCA) helps us to measure the linear relationship in multivariate models that display “between-association” and “within-association” of different ecological variables. Here, CCA provides an automated interpretation of the ordination axes for two years spanning from September, 2015 to September, 2017. In addition, the observed result is very concordant with that obtained in previous studies performed on different groups of mites (Yanar and Ecevit 2008; Wissuwa et al. 2012; Wang et al. 2014; Tixier 2018). According to Yanar and Ecevit (2008) seasonal occurrence of spider mite population and their predators are influenced by environmental and chemical variables. Similarly, our study suggested that abundance and seasonal occurrence of plant mite on selected host plant species significantly depends upon different biotic and abiotic factors.. From CCA analysis it can be inferred that the population densities of Tarsonemidae, Phytoseiidae, Cunaxidae, Tydeidae, Stigmaeidae and other predatory mites are positively correlated with relative humidity and as expected we recorded increase in density of these species during monsoon and post-monsoon seasons when relative humidity remains high. The family Tenuipalpidae is positively correlated with temperature and during pre-monsoon season, when ambient temperature of south Bengal remains high, their population exhibited significant increase. The family Tetranychidae is negatively influenced by relative humidity and rainfall. Similar to our observation, the result of study by Wang et al. (2014) on gall mite have proved that temperature and leaf length are major factors that influenced changes in eriophyoid mite assemblages. It has been hypothesized that host plant species diversity has significant effects on population dynamics, diversity and assemblage of parasitic mite species (Wissuwa et al. 2012). The outcome of our present study provides strong support to this notion. In addition, our result suggests that the phytophagous and predacious groups have different choice of hosts/habitats and exhibit significant fluctuations in population densities across the three seasonal divides.

Conclusion

The mite communities from an Agro-Climatic zone in tropical area fluctuate according to different ecological parameters. Our results have some agro-economic implications. Depending of the result of our study and of other, one can design strategy of the biological control of pest mite using the predatory mites at different seasons and can obtain more economic benefit in term of greater crop production. Further ecological characterization is needed on different host plants to get more holistic picture of plant mite population dynamics in southern West Bengal, India. From the ecological perspective, the study provides the distribution, abundance in relation to the heterogeneity of the environmental variables in tropical standpoint, if we imply the predatory mites against pest species in accordance with seasons that will be more beneficial for agricultural crop protection. So outcome of this study may be implemented towards the introduction of predatory mites against seasonal infestation of pest species especially in tropical scenario which can be utilized as a potential solution of better crop protection and increased productivity.

Declarations

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Conflicts of interest statement

The authors declare that they have no conflict of interest. The ecological study was purely academic purpose.

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Table 1

Table 1 is available in the Supplementary Files section.

Figures

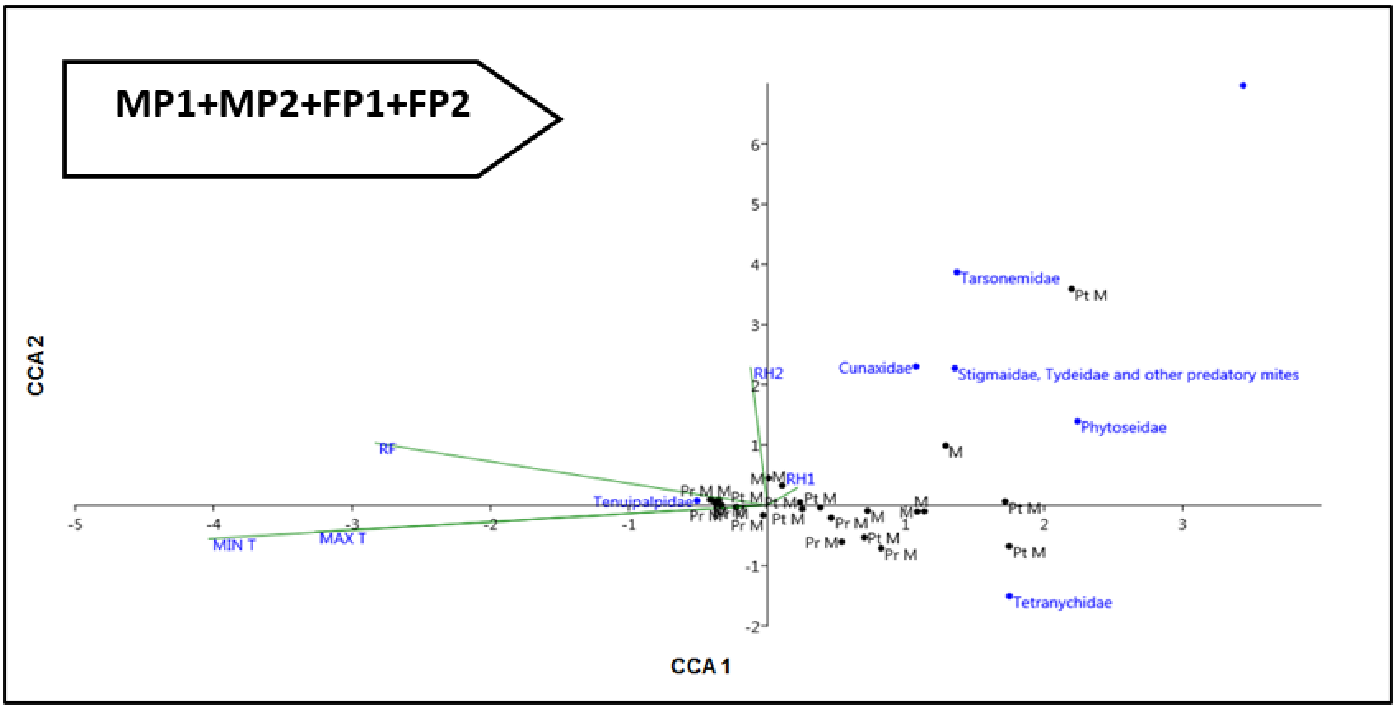

Figure 1

CCA ordination diagram on population density of all mites with environmental variables and different seasons on four habitats

(CCA ordination diagram on population density of all mites with environmental variables and different seasons on four habitats: MP1= Medicinal plant 1, MP2= Medicinal plant 2, FP1= Fruit plant 1, FP2= Fruit plant 2, Environmental variables: MAX T= Maximum temperature, MIN T= Minimum temperature, RH1= Relative humidity at 08:30 hrs, RH2= Relative humidity at 17:30 hrs, RF= Rainfall, Seasonal variables: Pr M= Pre-monsoon, M= Monsoon, Pt M= Post-monsoon)

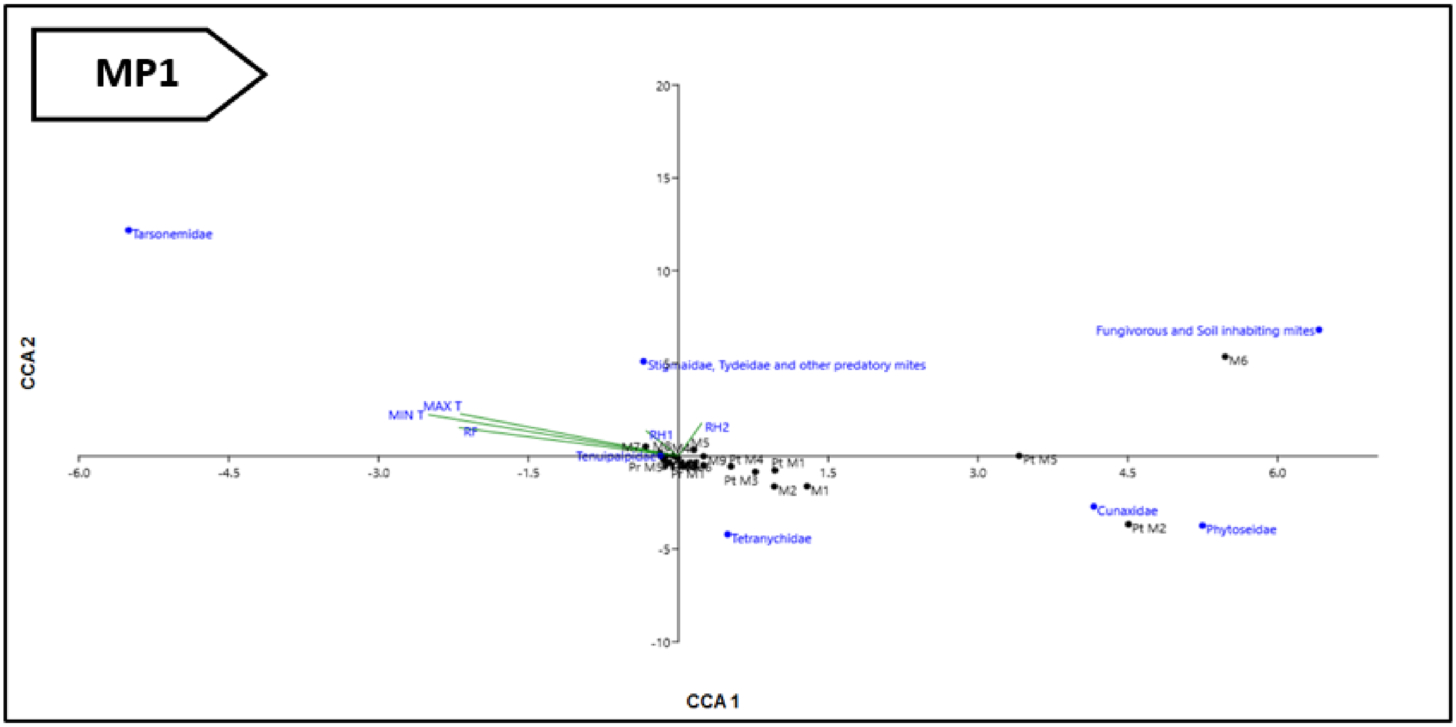

Figure 2

Canonical correspondence analysis (CCA) ordination diagram of ecological observation for population density of mite on Medicinal Plant-1 *Justicia adhatoda* L. [Malabar nut]

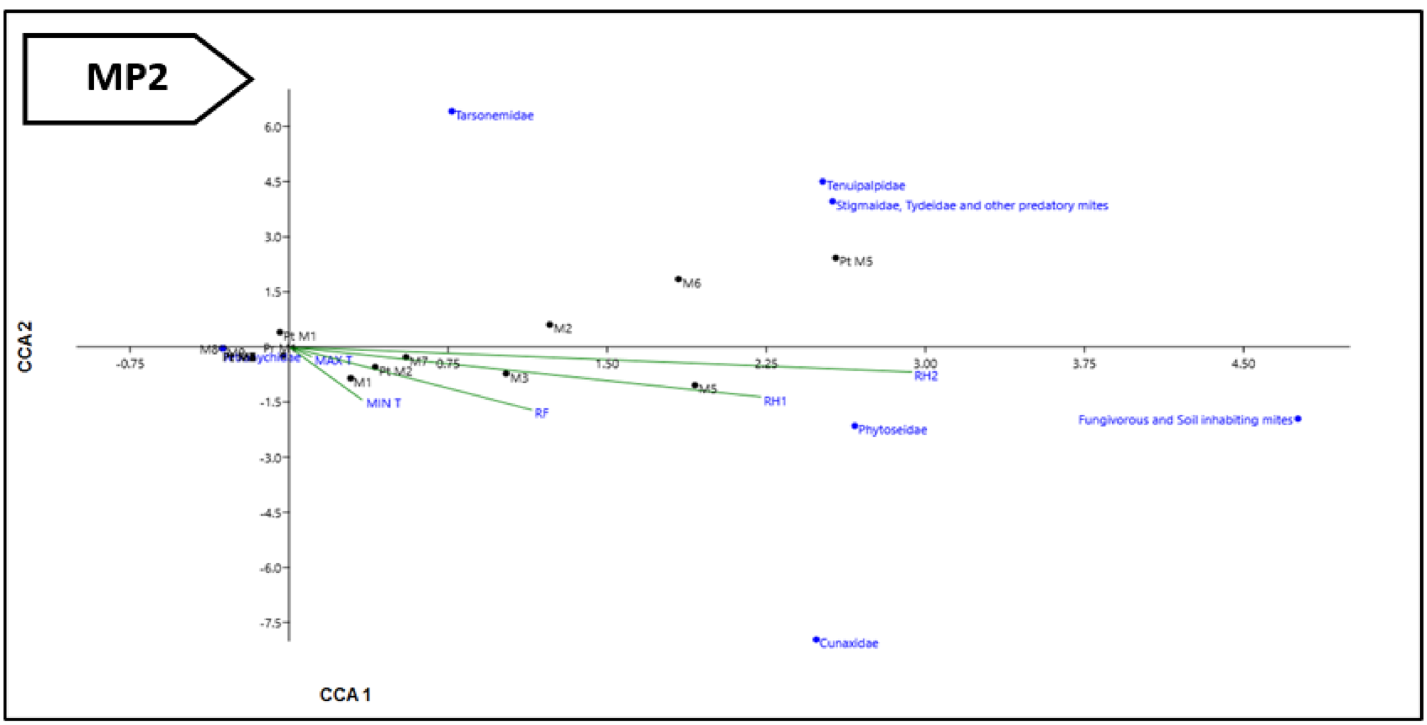

Figure 3

Canonical correspondence analysis (CCA) ordination diagram of ecological observation for population density of mite on Medicinal Plant-2 *Wissadula periplocifolia* (L.) Thwaites [White velvet leaf]

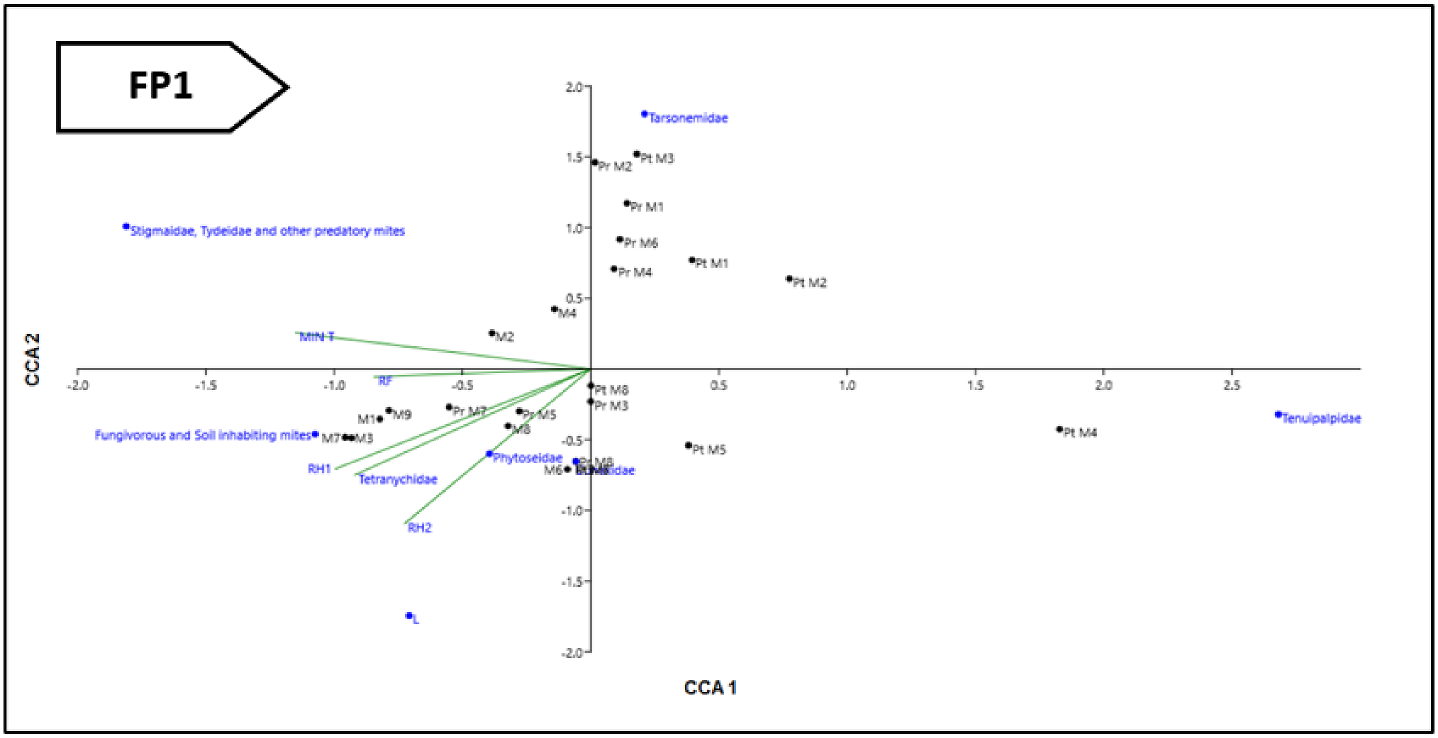

Figure 4

Canonical correspondence analysis (CCA) ordination diagram of ecological observation for population density of mite on Fruit plant-1 *Citrus maxima* (Burm.) Merr. [Sweet Lime/Pomelo]

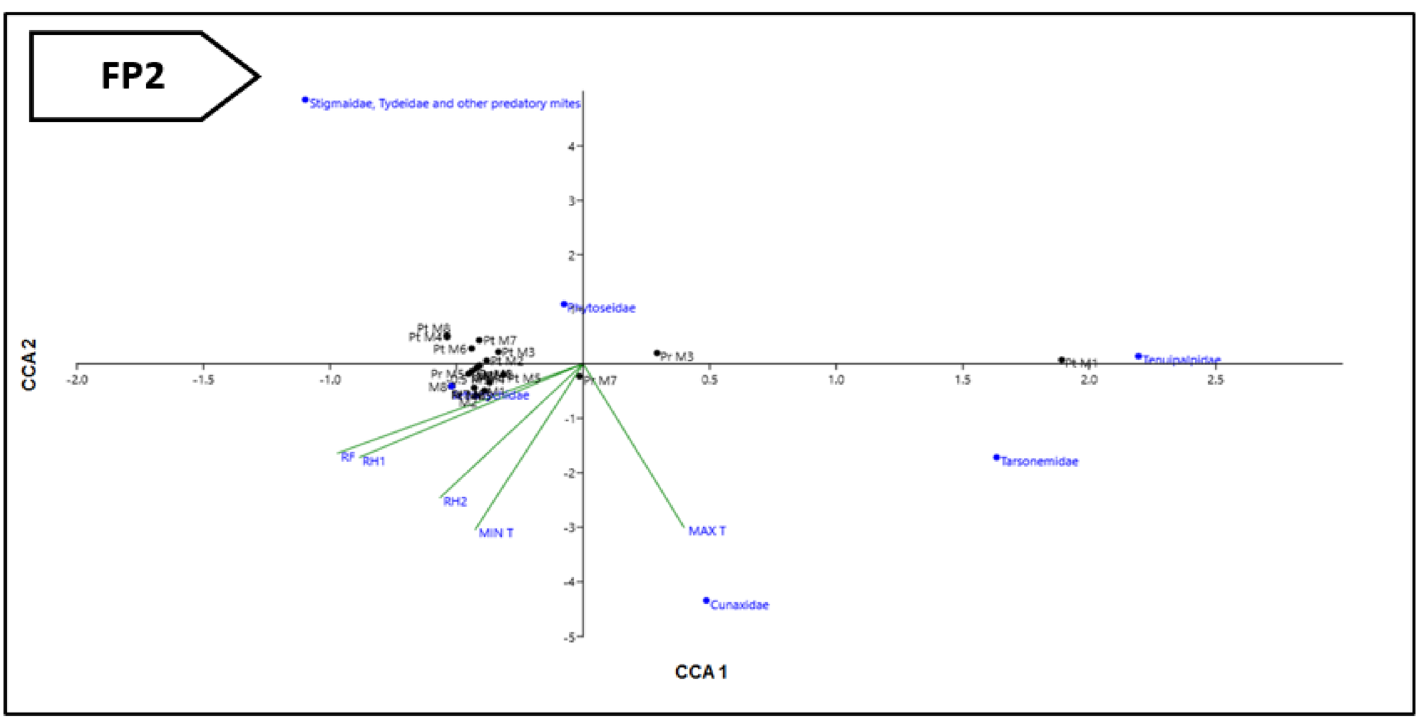

Figure 5

Canonical correspondence analysis (CCA) ordination diagram of ecological observation for population density of mite on Fruit plant-2 *Syzygium jambolanum* (Lam.) DC [Water apple]

Supplementary Files

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- Highlights.docx