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*Full Length Article*

# Diversity of Soil Inhabiting Mesostigmata (Acari) of Citrus Orchards from Punjab, Pakistan

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## Abstract

Mesostigmata is diverse, free living and generally predacious group of soil mites that plays a vital role in soil ecosystem. Study was conducted on mesostigmatid soil mites form citrus orchards of four districts of Punjab. Soil samples were collected monthly under the canopy of citrus trees throughout the study year. More than three thousand mesostigmatid mites were isolated out of 11250 collected specimens. Shannon diversity index, family richness and abundance were recorded high from Sargodha Toba Tek Singh and Faisalabad as compared to Layyah district. Maximum population of Mesostigmata was reported during April (12.92) while minimum was reported in November (4.08). Pachylaelapidae was dominant in Faisalabad district among 11 other reported families, while Sejidae and Uropodidae were found absent from Layyah district. The community structures of mesostigmatid mites from different districts and months are also given in this manuscript which showed maximum frequency of Laelapidae, Pachylaelapidae, Rhodacaridae and Uropodidae from Faisalabad, Melicaridae from Layyah, Ameroseiidae, Ascidae, Sejidae, Parasitidae and Macrochelidae from Sargodha and Phytoseiidae from Toba Tek Singh. Month wise community structure showed that Ameroseiidae, Pachylaelapidae and Laelapidae were found maximum during April, Macrochelidae and Phytoseiidae during September, Melicaridae and Uropodidae in August, Rhodacaridae in December, Phytoseiidae in February, Sejidae in October. 

**Keyword:** Diversity of Soil; Inhabiting Mesostigmata (Acari); Citrus Orchards; Punjab, Pakistan

## Introduction

Soil is an important and biologically diverse habitat on Earth. The soil enriched with organic matter is considered to contain 20 different linages of Arthropoda, which represent 85% of total soil fauna (Culliney 2013). Mites (Acari) are the largest group of arthropods, competent to insects and total taxonomically described mite species are 55214 from various ecosystems which constitute the major diversity of the arthropods (Zhang 2013). Among other soil arthropods, total relative abundance of Mesostigmata was recorded up to 43.31% (Desmond and Ugwumba 2013). The mites (Acari) are one of the most abundant groups of arthropods. Due to their evolutionary history and having small size, mites can be found in all types of habitats. Based on such characteristics, 55000 species of mites have been described and still more than million species of mites are yet to be described (Walter and Proctor 1999). Likewise, total mite species are much more than this current estimate of million or more (Gaston 1991). Among these, mites (Acari) and collembolans are most abundant. Mesostigmata alone contributes about 80% of soil arthropod fauna (Petersen and Luxton 1982; Minor and Norton 2004). Free living mesostigmatid mites are found in all types of habitats like soil, litter, dung, plants and decaying wood (Walter and Olivier 1989; Halliday 2000; Shaw and Walter 2003). Being predators, they are unable to impart major structural changes of soil as well as their direct role for enhancing the crop production is also negligible, while indirectly they can regulate the populations of other organisms due to their predation rates (Koehler 1997, 1999; Gulvik 2007; Salmane and Brumelis 2008). These mites are mostly found in soil below litter and humus layers. A substantial part of these mites are also found from 4–6″ soil layers (Krantz and Ainscough 1990). Diversity and abundance of Mesostigmata change during different seasons and found maximum during first six month of the year as compared to last six months. Maximum diversity was found during May, June, July and August. Also abundance was maximum in upper litter layer (34%), minimum recorded from soil depth of 10–15 cm (14%). Different factors like seasonal variation, soil depth and above ground plant species post great impact on abundance of Mesostigmata (Urhan *et al.* 2008).

Being predacious nature to control population of many pests, even some of these mites have such potential to control

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many herbivorous pests that spend some time of their life cycle within the soil, plant roots or litter (Eickwort 1983; Lesna *et al.* 1995; Koehler 1999; Gerson *et al.* 2003; Beaulieu and Weeks 2007). Thrips are important pest of citrus (Blank and Gill 1997; Marullo 1998; Mound and Jackman 1998; Varikou *et al.* 2002; Navarro-Campos *et al.* 2011) that damage the fruit by scraping tissues and formation of uniform ring, hence destroy the cosmetic value of such fruits and also unsalable in quality market (Jeppson 1989; Crisp and Baker 2011). Because thrips pupate within soil (as pseudo pupae) and mesostigmatid mites have ability to find and control the population of soil dwelling thrips efficiently (El-Titi and Ipach 1989). Many studies have reported from different parts of the world which exhibit that mesostigmatid mites can successfully feed and control thrips (El-Banhawy *et al.* 2006; Messelink and Holstein-Saj 2008). From Pakistan, no studies on the diversity of Mesostigmata have been carried out so far. Keeping in view the importance of this group, the present research was conducted to explore the diversity of soil inhabiting Mesostigmata from citrus orchards of Punjab.

## Materials and Methods

Four citrus growing districts of Punjab *viz*., Faisalabad, Sargodha, Toba Tek Singh and Layyah were selected. Three orchards were selected from each site having similar agronomic and pest management practices. Three samples were collected from each site. Soil samples were collected at monthly interval from each site with the help of a steel core measuring one litre capacity (10.5 cm diameter and 12 cm length). The soil was transferred to zip lock polythene bags to avoid the escape of mites and moisture contents from samples. These samples were transferred immediately to Acarology Research Laboratory, Department of Entomology, University of Agriculture, Faisalabad. The modified Berlese Tulgren Funnels apparatus was used to extract the mites from collected samples. The soil samples were processed for 48 h to ensure the maximum collection of mites from the collected ones. The specimens were preserved in mini vials containing 75% ethanol and few drops of glycerine. Vials were tagged according to date of collection and locality, for further studies. These collected specimens were sorted and mounted permanently in Hoyer's medium under a stereoscope. The mounted specimens were studied under higher power phase contrast microscope (Meiji Techno MT4210H). The specimens were identified up to family level by using taxonomic keys of Krantz and Walter (2009) and Evans and Till (1979).

The individual-based rarefaction curves were calculated by using computer software 'PAST' (Hammer *et al.* 2001). Abundance of the mites recorded as the number of individuals per sample. Family richness was expressed as the number of families represented per sample while the Shannon-Weiner diversity index was calculated the represented the diversity of soil mites per sample. Chao 1 diversity index was also calculated to compute the richness of soil inhabiting mites to evaluate the rare number of families that may be missed due sampling methods (Chao 1984). Data of various factors was subject to ANOVA while Turkey's pair-wise comparison (Fisher test) was applied. These analyses were performed using R software with a significance level of $\alpha$=0.05.

## Results

Individual base rarefaction analysis was done for cumulative soil mite data and four selected sites viz., Faisalabad, Sargodha, Toba Tek Singh and Layyah for assessment whether the number of samples collected was enough to represent the maximum taxa. Standard curves obtained as a result of rarefaction analysis showed different data sets based on number of individuals. These individual based rarefaction curves for all the selected districts of Punjab showed that sampling effort was enough and represented the maximum taxa of mesostigmatid mites obtained from soil samples during this study (Fig. 1).

The sampling resulted in collection of 3431 mesostigmatid mites out of 11250. Shannon diversity of all the four different districts varied slightly, maximum value of Shannon diversity index (H'=2.12) was recorded for Sargodha followed by Faisalabad (H'=2.03) while minimum (H'=1.90) was reported for Layyah and Toba Tek Singh districts (Table 1). The Fisher's Alpha diversity index also varied slightly between four districts and maximum value (1.65) was recorded from Toba Tek Singh followed by Sargodha (1.51), Layyah (1.36) and Faisalabad (1.34) (Table 1). The Chao1 diversity index of Mesostigmata of citrus orchards of four districts of Punjab revealed slight variations. Maximum number of families per district Chao1 (S. obs.) value (10) was observed from Faisalabad and Sargodha districts while minimum (S. obs.= 9) was recorded from Layyah and Toba Tek Singh districts. This result showed that observed and chao1 estimator was same and represented the number of families per district of mesostigmatid mites of citrus orchards of four districts of Punjab (Table 2). Maximum value of Shannon Diversity (H') was reported in June (H'=2.23) whereas, the maximum value of Fisher's alpha 2.85 in the same moth (Table 3). Month wise Chao1 diversity index values are given in Table 4 which represents no variation during all the year.

Data regarding the abundance showed highly significant differences in all the districts ($F_{value}$ =8.26; $P \leq$ 0.000). The maximum mean values of abundance of Mesostigmata (9.67 ± 0.60) were recorded from Layyah and minimum (7.50 ± 0.55) from Toba Tek Singh. Faisalabad showed 8.03 ± 0.57 and Sargodha 7.53 ± 0.54 mean abundance. Different months also showed highly significant variations ($F_{value}$ =24.79; $P \leq$ 0.000). Maximum population reported was 12.92 ± 0.99 during April followed by 12.25 ± 1.14, 11.33 ± 0.97 and 9.33 ± 1.09 in March, June and January, respectively. All these are statistically at par.

**Table 1:** Shannon diversity and Fisher's alpha index of Mesostigmata from different districts

| Districts | Shannon diversity | Fisher's alpha |
|---|---|---|
| Faisalabad | 2.03 | 1.34 |
| Layyah | 1.90 | 1.36 |
| Sargodha | 2.12 | 1.51 |
| Toba Tek Singh | 1.90 | 1.65 |

**Table 2:** Observed and estimates no. of families of soil mesostigmatid mites based on Chao 1 estimator in relation to citrus orchards from different districts of Punjab

| Districts | Observed | Estimated | |
|---|---|---|---|
| | | Chao1 | S. ACE |
| Faisalabad | 10 | 10 | 10 |
| Layyah | 9 | 9 | 9 |
| Sargodha | 10 | 10 | 10 |
| T.T. Singh | 9 | 9 | 9 |

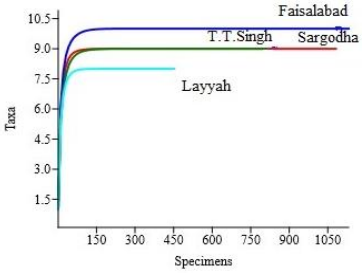


**Fig. 1:** Rarefaction curve for cumulative data of citrus orchards of Punjab

Minimum abundance was reported during 4.08 ± 0.48 in November, which was statistically similar to October (4.22 ± 0.53) December (4.61 ± 0.40) and August (5.69 ± 0.55) (Table 5). Interaction of months and districts also had significant differences ($F_{value}$=9.04; $P \leq 0.000$).

Data of richness expressed highly significant variations in all the districts ($F_{value}$ =49.49; $P \leq 0.000$). The maximum mean values of richness of Mesostigmata (4.69 ± 0.20) were reported from Layyah and minimum (3.88 ± 1.72) from Sargodha. Faisalabad showed 4.22 ± 1.21 and Toba Tek Singh 3.98 ± 1.95 (mean richness). Different months also showed highly significant variations ($F_{value}$ =3.307; $P \leq 0.000$). Maximum richness reported was 5.94 ± 0.32 during April followed by 5.42 ± 36 and 5.42 ± 30 in June and March, respectively. All these are statistically at par. Minimum richness was reported during 2.53 ± 0.27 in October, which was statistically similar to November 2.69 ± 0.27 (Table 6). Interaction of months and districts also had significant differences ($F_{value}$= 3.18; $P \leq 0.000$).

Data of community structure of soil Mesostigmata from different districts of Punjab showed that Pachylaelapidae, Rhodacaridae and Uropodidae was found maximum form Faisalabad, Ameroseiidae, Ascidae, Macrochelidae, Parasitidae and Sejidae was recorded maximum form citrus orchards of Sargodha, Phytoseiidae was found maximum from Toba Tek Singh and Melicheridae form Layyah. While family Melicheridae was not found form Faisalabad and Sargodha, Rhodacaridae from

**Table 3:** Month wise Shannon diversity and Fisher's alpha index of Mesostigmata

| Month | Shannon diversity | Fisher's alpha |
|---|---|---|
| January | 2.01 | 2.59 |
| February | 2.05 | 2.29 |
| March | 1.98 | 2.08 |
| April | 1.97 | 2.03 |
| May | 2.07 | 2.18 |
| June | 2.23 | 2.85 |
| July | 2.13 | 2.72 |
| August | 2.15 | 2.13 |
| September | 2.04 | 2.08 |
| October | 2.01 | 2.09 |
| November | 2.08 | 2.24 |
| December | 2.08 | 2.44 |

**Table 4:** Observed and estimates no. of families of soil mesostigmatid mites based on Chao 1 estimator in relation to citrus orchards during different months

| Months | Observed | Estimated | |
|---|---|---|---|
| | | Chao1 | S. ACE |
| January | 10 | 11 | 11.63 |
| February | 11 | 11 | 11 |
| March | 11 | 11 | 11 |
| April | 11 | 11 | 11 |
| May | 11 | 11 | 11 |
| June | 11 | 11 | 11 |
| July | 10 | 10 | 10 |
| August | 11 | 11 | 11 |
| September | 11 | 11 | 11 |
| October | 11 | 11 | 11 |
| November | 11 | 11 | 11 |
| December | 11 | 11 | 11 |

Toba Tek Singh, Sejidae from Layyah and Toba Tek Singh and Uropodidae was nil in Layyah (Fig. 2). The month wise community structure showed that population of Laelapidae was maximum during April and October, Pachylaelapidae, Ameroseiidae, Phytoseiidae in April, Parasitidae and Macrochelidae in September, Melicheridae and Uropodidae in August, Ascidae in March, Sejidae in October and Rhodacaridae in month of December, respectively (Fig. 3).

## Discussion

The present study resulted in collection of 3431 specimens of Mesostigmata which makes 30% of total collected specimens of soil inhabiting mites from all the four regions. These results are closely similar to the results of Banerjee *et al.* (2009) who reported 27.22% from West Bengal, whereas, Desmond and Ugwumba (2013) also reported 43.31% abundance of Mesostigmata while Imen *et al.* (2018) reported 43.99% relative abundance of mesostigmatid soil mites from citrus orchards. The Shannon diversity (H') of the citrus orchards of different regions varied from 1.90–2.12, these results are in close agreement of Khan *et al.* (2017) who reported a maximum of 1.93 (H') for soil inhabiting Mesostigmata from D.G. Khan. These results reveal that the citrus orchards are rich in predatory fauna of this very important group. The results very clearly indicate that a varying overall mean value mesostigmatid soil mites from all districts during different months with abundance values

**Table 5:** Abundance of mesostigmatid mites from different Districts during different months

| Month | FAISALABAD | | | | LAYYAH | | | | SARGODHA | | | | TOBA TEK SINGH | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | + | S.E. | | Mean | + | S.E. | | Mean | + | S.E. | | Mean | + | S.E. | | Averages |
| January | 2.78 | ± | 0.49 | ef | 14.67 | ± | 2.40 | a | 13.33 | ± | 1.26 | ab | 6.56 | ± | 1.20 | c | 9.33 ± 1.09 A |
| February | 11.33 | ± | 1.44 | b | 15.33 | ± | 2.87 | a | 4.56 | ± | 0.99 | d | 4.44 | ± | 0.47 | cd | 8.92 ± 1.13 BC |
| March | 17.78 | ± | 1.62 | a | 5.33 | ± | 0.94 | cd | 9.67 | ± | 1.32 | c | 16.22 | ± | 2.21 | a | 12.25 ± 1.14 A |
| April | 7.67 | ± | 2.13 | cd | 13.22 | ± | 0.89 | a | 16.11 | ± | 2.23 | a | 14.67 | ± | 1.34 | a | 12.92 ± 0.99 A |
| May | 10.00 | ± | 1.31 | bc | 13.44 | ± | 2.35 | a | 3.00 | ± | 0.65 | de | 3.67 | ± | 0.83 | cd | 7.53 ± 1.01 C |
| June | 15.44 | ± | 1.42 | a | 8.89 | ± | 1.59 | b | 9.78 | ± | 2.25 | c | 11.22 | ± | 1.91 | b | 11.33 ± 0.97 A |
| July | 1.67 | ± | 0.53 | f | 15.56 | ± | 1.42 | a | 10.11 | ± | 1.21 | bc | 6.56 | ± | 0.82 | c | 8.47 ± 0.99 BC |
| August | 9.00 | ± | 0.71 | bc | 7.11 | ± | 0.77 | bc | 3.11 | ± | 0.81 | de | 3.56 | ± | 0.78 | cd | 5.69 ± 0.55 D |
| September | 7.00 | ± | 0.82 | cd | 7.89 | ± | 1.20 | bc | 9.89 | ± | 1.36 | c | 10.44 | ± | 1.04 | b | 8.81 ± 0.59 BC |
| October | 1.22 | ± | 0.64 | f | 7.11 | ± | 0.54 | bc | 5.56 | ± | 0.85 | d | 3.00 | ± | 0.91 | d | 4.22 ± 0.53 D |
| November | 7.00 | ± | 0.37 | cd | 5.22 | ± | 0.46 | cd | 1.00 | ± | 0.33 | e | 3.11 | ± | 0.99 | d | 4.08 ± 0.48 D |
| December | 5.44 | ± | 0.75 | de | 2.22 | ± | 0.49 | d | 4.22 | ± | 0.43 | de | 6.56 | ± | 0.77 | c | 4.61 ± 0.40 D |
| Overall Means | 8.03 | ± | 0.57 | B | 9.67 | ± | 0.60 | B | 7.53 | ± | 0.54 | A | 7.50 | ± | 0.55 | B | |

Means sharing similar letters are non-significant ($P \geq 0.05$); Small letters in each column represent differences between months at each locality while capital letters in the last column represent month wise difference in all localities, capital letters in last row, represent overall difference in each locality

**Table 6:** Richness of mesostigmatid mites from different Districts during different months

| Months | Faisalabad | | | | Layyah | | | | Sargodha | | | | Toba Tek Singh | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | | SE | | Mean | | SE | | Mean | | SE | | Mean | | SE | | Averages |
| January | 2.44 | ± | 0.38 | d | 5.56 | ± | 0.29 | ab | 6.00 | ± | 0.41 | ab | 4.22 | ± | 0.36 | cd | 4.56 ± 0.29 B |
| February | 5.67 | ± | 0.55 | ab | 5.78 | ± | 0.52 | ab | 3.11 | ± | 0.61 | d | 3.33 | ± | 0.33 | def | 4.47 ± 0.32 B |
| March | 6.89 | ± | 0.35 | a | 3.78 | ± | 0.62 | d | 5.00 | ± | 0.33 | bc | 6.00 | ± | 0.50 | ab | 5.42 ± 0.30 A |
| April | 3.78 | ± | 0.70 | c | 6.33 | ± | 0.33 | a | 6.56 | ± | 0.41 | a | 7.11 | ± | 0.42 | a | 5.94 ± 0.32 A |
| May | 5.22 | ± | 0.46 | b | 6.22 | ± | 0.52 | a | 2.33 | ± | 0.53 | d | 3.00 | ± | 0.58 | defg | 4.19 ± 0.37 BC |
| June | 6.67 | ± | 0.44 | a | 4.89 | ± | 0.77 | bcd | 5.11 | ± | 0.79 | bc | 5.00 | ± | 0.78 | bc | 5.42 ± 0.36 A |
| July | 1.22 | ± | 0.32 | de | 5.33 | ± | 0.33 | abc | 4.67 | ± | 0.29 | c | 3.44 | ± | 0.29 | def | 3.67 ± 0.30 CD |
| August | 5.33 | ± | 0.41 | b | 4.56 | ± | 0.38 | bcd | 2.11 | ± | 0.51 | de | 2.78 | ± | 0.60 | efg | 3.69 ± 0.32 CD |
| September | 4.56 | ± | 0.56 | bc | 4.22 | ± | 0.36 | cd | 5.00 | ± | 0.44 | bc | 4.89 | ± | 0.39 | bc | 4.67 ± 0.22 B |
| October | 1.11 | ± | 0.54 | e | 3.89 | ± | 0.39 | d | 3.11 | ± | 0.35 | d | 2.00 | ± | 0.33 | g | 2.53 ± 0.27 E |
| November | 3.89 | ± | 0.20 | c | 3.78 | ± | 0.28 | d | 0.89 | ± | 0.26 | e | 2.22 | ± | 0.60 | fg | 2.69 ± 0.27 E |
| December | 3.89 | ± | 0.39 | c | 2.00 | ± | 0.50 | e | 2.67 | ± | 0.17 | d | 3.78 | ± | 0.40 | cde | 3.08 ± 0.23 DE |
| Overall Means | 4.22 | ± | 1.21 | B | 4.69 | ± | 0.20 | B | 3.88 | ± | 1.72 | A | 3.98 | ± | 1.95 | B | |

Means sharing similar letters are non-significant ($P \geq 0.05$); Small letters in each column represent differences between months at each locality while capital letters in the last column represent month wise difference in all localities, capital letters in last row, represent overall difference in each locality

ranging from 12.92 to 4.08 have been reported during April and November respectively. These results are in line of findings reported by Imen *et al.* (2018). The availability of predatory mites of Mesostigmata is a sign of soil health and results of this study showed that maximum 1.62 individuals per sample during month of September from Faisalabad and minimum 0.00 individuals per sample of mesostigmatid mites from Layyah have been collected during month of July. The studies in different parts of the world have revealed as low as 0.25 individuals per sample mesostigmatid mites (Usher 1971). In comparison with other natural ecosystem, density of Mesostigmata of citrus orchard was low as reported by Hermosilla *et al.* (1977), Curry and Monem (1988), Hulsmann and Wolters (1998). However, some other workers like Koehler (1999); Bedano and Cantú (2003) reported high density of Mesostigmata. Community structure of mesostigmatid soil mites from different districts showed great variations and results are in the line of findings of Khan *et al.* (2017). Similarly, community structure for different months showed great variation and each family showed maximum population during different months and results are in agreement with Imen *et al.* (2018). Reasons for this variation may be due to the soil parameters including organic matter, use of agrochemicals and agronomic practices.

## Conclusion

The soils of citrus orchards of Punjab are rich in mesostigmatid fauna. These mites remain available throughout year and can play an important role in pest management. Further studies are needed on species level to find an appropriate predator against specific pests.

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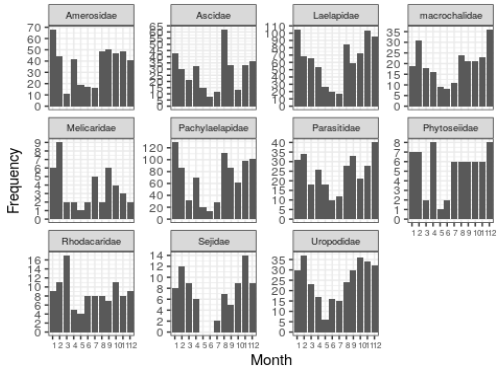


**Fig. 2:** Community Structure of Mesostigmata from Different Districts

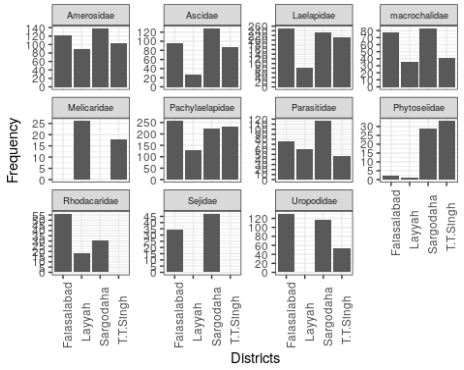


**Fig. 3:** Community Structure of Mesostigmata during different months


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