



Influence of Soil Properties on Soil Oribatid Mites in Different Agroecosystems

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Article Info

P-ISSN: 3051-3448

E-ISSN: 3051-3456

Volume: 07

Issue: 02

Received: 03-08-2026

Accepted: 01-09-2026

Published: 02-10-2026

Page No: 85-98

Abstract

Influence of soil properties indicated that the organic carbon, available nitrogen, zinc, iron, manganese, copper, porosity of soil and soil moisture were significant to highly significant positive relationship, while pH, electrical conductivity and bulk density had a significant to highly significant negative relationship with the soil oribatid mites in different agroecosystems. The highest value of abundance was recorded in banana (2.1272), while lowest value was recorded in fallow land (0.9630). The result of Simpson's index was lowest in banana (0.1385) which makes the greater species diversity (0.8615), while the lowest species diversity was noticed in fallow land (0.4213) and (0.5787). The highest evenness was recorded in fallow land (1.1868) and lowest was noticed in teak (0.5218). Biodiversity park (10 species) showed highest species richness, while lowest species richness was observed in fallow land with two species.

DOI: <https://doi.org/10.54660/JSFR.2026.7.2.85-98>

Keywords: Soil properties, oribatid mite, population, diversity

1. Introduction

The shape, size and spatial distribution of pores control the behaviour of water and air, and provide information on transfer processes and life in the soil (Porta *et al.*, 1999) ^[51]. Soil managements have negative effects on total porosity, quantity, distribution, and continuity of pores and thus causes changes in the flow of air, gases and water inside the pores, affecting the development of soil organisms (Kay and VandenBygaart 2002; Iglesias *et al.*, 2007; Alvarez *et al.*, 2008) ^[1, 33, 39]. Soil is a complex system and provides space for the development of organisms of different sizes (Estrade *et al.*, 2010) ^[21].

Among soil mesofauna, Acari is one of the major microarthropod groups and is often found to constitute the largest fraction of them (Bhattacharya, 1979; Choudhuri and Pande, 1981; Sanyal, 1982) ^[5, 17, 57]. Their importance owing to their high numerical abundance and diversity in the context of edaphic environment is well established (Crossley, 1977; Heneghan *et al.*, 1998) ^[19, 30]. Population of mites in soil varies in relation to environmental factors like temperature, moisture, organic matters, nutrient availability etc. (Choudhuri and Pande, 1981; Sanyal, 1982; Ghatak and Roy, 1991; Tousignant and Coderre, 1992; Rutigliano *et al.*, 2013; Bokhorst *et al.*, 2014) ^[9, 17, 23, 54, 57, 77]. The ecology of soil microarthropods including mites in polluted or ecologically disturbed areas has drawn the attention of many researchers in different parts of the world (Russek and Marshall, 2000; Zaitsev and van Straalen, 2001; Iloba and Ekrakene, 2008; Sarkar *et al.*, 2015; Manu *et al.*, 2017) ^[35, 43, 53, 63, 82]. In India however, a few studies on different groups of soil microarthropods in degraded and polluted areas have been attempted (Hazra *et al.*, 1982; Hazra and Choudhuri, 1990; Bhattacharya and Chakraborti, 1994; Ghosh *et al.*, 2007) ^[6, 24, 27, 28], but specific studies relating edaphic factors and abundance of acarines in degraded or polluted sites is limited when the large variability in their ecology is considered.

Oribatid mites (Cryptostigmata) are, by their number and ecological role, one of the most dominant groups in most of the organic layers of soil where their densities can reach several hundreds of thousand specimens per m² (Borah and Kakati, 2013; Norton,

1990) [10, 48]. These mites can usually be found where there is an accumulation of organic matter under reasonable humidity and temperature ranges. Many oribatid mite species live in natural and altered conditions. Other species have a limited distribution or have a large abundance in places with an anthropogenic impact (Aoki, 1979; Eeva and Penttinen, 2009; Hunter, 2007) [2, 20, 32]. These mites are usually characterized by having a low fecundity and a very low capacity to increase their populations in a short time. Very few species have modifications for dispersion, so they cannot escape from the stress of their environments. This characteristic has made them very important as bioindicators due to the incorporation of information about the habitat and niche history and profiles (Behan-Pelletier, 1999) [3]. The present work was therefore taken up to deal with this aspect

and to add up to the information base necessary for future assessment of the environmental conditions and biomonitoring as well.

2. Erials and Methods

2.1. Study Sites

The study sites were located within the Navsari Agricultural University Campus, South Gujarat (Fig. 1) and different agroecosystems of campus and nearby areas were comprehensively surveyed for the collection of soil mites from different disturbed and undisturbed soil of orchards and supporting vegetables, field crops, greenhouse, forest plants, ornamental and medicinal plants, etc. during the year 2018 and 2019. Following sources (one field for each source) were selected for the collection of soil oribatid mites.

Table 1

(a) Crops (Sugarcane, Rice, Pigeon pea, Lucerne, Castor)	(b) Spices and Medicinal (Turmeric and Aloe vera)
(c) Vegetables (Brinjal / Okra / Tomato)	(d) Green house soil
(e) Fruits (Mango, Coconut and Banana)	(f) Vermicompost bed
(g) Forest (Teak)	(h) Biodiversity park
(i) Organic farm	(j) Fallow land/farm bunds

2.2 Collection, extraction, preservation and mounting of oribatid mites: Soil and litter samples from the various sites were collected from 5 different sites per plots with three different depths (0-5 cm, 5-10 cm, 10-15 cm). Sampled soils were brought to the Acarology laboratory in individually labeled polythene bags (500 gm) tied with rubber band. The process of extraction was carried out in an open brass funnel apparatus (Fig. 2) following the extraction principles of Berlese (1905) [4] and Tullgren (1918) [79]. These samples were properly labeled and kept in plastic vials having alcohol (90 %) with tightly closed caps for further studies.

2.3. Analysis of Diversity

Diversity generally consists of two basic components - the number of species and their relative abundances. More than one approach appears necessary to get a better insight of the communities as there is no unanimous view as to which diversity index may satisfy all aspects sought to assess an ecological condition (Magurran, 1988) [42]. Following indices were worked out in the present study

Shannon Index of Diversity (Shannon and Weaver, 1963):

The equation of Shannon-Weaver index is given below –

$$H = - \sum p_i \ln p_i$$

Where p_i is the ratio of individual species abundance and total number of individuals of all species.

As a heterogeneity measure, Shannon's index also includes the aspect of evenness of the species (Peet, 1974) [50]. The value of Shannon diversity index usually ranges from 1.5 and 3.5 and rarely crosses 4.5 (Margalef, 1972) [44].

Dominance (Simpson, 1949)

Dominance measurement also provides information on diversity in a community, it however, emphasizes the

dominance of most abundant species rather than the variety of species. The equation for the index is as follows:

$$D = \sum p_i^2$$

Where p_i is the ratio of individual species abundance and total number of individuals of all species.

This index ascribes high weightage on the most abundant species and is less sensitive to the number of species. As a diversity measure the index usually is expressed as $1/D$.

Evenness

Evenness index has been used in the present work which is as follows:

$$E = 1/D = \frac{1}{D} / S$$

Richness

Richness index was used in the present study. The equation is given below:

Where, S = Number of species

Species richness is a measure of the number of different kinds of species present in a particular area. One would presume that more species equals more diversity.

The per cent proportion of different oribatid mite species was determined and percentage of each species was calculated. This analysis was made to determine the most abundant oribatid mite species in the region.

In the present the properties including and particle and bulk density of soil, soil moisture, soil temperature, organic carbon, pH, EC and available nitrogen, available phosphorus, potassium, Sulphur and micronutrient etc. The impact of soil properties on oribatid mite abundance, distribution and diversity were worked out by using Shannon diversity index (Shannon, 1948) [68]. The correlation between various oribatid mite species and the soil properties were also worked out by using a simple correlation coefficient (r).

Soil Moisture

10 gm of collected soil sample was kept in a hot air oven at 105°C for a few hours depending upon the moisture content of the soil. The soil was then cooled in desiccators and weighed. This method of heating and cooling of the sample was repeated until the constant weight obtained. The moisture content was expressed in percentage in the following way

$$R = S$$

$$\text{Soil moisture (\%)} = \{(\text{Initial weight} - \text{Dry weight}) / (\text{Dry weight})\} \times 100$$

Table 2: Methods used for the determination of soil properties

Properties	Method adopted	Reference
Sand, Silt and Clay	Hydrometer method	Bouyoucos (1962) [11]
pH (1:2.5::soil:water)	Potentiometric	Jackson (1979) [36]
EC (1:2.5::soil:water)	Conductometric	Jackson (1979) [36]
Organic carbon	Walkley and Black rapid titration method	Jackson (1979) [36]
Available - N	0.32% Alkaline Potassium permanganate method	Subbiah and Asija (1956) [76]
Available - P ₂ O ₅	0.5 M NaHCO ₃ (pH 8.5)	Olsen <i>et al.</i> (1954) [49]
Available - K ₂ O	Flame photometric (Extraction with 1 N NH ₄ OAc)	Jackson (1979) [36]
Available - S	Turbidometric (extraction with 0.15% CaCl ₂)	Chopra and Kanwar (1980) [15]
DTPA Extractable Fe, Mn, Zn and Cu	0.05 M DTPA and estimated on AAS spectrophotometer	Lindsay and Norvell (1978) [40]

3. Results and Discussion

3.1. Relationship Between Oribatid Mites and Soil Properties

To study the relationship between different soil properties and oribatid mites, they were subjected to the statistical analysis separately for each agroecosystem to find out the correlation. The dependence of the mean number of oribatid and different oribatid species (Y) on each of the sixteen variables (organic carbon, pH, electrical conductivity, available nitrogen, phosphorus, potassium, sulphur, zinc, iron, manganese, copper, bulk density, particle density, porosity of soil, soil moisture and soil temperature) (X) considered herewith. It was verified by means of statistical test whether the relationships between the number of oribatids and different oribatid species (Y) and different variables (X) remain the same throughout the experimental period or not. The results were presented in Tables 2 revealed more or less identical relationships in the two sampling years in respect, to each agroecosystem.

3.2. Relationship Between Mean Population of Oribatid and Soil Properties

3.2.1 Sugarcane

During the year 2018, the results showed highly significant positive relationship between oribatid (mean population) with organic carbon ($r = 0.982$), available nitrogen ($r = 0.911$), available zinc ($r = 0.852$), available iron ($r = 0.928$), available manganese ($r = 0.832$), available copper ($r = 0.914$), soil porosity ($r = 0.799$) but highly significant negative relationship with pH ($r = -0.867$), electrical conductivity ($r = -0.927$) and bulk density of soil ($r = -0.799$) while, soil moisture ($r = 0.627$) showed significant positive relationship. In the year (2019), there was highly significant positive correlation between oribatid (mean population) and organic carbon ($r = 0.974$), available nitrogen ($r = 0.928$), available zinc ($r = 0.987$), available iron ($r = 0.957$), available manganese ($r = 0.955$), available copper ($r = 0.903$), soil porosity ($r = 0.932$) and soil moisture ($r = 0.731$), but highly significant negative relationship with pH ($r = -0.817$), electrical conductivity ($r = -0.957$) and bulk density of soil ($r = -0.937$).

The moisture content calculated as above included the moisture obtained from both hygroscopic water and some from capillary water.

Soil temperature was recorded at the sites during the collection of samples using a soil thermometer. The collected soil samples from the five plots of each collection were analyzed at Central Instrumentation Laboratory, Department of Soil Science and Agricultural Chemistry, N.M. College of Agriculture, Navsari Agricultural University, Navsari as per Table 2.

Available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with the mean number of oribatid in both years of investigation (Table 2) (Table 3).

3.2.2 Rice

Organic carbon ($r = 0.784$), available zinc ($r = 0.949$), available iron ($r = 0.932$), available manganese ($r = 0.960$) and available copper ($r = 0.968$) showed highly significant positive correlation, while available nitrogen ($r = 0.699$), soil porosity ($r = 0.666$) and soil moisture ($r = 0.670$) had significant positive relationship, but pH ($r = -0.968$) and electrical conductivity ($r = -0.810$) had highly significant negative relationship with oribatid mean in the year 2018. Moreover, the bulk density of soil ($r = -0.675$) had significant negative relationship with mean population of oribatid (mean population) in the year 2018. During the year 2019, organic carbon ($r = 0.934$), available zinc ($r = 0.940$), available iron ($r = 0.907$), available manganese ($r = 0.966$), available copper ($r = 0.932$), available nitrogen ($r = 0.887$) and soil porosity ($r = 0.879$) showed highly significant positive correlation, while the soil moisture ($r = 0.620$) had significant positive relationship, but pH ($r = -0.959$), electrical conductivity ($r = -0.880$) and bulk density of soil ($r = -0.884$) showed highly significant negative relationship with oribatid mean population. The available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with oribatid mean numbers (Table 2) (Table 3).

3.2.3. Pigeon Pea

The result indicated highly significant positive correlation between oribatid (mean population) with organic carbon ($r = 0.947$), available nitrogen ($r = 0.934$), available zinc ($r = 0.953$), available iron ($r = 0.951$), available manganese ($r = 0.974$), available copper ($r = 0.987$), porosity ($r = 0.897$) and soil moisture ($r = 0.753$), but had highly significant negative relationship with pH ($r = -0.964$), electrical conductivity ($r = -0.954$) and bulk density of soil ($r = -0.940$) during 2018. There was highly significant positive correlation of oribatid's

mean population with organic carbon ($r = 0.888$), available nitrogen ($r = 0.895$), available zinc ($r = 0.959$), available iron ($r = 0.981$), available manganese ($r = 0.952$), available copper ($r = 0.987$) and soil moisture ($r = 0.780$) whereas the soil porosity ($r = 0.633$) showed significant positive relationship, but highly significant negative relationship with pH ($r = -0.950$) and electrical conductivity ($r = -0.888$). Moreover, the bulk density ($r = -0.672$) of soil showed significant negative relationship with oribatid (mean population) in the year 2019. Further, available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with the mean number of oribatid (Table 2) (Table 3).

3.2.4. Lucerne

The result (2018) indicated highly significant positive correlation between oribatid mean population and organic carbon ($r = 0.816$), available nitrogen ($r = 0.896$), available zinc ($r = 0.888$), available iron ($r = 0.894$), available copper ($r = 0.959$) and soil moisture ($r = 0.731$), but highly significant negative relationship with pH ($r = -0.857$) and electrical conductivity ($r = -0.967$). Further, the available manganese ($r = 0.617$) and soil porosity ($r = 0.624$) had significant positive correlation with mean number of oribatid. Bulk density showed significant negative correlation ($r = -0.606$) with oribatid's mean number. In the year 2019, the result highly significant positive correlation between oribatid mean and organic carbon ($r = 0.950$), available nitrogen ($r = 0.904$), available zinc ($r = 0.970$), available iron ($r = 0.963$), available copper ($r = 0.967$), available manganese ($r = 0.940$) and soil moisture ($r = 0.788$), but highly significant negative relationship with pH ($r = -0.964$) and electrical conductivity ($r = -0.925$). The bulk density of soil showed significant negative correlation ($r = -0.647$) while, soil porosity had significant positive ($r = 0.625$) relationship with oribatid (mean number) in the year 2019. Moreover, available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with the mean number of oribatid during the present investigation (Table 2) (Table 3).

3.2.5. Castor

Organic carbon ($r = 0.909$), available nitrogen ($r = 0.937$), available zinc ($r = 0.921$), available iron ($r = 0.907$), available manganese ($r = 0.951$), available copper ($r = 0.949$), soil porosity ($r = 0.728$) and soil moisture ($r = 0.781$) showed highly significant positive correlation, while pH ($r = -0.970$) and electrical conductivity ($r = -0.959$) showed highly significant negative relationship with oribatid mean in the year 2018. Moreover, the bulk density of soil ($r = -0.656$) had significant negative relationship with oribatid mean numbers. During the year 2019, organic carbon ($r = 0.830$), available nitrogen ($r = 0.890$), available zinc ($r = 0.901$), available iron ($r = 0.956$), available manganese ($r = 0.919$), available copper ($r = 0.968$) and soil moisture ($r = 0.781$) showed highly significant positive correlation, while pH ($r = -0.944$) and electrical conductivity ($r = -0.935$) had highly significant negative relationship with oribatid's mean population. Further, the bulk density of soil ($r = -0.671$) had significant negative relationship and soil porosity ($r = 0.700$) showed significant positive relationship with mean number of oribatid. Available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature

showed non-significant correlation with oribatid mean numbers in both years. (Table 2) (Table 3).

3.2.6. Okra

During the year 2018, organic carbon ($r = 0.986$), available nitrogen ($r = 0.877$), available zinc ($r = 0.865$), available iron ($r = 0.954$), available manganese ($r = 0.974$) and available copper ($r = 0.966$) showed highly significant positive correlation, while soil porosity ($r = 0.676$) and soil moisture ($r = 0.682$) had significant positive correlation, but pH ($r = -0.928$) and electrical conductivity ($r = -0.973$) had highly significant negative relationship with oribatid (mean population). Further, the bulk density of soil ($r = -0.590$) had significant negative relationship with oribatid (mean numbers) in the year 2018. Moreover, during the year 2019, organic carbon ($r = 0.903$), available nitrogen ($r = 0.901$), available zinc ($r = 0.870$), available iron ($r = 0.946$), available manganese ($r = 0.934$) and available copper ($r = 0.915$) showed highly significant positive correlation, while soil porosity ($r = 0.647$) and soil moisture ($r = 0.619$) had significant positive correlation, but pH ($r = -0.913$) and electrical conductivity ($r = -0.933$) had highly significant negative relationship with oribatid mean population. Moreover, the bulk density of soil ($r = -0.663$) had significant negative relationship with oribatid mean numbers. The available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with oribatid mean population during the present investigation (Table 2) (Table 3).

3.2.7. Mango

In the year 2018, the results showed highly significant positive correlation exist between oribatid mean and organic carbon ($r = 0.964$), available nitrogen ($r = 0.973$), available zinc ($r = 0.959$), available iron ($r = 0.883$), available manganese ($r = 0.968$), available copper ($r = 0.916$) and soil porosity ($r = 0.895$) while, soil moisture ($r = 0.647$) had significant positive correlation, but highly significant negative relationship with pH ($r = -0.946$), electrical conductivity ($r = -0.899$) and bulk density of soil ($r = -0.875$). In the year 2019, the finding indicated highly significant positive correlation between oribatid (mean population) and available nitrogen ($r = 0.957$), available zinc ($r = 0.968$), available iron ($r = 0.896$), available manganese ($r = 0.986$), available copper ($r = 0.903$) and soil porosity ($r = 0.798$) while, soil moisture ($r = 0.645$) and organic carbon ($r = 0.681$) had significant positive correlation, but highly significant negative relationship with pH ($r = -0.869$), electrical conductivity ($r = -0.734$) and bulk density of soil ($r = -0.859$). The available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with the mean number of oribatid in both years (Table 2) (Table 3).

3.2.8. Coconut

Organic carbon ($r = 0.926$), available nitrogen ($r = 0.920$), available zinc ($r = 0.860$), available iron ($r = 0.871$), available manganese ($r = 0.977$), available copper ($r = 0.867$) and soil porosity ($r = 0.834$) showed highly significant positive correlation, but highly significant negative relationship with pH ($r = -0.804$), electrical conductivity ($r = -0.916$) and bulk density of soil ($r = -0.818$) while, soil moisture showed significant positive ($r = 0.662$) relationship with oribatid

mean numbers in the year 2018. During the year 2019, the organic carbon ($r = 0.902$), available nitrogen ($r = 0.894$), available zinc ($r = 0.935$), available iron ($r = 0.935$), available manganese ($r = 0.977$), available copper ($r = 0.738$) and soil porosity ($r = 0.869$) showed highly significant positive correlation, but highly significant negative relationship with pH ($r = -0.825$), electrical conductivity ($r = -0.899$) and bulk density of soil ($r = -0.800$) while, soil moisture showed significant positive ($r = 0.684$) relationship with oribatid mean numbers. The available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with the mean number of oribatid during the present investigation (Table 2) (Table 3).

3.2.9. Banana

During the year 2018, the results indicated significant positive correlation between oribatid (mean population) with organic carbon ($r = 0.591$) and soil moisture ($r = 0.620$) while, available nitrogen ($r = 0.943$), available iron ($r = 0.933$), available manganese ($r = 0.956$), available copper ($r = 0.861$), available zinc ($r = 0.886$) and soil porosity ($r = 0.804$) showed highly significant positive, but highly significant negative relationship with pH ($r = -0.922$), electrical conductivity ($r = -0.917$) and bulk density of soil ($r = -0.791$). In the year 2019, the finding showed significant positive correlation between oribatid mean and organic carbon ($r = 0.666$), available zinc ($r = 0.625$) and soil moisture ($r = 0.616$) while, available nitrogen ($r = 0.879$), available iron ($r = 0.912$), available manganese ($r = 0.931$), available copper ($r = 0.739$), soil porosity ($r = 0.808$) showed highly significant positive relationship, but highly significant negative relationship with pH ($r = -0.930$), electrical conductivity ($r = -0.799$) and bulk density of soil ($r = -0.802$). The available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with the mean number of oribatid during the present study (Table 3) (Table 4).

3.2.10. Teak

Organic carbon ($r = 0.829$), available nitrogen ($r = 0.966$), available zinc ($r = 0.953$), available iron ($r = 0.903$) and available manganese ($r = 0.912$) showed highly significant positive relationship, while soil moisture ($r = 0.662$), available copper ($r = 0.658$) and soil porosity ($r = 0.624$) had significant positive relationship, but it had highly significant negative relationship with electrical conductivity ($r = -0.894$) and bulk density of soil ($r = -0.709$) in the year 2018. Further, pH showed significant negative ($r = -0.664$) relationship with mean number of oribatid during the year 2018. In the year 2019, organic carbon ($r = 0.885$), available nitrogen ($r = 0.920$), available zinc ($r = 0.893$), available iron ($r = 0.899$), available copper ($r = 0.862$), available manganese ($r = 0.884$) and soil porosity ($r = 0.777$) showed highly significant positive correlation, while soil moisture had significant positive relationship ($r = 0.694$), but it had highly significant negative relationship with pH ($r = -0.800$), electrical conductivity ($r = -0.927$) and bulk density of soil ($r = -0.795$). Available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with the mean number of oribatid during the present study (Table 2) (Table 3).

3.2.11. Organic Farm

During the year 2018, the results showed highly significant positive correlation between oribatid mean and organic carbon ($r = 0.925$), available nitrogen ($r = 0.870$), available zinc ($r = 0.868$), available manganese ($r = 0.875$), available copper ($r = 0.856$) and soil porosity ($r = 0.723$) while, available iron ($r = 0.580$) and soil moisture ($r = 0.669$) showed significant positive relationship with oribatid mean, but highly significant negative relationship with pH ($r = -0.853$), electrical conductivity ($r = -0.929$) and bulk density of soil ($r = -0.768$). In the year 2019, the data indicated highly significant positive correlation of oribatid (mean population) with organic carbon ($r = 0.891$), available nitrogen ($r = 0.909$), available zinc ($r = 0.771$), available manganese ($r = 0.945$), available copper ($r = 0.936$), available iron ($r = 0.945$) and soil moisture ($r = 0.743$) while, soil porosity ($r = 0.597$) showed significant positive relationship, but highly significant negative with pH ($r = -0.871$) and electrical conductivity ($r = -0.908$). The bulk density of soil ($r = -0.641$) indicated significant negative relationship with oribatid (mean population) in the year 2019. Available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with the mean number of oribatid in both years of investigation (Table 2) (Table 3).

3.2.12. Turmeric

Organic carbon ($r = 0.758$), available zinc ($r = 0.952$), available iron ($r = 0.922$), available manganese ($r = 0.855$), available copper ($r = 0.960$), soil porosity ($r = 0.863$) and soil moisture ($r = 0.720$) showed highly significant positive correlation, while available nitrogen ($r = 0.626$) indicated significant positive relationship with oribatid mean, but highly significant negative relationship with pH ($r = -0.916$), electrical conductivity ($r = -0.921$) and bulk density of soil ($r = -0.946$) in the year 2018. In the year 2019, available nitrogen ($r = 0.858$), available zinc ($r = 0.907$), available iron ($r = 0.907$), available manganese ($r = 0.899$), available copper ($r = 0.922$) showed highly significant positive relationship with mean number of oribatid while, organic carbon ($r = 0.608$), soil porosity ($r = 0.704$) and soil moisture ($r = 0.678$) had significant positive correlation whereas it had highly significant negative relationship with pH ($r = -0.870$), electrical conductivity ($r = -0.911$) and bulk density of soil ($r = -0.810$). Further, available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with the mean number of oribatid during the present study (Table 2) (Table 3).

3.2.13. Aloe Vera

Organic carbon ($r = 0.925$), available nitrogen ($r = 0.940$), available zinc ($r = 0.953$), available iron ($r = 0.910$), available manganese ($r = 0.996$), available copper ($r = 0.954$), soil porosity ($r = 0.717$) and soil moisture ($r = 0.764$) showed highly significant positive correlation, while pH ($r = -0.862$), electrical conductivity ($r = -0.884$) and bulk density of soil ($r = -0.723$) had highly significant negative relationship with oribatid mean in the year 2018. In the year 2019, organic carbon ($r = 0.952$), available nitrogen ($r = 0.943$), available zinc ($r = 0.938$), available iron ($r = 0.949$), available manganese ($r = 0.981$), available copper ($r = 0.981$) and soil

moisture ($r = 0.726$) showed highly significant positive correlation, while pH ($r = -0.822$) and electrical conductivity ($r = -0.814$) had highly significant negative with oribatid mean numbers. Further, the soil porosity showed significant positive ($r = 0.661$), but bulk density of soil ($r = -0.632$) indicated significant negative relationship with mean number of oribatid in the year 2019. Available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with oribatid mean numbers during both years of study (Table 2) (Table 3).

3.2.14. Greenhouse Soil

In the year 2018, organic carbon ($r = 0.952$), available nitrogen ($r = 0.945$), available zinc ($r = 0.887$), available iron ($r = 0.956$), available manganese ($r = 0.925$), available copper ($r = 0.972$) and soil porosity ($r = 0.768$) showed highly significant positive correlation, while pH ($r = -0.874$), electrical conductivity ($r = -0.858$) and bulk density of soil ($r = -0.764$) had highly significant negative relationship with oribatid (mean population). Further, soil moisture had significant positive ($r = 0.694$) relationship with mean number of oribatid in the year 2018. In the year 2019, organic carbon ($r = 0.943$), available nitrogen ($r = 0.975$), available zinc ($r = 0.973$), available iron ($r = 0.973$), available manganese ($r = 0.954$), available copper ($r = 0.927$), soil porosity ($r = 0.952$) and soil moisture ($r = 0.715$) showed highly significant positive correlation, while pH ($r = -0.884$), electrical conductivity ($r = -0.881$) and bulk density of soil ($r = -0.971$) had highly significant negative relationship with oribatid mean. Moreover, available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with oribatid (mean population) during the present study (Table 2) (Table 3).

3.2.15. Vermicompost Bed

During the year 2018, organic carbon ($r = 0.945$), available nitrogen ($r = 0.953$), available zinc ($r = 0.974$), available iron ($r = 0.949$), available manganese ($r = 0.900$), available copper ($r = 0.955$), soil porosity ($r = 0.708$) and soil moisture ($r = 0.737$) showed highly significant positive correlation, while pH ($r = -0.838$), electrical conductivity ($r = -0.884$) and bulk density of soil ($r = -0.825$) had highly significant negative relationship with mean number of oribatid. In the year 2019, organic carbon ($r = 0.961$), available nitrogen ($r = 0.909$), available zinc ($r = 0.939$), available iron ($r = 0.914$), available manganese ($r = 0.854$), available copper ($r = 0.947$), soil porosity ($r = 0.814$) and soil moisture ($r = 0.726$) showed highly significant positive correlation, while pH ($r = -0.756$), electrical conductivity ($r = -0.834$) and bulk density of soil ($r = -0.872$) had highly significant negative relationship with mean number of oribatid. Available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with oribatid

(mean population) during the investigation (Table 2) (Table 3).

3.2.16. Biodiversity Park

In the year 2018, the results showed highly significant positive correlation between oribatid (mean numbers) and organic carbon ($r = 0.710$), available zinc ($r = 0.933$), available iron ($r = 0.976$), available manganese ($r = 0.877$), available copper ($r = 0.959$) and soil porosity ($r = 0.777$) while, available nitrogen ($r = 0.658$) and soil moisture ($r = 0.588$) had significant positive relationship with oribatid mean values whereas it had highly significant negative relationship with pH ($r = -0.832$), electrical conductivity ($r = -0.943$) and bulk density of soil ($r = -0.750$). In the year 2019, the result indicated highly significant positive correlation between oribatid (mean numbers) and organic carbon ($r = 0.910$), available zinc ($r = 0.961$), available iron ($r = 0.965$), available manganese ($r = 0.894$), available copper ($r = 0.935$) and soil porosity ($r = 0.746$) while, available nitrogen ($r = 0.621$) and soil moisture ($r = 0.577$) showed significant positive relationship, but it had highly significant negative relationship with pH ($r = -0.911$) and electrical conductivity ($r = -0.883$). Further, bulk density of soil showed significant negative ($r = -0.692$) relationship with mean number of oribatid in the year 2019. Available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with the mean number of oribatid in both years of investigation (Table 2) (Table 3).

3.2.17. Fallow Land

Organic carbon ($r = 0.741$), available nitrogen ($r = 0.863$), available zinc ($r = 0.787$), available iron ($r = 0.881$), available manganese ($r = 0.840$) showed highly significant positive correlation, while available copper ($r = 0.691$), soil porosity ($r = 0.589$) and soil moisture ($r = 0.578$) showed significant positive correlation, but electrical conductivity ($r = -0.701$) and bulk density of soil ($r = -0.663$) significant negative with oribatid (mean population) in the year 2018. Further, pH ($r = -0.865$) showed highly significant negative relationship with mean number of oribatid in the year 2018. In the year 2019, available nitrogen ($r = 0.837$), available zinc ($r = 0.946$), available iron ($r = 0.919$), available manganese ($r = 0.878$) and available copper ($r = 0.768$) showed highly significant positive correlation, while organic carbon ($r = 0.576$), soil porosity ($r = 0.646$) and soil moisture ($r = 0.643$) showed significant positive correlation, but pH ($r = -0.688$) and bulk density of soil ($r = -0.651$) had significant negative relationship with oribatid's mean population. Further, electrical conductivity ($r = -0.813$) showed highly significant negative relationship with mean number of oribatid in the year 2019. Moreover, available phosphorus, available potassium, available sulphur, particle density of soil and soil temperature showed non-significant correlation with oribatid mean numbers during the study (Table 2) (Table 3).

Table 3: Oribatid mean population and mean value of soil properties in different agroecosystems (January, 2018 – December, 2019)

Cultivated crops	Oribatid mite	OC	pH	EC	N	P ₂ O ₅	K ₂ O	S	Zn	Fe	Mn	Cu	Bulk density	Particle density	Porosity	Soil moisture	Soil Temperature
	Mean	%		dS m ⁻¹	Kg ha ⁻¹			mg kg ⁻¹					mg m ⁻³		%	%	°C
Sugarcane	14.21	0.80	7.89	0.52	277.8	61.04	425.3	15.57	0.30	6.33	6.22	0.20	1.52	2.65	42.64	23.10	35.68
Rice	10.88	0.75	5.89	0.52	254.7	41.09	143.0	16.93	0.63	20.53	19.39	0.14	1.62	2.65	39.00	23.64	33.93
Pigeon pea	17.75	0.79	7.33	0.35	494.2	50.93	322.8	22.06	0.35	7.19	7.07	0.15	1.58	2.65	40.51	22.38	40.34
Lucerne	15.79	0.79	7.37	0.35	494.2	50.74	322.8	22.18	0.35	7.21	7.09	0.15	1.57	2.65	40.80	22.51	38.74
Castor	18.46	0.79	7.32	0.35	493.8	50.77	322.9	22.16	0.36	7.20	7.06	0.15	1.57	2.65	40.62	23.91	35.90
Okra	8.75	0.54	7.48	0.35	211.5	46.12	255.2	15.70	0.29	4.14	4.99	0.12	1.70	2.65	35.85	22.35	32.84
Mango	21.46	0.95	7.78	0.28	315.42	55.47	322.58	22.10	0.46	9.68	5.72	0.23	1.45	2.65	45.01	24.85	30.46
Coconut	20.29	0.97	7.34	0.37	334.63	57.07	372.00	19.40	0.49	6.66	8.34	0.29	1.49	2.65	43.92	24.19	31.91
Banana	24.00	0.75	7.60	0.48	256.25	45.66	353.50	23.47	0.40	6.74	6.95	0.17	1.59	2.65	40.08	24.27	35.45
Teak	19.08	0.95	7.97	0.35	284.50	53.46	343.33	23.22	0.44	4.76	4.94	0.26	1.46	2.65	44.69	23.84	28.40
Organic farm	22.58	0.97	7.36	0.38	335.50	57.20	372.58	19.46	0.31	6.30	6.14	0.20	1.51	2.65	42.80	23.83	37.75
Turmeric	17.83	0.79	7.32	0.36	493.71	51.01	323.46	22.04	0.36	7.17	7.19	0.15	1.58	2.65	40.49	22.25	34.57
Aloe vera	17.63	0.97	7.39	0.39	337.33	57.23	373.00	19.50	0.51	6.73	8.40	0.17	1.49	2.65	43.51	22.27	35.56
Greenhouse soil	9.33	0.46	7.72	0.43	254.13	42.12	297.13	15.22	0.22	5.90	7.14	0.16	1.71	2.65	35.47	24.24	34.52
Vermicompost bed	19.46	28.33	7.45	0.75	1.97	2.30	1.56	357.75	47.00	8670.83	24.25	92.04	0.49	1.50	67.33	23.90	32.38
Biodiversity park	24.96	0.99	7.80	0.37	239.67	33.82	310.33	17.22	0.35	5.27	6.32	0.13	1.54	2.65	41.91	24.87	32.05
Fallow land	7.79	0.98	7.71	0.35	237.6	33.57	305.6	17.15	0.35	5.53	6.39	0.12	1.53	2.65	42.06	25.42	32.88

Table 4: Relationship between oribatid population and soil properties from different agroecosystems of NAU Campus (Year 2018 - 2019)

Soil properties	Sugar cane	Rice	Pigeon pea	Lucerne	Castor	Okra	Mango	Coconut	Banana	Teak	Organic farm	Turmeric	Aloe vera	Green-house soil	Vermi-compost bed	Bio-diversity park	Fallow land
January 2018 – December 2018																	
Organic carbon	0.982* *	0.784* *	0.947* *	0.816* *	0.909* *	0.986* *	0.964* *	0.926**	0.591*	0.829** *	0.925**	0.758**	0.925** *	0.952**	0.945**	0.710**	0.741* *
pH	0.867* *	0.968* *	0.964* *	0.857* *	0.970* *	0.928* *	0.946* *	-0.804**	- 0.922**	0.664* *	-0.853**	-0.916**	0.862** *	- 0.874**	-0.838**	-0.832**	0.865* *
EC	0.927* *	0.810* *	0.954* *	0.967* *	0.959* *	0.973* *	0.899* *	-0.916**	- 0.917**	0.894** *	-0.929**	-0.921**	0.884** *	- 0.858**	-0.884**	-0.943**	- 0.701*
Nitrogen	0.911* *	0.699*	0.934* *	0.896* *	0.937* *	0.877* *	0.973* *	0.920**	0.943**	0.966** *	0.870**	0.626*	0.940** *	0.945**	0.953**	0.658*	0.863* *
Phosphorus	0.436 NS	0.193 NS	0.086 NS	0.257 NS	0.216 NS	0.210 NS	0.483 NS	-0.056 NS	0.211 NS	- 0.552 NS	0.212 NS	0.546 NS	0.385 NS	0.093 NS	0.231 NS	0.362 NS	0.037 NS
Potassium	0.136 NS	0.381 NS	0.239 NS	0.171 NS	0.365 NS	0.346 NS	0.078 NS	0.038 NS	- 0.035 NS	0.452 NS	0.230 NS	0.512 NS	- 0.008 NS	0.527 NS	0.285 NS	- 0.038 NS	- 0.434 NS
Sulphur	0.025 NS	0.129 NS	0.139 NS	0.281 NS	0.132 NS	0.390 NS	0.569 NS	0.079 NS	- 0.001 NS	0.520 NS	0.067 NS	0.052 NS	0.190 NS	0.264 NS	0.264 NS	0.172 NS	0.064 NS
Zinc	0.852* *	0.949* *	0.953* *	0.888* *	0.921* *	0.865* *	0.959* *	0.860**	0.886**	0.953** *	0.868**	0.952**	0.953** *	0.887**	0.974**	0.933**	0.787* *
Iron	0.928* *	0.932* *	0.951* *	0.894* *	0.907* *	0.954* *	0.883* *	0.871**	0.933**	0.903** *	0.580*	0.922**	0.910** *	0.956**	0.949**	0.976**	0.881* *
Manganese	0.832* *	0.960* *	0.974* *	0.617*	0.951* *	0.974* *	0.968* *	0.977**	0.956**	0.912** *	0.875**	0.855**	0.996** *	0.925**	0.900**	0.877**	0.840* *
Copper	0.914* *	0.968* *	0.987* *	0.959* *	0.949* *	0.966* *	0.916* *	0.867**	0.861**	0.658* *	0.856**	0.960**	0.954** *	0.972**	0.955**	0.959**	0.691*
Bulk density	0.799* *	0.675*	0.940* *	-0.606*	- 0.656*	- 0.590*	0.875* *	-0.818**	- 0.791**	0.709** *	-0.768**	-0.946**	0.723** *	- 0.764**	-0.825**	-0.750**	- 0.663*
Particle density	0.092 NS	0.111 NS	0.012 NS	0.358 NS	0.437 NS	0.124 NS	0.182 NS	0.345 NS	0.177 NS	0.231 NS	0.078 NS	0.066 NS	0.129 NS	0.084 NS	-0.040 NS	0.410 NS	0.024 NS
Porosity	0.799* *	0.666*	0.897* *	0.624*	0.728* *	0.676*	0.895* *	0.834**	0.804**	0.624* *	0.723**	0.863**	0.717** *	0.768**	0.708**	0.777**	0.589*
Soil moisture	0.627* *	0.670*	0.753* *	0.731* *	0.781* *	0.682*	0.647*	0.662*	0.620*	0.662* *	0.669*	0.720**	0.764** *	0.694*	0.737**	0.588*	0.578*

Soil temperature	-0.272 NS	-0.292 S	-0.276 S	-0.204 S	-0.224 S	-0.247 S	-0.286 S	-0.290 NS	-0.170 S	-0.300 NS	-0.065 NS	-0.258 NS	-0.255 NS	-0.285 S	-0.271 NS	-0.265 NS	-0.298 NS
January 2019 – December 2019																	
Organic carbon	0.974* *	0.934* *	0.888* *	0.950* *	0.830* *	0.903* *	0.681* *	0.902** *	0.666* *	0.885** **	0.891** **	0.608* *	0.952** **	0.943** **	0.961** **	0.910** **	0.576* *
pH	0.817* *	0.959* *	0.950* *	0.964* *	0.944* *	0.913* *	0.869* *	-0.825** **	0.930** **	0.800** **	-0.871** **	-0.870** **	0.822** **	0.884** **	-0.756** **	-0.911** **	0.688* *
EC	0.957* *	0.880* *	0.888* *	0.925* *	0.935* *	0.933* *	0.734* *	-0.899** **	0.799** **	0.927** **	-0.908** **	-0.911** **	0.814** **	0.881** **	-0.834** **	-0.883** **	0.813* *
Nitrogen	0.928* *	0.887* *	0.895* *	0.904* *	0.890* *	0.901* *	0.957* *	0.894** **	0.879** **	0.920** **	0.909** **	0.858** **	0.943** **	0.975** **	0.909** **	0.621* *	0.837* *
Phosphorus	0.077 NS	0.009 S	0.512 S	0.383 S	0.308 S	0.535 S	0.376 S	0.144 NS	0.014 S	0.194 NS	0.175 NS	0.097 NS	0.111 NS	0.132 S	0.498 NS	0.047 NS	0.359 NS
Potassium	0.046 NS	0.050 S	0.552 S	0.388 S	0.558 S	0.285 S	0.369 S	-0.362 NS	0.072 S	0.031 NS	0.073 NS	0.308 NS	-0.027 NS	0.193 S	0.380 NS	0.191 NS	0.118 NS
Sulphur	0.201 NS	0.159 S	0.302 S	0.081 S	0.193 S	0.170 S	0.510 S	-0.291 NS	0.060 S	0.201 NS	0.147 NS	-0.405 NS	0.123 NS	0.064 S	0.419 NS	0.260 NS	0.078 NS
Zinc	0.987* *	0.940* *	0.959* *	0.970* *	0.901* *	0.870* *	0.968* *	0.935** **	0.625* *	0.893** **	0.771** **	0.907** **	0.938** **	0.973** **	0.939** **	0.961** **	0.946* *
Iron	0.957* *	0.907* *	0.981* *	0.963* *	0.956* *	0.946* *	0.896* *	0.935** **	0.912** **	0.899** **	0.945** **	0.907** **	0.949** **	0.973** **	0.914** **	0.965** **	0.919* *
Manganese	0.955* *	0.966* *	0.952* *	0.940* *	0.919* *	0.934* *	0.986* *	0.977** **	0.931** **	0.884** **	0.945** **	0.899** **	0.981** **	0.954** **	0.854** **	0.894** **	0.878* *
Copper	0.903* *	0.932* *	0.987* *	0.967* *	0.968* *	0.915* *	0.903* *	0.738** **	0.739** **	0.862** **	0.936** **	0.922** **	0.981** **	0.927** **	0.947** **	0.935** **	0.768* *
Bulk density	0.937* *	0.884* *	0.672* *	-0.647* *	0.671* *	0.663* *	0.859* *	-0.800** **	0.802** **	0.795** **	-0.641* *	-0.810** **	0.632* *	0.971** **	-0.872** **	-0.692* *	0.651* *
Particle density	0.202 NS	0.417 S	0.091 S	0.059 S	0.048 S	0.244 S	0.126 S	0.557 NS	0.465 S	0.296 NS	-0.340 NS	-0.011 NS	0.307 NS	0.052 S	-0.391 NS	0.061 NS	0.165 NS
Porosity	0.932* *	0.879* *	0.633* *	0.625* *	0.700* *	0.647* *	0.798* *	0.869** **	0.808** **	0.777** **	0.597* *	0.704* *	0.661* *	0.952** **	0.814** **	0.746** **	0.646* *
Soil moisture	0.731* *	0.620* *	0.780* *	0.788* *	0.781* *	0.619* *	0.645* *	0.684* *	0.616* *	0.694* *	0.743** **	0.678* *	0.726** **	0.715** **	0.726** **	0.577* *	0.643* *
Soil temperature	-0.524 NS	-0.483 S	-0.503 S	-0.292 S	-0.248 S	-0.287 S	-0.384 S	-0.338 NS	-0.179 S	-0.191 NS	-0.483 NS	-0.177 NS	-0.188 NS	-0.294 S	-0.181 NS	-0.289 NS	-0.257 NS

Note: ** indicates significant at 1% level ($r + 0.708$); * indicates significant at 5% level ($r + 0.576$). NS = Non-significant.

Table 5: Oribatid species and their mean percentage of total population (January, 2018 – December, 2019) from different agroecosystems

Cultivated crops	Different oribatid species and their mean percentage												
	<i>Scheloribates curvialatus</i> Hammer	<i>Schelori bates</i> sp.	<i>Scheloribates huancayensis</i> Hammer	<i>Protori bates magnus</i> Aoki	<i>Rostrozetes foveolatus</i> Sellnick	<i>Oppia kuehnelti</i> Balogh	<i>Amerio ppia</i> sp.	<i>Unguizetes clavatus</i> Aoki	<i>Javacarus kuehnelti</i> Balogh	<i>Rhyso tritita</i> sp.	<i>Trichori bates</i> sp.	<i>Galumna</i> sp.	Nymphs
Sugarcane	29.17	16.67	---	9.72	16.67	---	---	---	---	---	---	---	27.78
Rice	25.00	12.50	---	11.11	15.28	---	---	---	---	---	---	---	36.11
Pigeon pea	31.94	12.50	9.72	5.56	---	---	---	4.17	8.33	---	---	---	13.89
Lucerne	27.78	11.11	9.72	5.56	---	12.50	2.78	6.94	9.72	---	---	---	13.89
Castor	33.33	13.89	11.11	5.56	---	12.50	5.56	4.17	---	---	---	---	13.89
Okra	22.22	9.72	---	8.33	11.11	---	---	---	---	---	---	---	48.61
Mango	40.28	---	---	12.50	---	---	---	9.72	---	4.17	6.94	2.78	23.61
Coconut	37.50	---	---	9.72	---	---	---	8.33	---	4.17	5.56	2.78	31.94
Banana	---	25.01	11.11	6.94	9.72	12.50	5.56	---	---	4.17	---	2.78	15.28
Teak	34.72	---	---	8.33	---	---	---	6.94	---	2.78	2.78	1.39	43.06
Organic farm	34.72	---	12.50	8.33	---	---	---	6.94	9.72	4.17	5.56	2.78	15.28
Turmeric	31.94	---	15.28	9.72	---	---	---	6.94	12.50	---	---	---	23.61
Aloe vera	33.33	---	---	15.28	---	---	---	9.72	---	8.33	5.56	---	27.78
Greenhouse soil	23.61	11.11	13.89	---	---	18.06	---	6.94	---	---	---	---	26.39
Vermicompo st bed	34.72	13.89	11.11	6.94	---	12.50	---	4.17	---	---	---	---	16.67
Biodiversity park	41.67	9.72	8.33	4.17	5.56	8.33	4.17	2.78	---	2.78	1.39	---	11.11
Fallow land	---	---	---	---	---	---	---	13.89	---	30.56	---	---	55.56

In the present investigation, oribatid mite and their species (Table 5) correlated with different soil properties in different agroecosystems. The result indicated that organic carbon, available nitrogen, available zinc, available iron, available manganese, available copper, soil porosity and soil moisture showed significant to highly significant positive relationship, while pH, electrical conductivity, bulk density of soil showed significant negative to highly significant negative correlation with the mean number of oribatid mite as well as with different species (Table 5). The findings of present investigation corroborate with earlier findings of Moitra (2017)^[46] who stated that soil moisture and organic carbon exhibited statistically significant and positive correlation with the soil mite population in four solid waste disposal sites while, soil temperature and heavy metals showed weak or strong negative effects in most instances. Interrelations between edaphic factors and soil mite population indicated negative influence of moisture on metal content in many instances. A significant positive correlation between the soil moisture and soil mite populations was recorded in the present study which was in agreement with finding of by Choudhuri and Pande, 1979; Joy and Bhattacharya 1981; Sanyal, 1981a, 1981b, 1982; Sanyal *et al.*, 1999. Choudhuri and Pande (1979, 1981)^[16, 17] and Ghosh and Roy (2004)^[25] who reported significant negative correlation with moisture in the Darjeeling Himalayas. Sarkar (1991)^[62], Sengupta and Sanyal (1991)^[64], Sanyal and Sarkar (1993)^[60] and Roy *et al.*, (2004) also recorded similar observations in other parts of West Bengal. Singh and Yadava (1998)^[70] and Chitrapati and Singh (2006)^[14] recorded positive interaction in Manipur and Tripathi *et al.* (2007) observed in Thar Desert, Rajasthan. The influence of organic carbon on soil mite populations was significantly positive at all agroecosystems. This conforms with the earlier observations made by different scientist (Choudhuri and Pande, 1979, 1981, 1982; Ghosh and Roy, 2004; Bhattacharya and Raychaudhuri, 1979; Joy and Bhattacharya, 1981; Sanyal, 1981a, 1981b, 1982, 1991b; Sanyal *et al.*, 1999; Roy *et al.*, 2004)^[5, 16, 17, 18, 25, 37, 52, 55, 56, 57, 58, 61]. Chitrapati and Singh (2006)^[14] recorded positive correlation in Manipur and in Thar Desert, Rajasthan by Tripathi *et al.* (2007)^[78]. Negative influence of carbon on acarines, was reported by Chattopadhyay and Hazra (2000)^[13] at a few sites in Kolkata while studying the effect of sewage effluents on arthropods. Hydrogen ion concentration (pH) exhibited a significant negative relationship with soil mites in the present study. Different mode of interactions between the soil mite populations and soil pH has also been reported from various other studies. Bhattacharya and Raychaudhuri (1979)^[5], Sanyal (1981b)^[56], Sanyal and Sarkar (1993)^[60], Sanyal *et al.*, (1999), Roy *et al.* (2004)^[52] and Tripathi *et al.*, (2007) observed negative correlation, while Joy and Bhattacharya (1981)^[37], Sanyal (1981a)^[55] and Sarkar (1991)^[62] reported either weak or significant positive impact of pH. Choudhuri and Pande (1979, 1981, 1982)^[16, 17, 18], and Ghosh and Roy (2004)^[25] reported negative correlation with pH at different sites in the Darjeeling Himalayas, West Bengal. Thus, more or less present findings. Available zinc, available iron, available manganese and available copper were found significant positive with oribatid mite population in the present study. Skubala and Kafel (2004)^[71] observed that despite the high Zn concentrations, there was non-significant decrease in density compared to the control and thus, it could be concluded that Zn does not have a significant effect on this

group. Similar result was reported by Hågvar and Abrahamsen (1990)^[26]. Skubala *et al.*, (2016) observed positive correlation between the soil Zn content and oribatid mites and their microhabitat which indicates that the group is prone to bioaccumulation of this metal. The incorporation of low concentrations of Cu (42-418 mg) in the diet of some oribatid mites can increase their fertility, however, if they exceed certain limits (above 700 mg), their life cycle can be affected and cause their death (Seniczak *et al.*, 1997, 1999)^[65, 66]. The concentration in trial was lower than 15 mg, so it can be beneficial to those mites (Skubala and Zaleski, 2011)^[72]. Skubala and Kafel (2004)^[71] have studied the bioaccumulation of metals in oribatid mites in a gradient of forestry ecosystems. Iglesias *et al.*, (2019) found that the concentration of Zn and Cu was higher in the mycophagous species (*Oppiella nova* and *Tectocephus velatus*) than in the panfitophagous species (*Oribatula tibialis* and *Pergalumna nervosa*) or the macrofitophagous (*Atropacarus striculus*). Other studies have demonstrated that the communities of some oribatid mites are almost completely tolerant to the presence of Fe, Zn, Cu, Cd, and Pb in the soil (Vladislav *et al.*, 2015; Zaitsev and van Straalen, 2001)^[81, 82]. It has been observed that Zn is the metal that accumulates the most in the microfitophagous oribatid mites (Zaitsev and van Straalen, 2001)^[82]. This may explain the reason for a positive correlation of this metal and the densities of *Oppiella nova* and *Tectocephus elegans*, considered as microfitophagus. The correlation analysis between the edaphic parameters, heavy metals, and oribatid mites shows that the most significant relationship was presented by *T. velatus elegans* ($r = 0.80$), which was positively correlated with Mn and Cr, and negatively with Zn. *Schelorbitates* sp. had a positive and significant correlation with K ($r = 0.74$). *Rhysotritia ardua* also had a negative correlation with K and Mn, and positive with Cu and Ni ($r = 0.69$). On the other hand, in *B. Allonothrus* sp. had a positive correlation with the porosity and Cd ($r = 0.72$). *Ramusella* was negatively correlated with Ca and Mg, and had a positive correlation with porosity ($r = 0.69$). The principal component analysis has shown that there are two main factors: the first one is related to the heavy metals (Fe, Cu, Zn, Cd, Ni, Pb) and the pH, and it explains 42.51 per cent of the variation (eigenvalue = 8.80). The second factor is related to the content of K and Ca, and it explains 56.31 per cent of variation (eigenvalue = 2.21). This study corroborates earlier findings within the ecological zone by Sridhar and Bammekke (1986)^[74] and in other places (Nahmani and Lavelle, 2002; Skubala and Kafel, 2004; Kapusta and Sobczyk, 2015; Madani *et al.*, 2015)^[38, 41, 47, 71]. The heavy metal contamination measured in this study serves as an indication of the extent of pollution as a result of the landfill site in Aba-Eku, Ibadan. The study shows that soil mites can be used as biological indicators to ascertain the level of ecological imbalance caused by the solid wastes in a landfill (Gergocs and Hufnagel, 2009; Huguier *et al.*, 2014)^[22, 31]. The correlation that exists in the study between the heavy metal levels in the soil and abundance of soil mites at the demarcated plots indicates that they both interact biologically in the landfill. For example, there was significant correlation between Fe (II) and oribatid mites ($r=0.949$ at $P>0.05$), Zn and gamasid mites ($r=0.953$, $p>0.05$) showing the biota is affected in one way or the other. Other studies have shown similar trends on the effects of heavy metals on the soil mite community (Streit, 1984; Heikens *et al.*, 2001; Nahmani and Lavelle, 2002; and Migliorini, *et al.*, 2004)^[29].

45, 75]. The Berger- Parker Dominance Index (BPDI) showing the percentage contribution of each species, family or taxonomic group to the total number of soil mites in each study plot indicated that values of ≥ 10 per cent density showed that the species were dominant. The sampled plots with the relatively higher number of dominant groups were an indication of an unstable community in transition with several ecological opportunities for diverse niches. It was also an indication of natural or anthropogenic impacts that had upset the ecological balance thereby favoring opportunistic colonization and flourishing of less viable species with the flourishing invasive species (Chapman and Reiss, 1992)^[12]. Since soil mites are sedentary in nature, they can be used as ecological biota for biomonitoring perturbations in the soil ecosystem. Comparatively, Cr, Ni, Zn, Cu, Mn and Fe concentrations in the study exceeded guideline limits set by the Federal Ministry of Environment (FEPA, 1992). This study therefore, shows that the soil in Aba- Eku landfill in Ibadan is contaminated by heavy metals (Tyokumbur *et al.*, 2016)^[80]

Soil temperature showed significant negative relationship with *S. huancayensis* in pigeon pea, castor, banana and biodiversity park while, other oribatid mite species showed non-significant correlation in different agroecosystems. The soil temperature showed non-significant correlation with oribatid mite and different species mean in the present investigation. Those results showed no relation between soil temperature and oribatid mite. It was due to the study area condition. The study area having high water table which showed no effect of soil temperature on oribatid mite. The present results are unrelated with others earlier findings. Negative impact of temperature on mite population is a common observation in northern parts of India and earlier reported by workers like Sengupta and Sanyal (1991)^[64], Sanyal (1996)^[59], Sanyal *et al.* (1999)^[61], Roy *et al.* (2004)^[52], as well as in other parts of India, by Singh and Yadava (1998)^[70] and Chitrapati and Singh (2006)^[14] who recorded positive interaction in Manipur, while negative correlation was observed by Tripathi *et al.* (2007)^[78] at Thar Desert, Rajasthan. Significant positive correlation with temperature however was reported by Choudhuri and Pande (1981)^[17] in Darjeeling Himalayas, while some workers reported the same in other parts of West Bengal (Sanyal, 1981b, 1982; Sanyal, 1991a)^[56, 57, 58]. Of them however, significant positive correlation was reported only by Sanyal (1981b)^[56]. Negative correlation in Darjeeling was recorded by Choudhuri and Pande (1979, 1981)^[16, 17] and Ghosh and Roy (2004)^[25].

Available phosphorus, available potassium, available sulphur and particle density of soil showed non-significant correlation with oribatid mite mean while, only few species of oribatid mite showed significant positive and negative correlation during the present study.

3.3. Impact of Soil Properties on Oribatid Mite Abundance, Distribution and Diversity at Navsari Agricultural University Campus

A total of 1224 mites were collected in different agroecosystems during present investigation. A total of 12 species of oribatid mites belonging to 10 genera and 8 families were found in the study.

The values of dominance, abundance, diversity, evenness, and species richness were analyzed in present investigation. The results showed the highest value of abundance in banana

(2.1272) followed by lucerne (2.0326), biodiversity park (1.9335), organic farm (1.9256), pigeon pea (1.8995), castor (1.8722) while, lowest value was recorded in fallow land (0.9630). The value of Simpson's index showed ranges between 0 to 1, zero represent infinite diversity and 1, no diversity. The results of Simpson's index was lowest in banana (0.1385), which make the greater species diversity (0.8615) followed by lucerne (0.1520) (0.8480), pigeon pea (0.1775) (0.8225), castor (0.1856) (0.8144), organic farm (0.1863) (0.8137), greenhouse soil (0.1944) (0.8056), vermicompost bed (0.2022) (0.7978), turmeric (0.2110) (0.7890) and biodiversity park (0.2176) (0.7824) while, lowest species diversity found in fallow land (0.4213) (0.5787). The evenness was measured the relative abundance of the different species making up the richness of an area. The highest evenness found in fallow land (1.1868) while, lowest was in teak (0.5218). The species richness was measured the number of different kinds of species present in particular agroecosystems. Biodiversity park (10 species) showed highest species richness followed by banana (9 species), organic farm and lucerne (8 species). Pigeon pea and castor recorded 7 species while, orchard (mango, coconut) and forest (Teak) recorded 6 species. Other agroecosystems recorded few species and lowest species richness was found in fallow land with 2 species (Table 5). The present findings are more or less similar to earlier work by Iglesias *et al.*, (2019) who studied abundance (number of individuals), density (ind/m²) and percentage of oribatid mites density in San Salvador (SS) and El Bondho (B), agricultural plots in Hidalgo, Mexico. A total of 39,487 mites were collected in the 2 plots, the oribatids represented only the 6 per cent of the total (2,448 individuals) including immature stages. In the SS plot, 1,345 oribatid mites were collected, while in the B plot 1,103 oribatids were recorded. A total of 20 species of oribatid mites belonging to 19 genera and 15 families were found in the study. In the SS plot, 18 species were recorded and 14 in the B plot. The most abundant species in SS was *Tectocepheus velatus elegans*, while in B, *Zygoribatula connexa* was the most abundant. The highest values of abundance, diversity, evenness and species richness were found in SS, only the dominance was higher in B. The exclusive species for SS were *Galumna* sp., *Lohmannia banksi*, *Hypochothonius* sp., *Setobates* sp., *Carabodes ecuadoriensis*, and *Brachiopoda* sp., and for B, *Microppia* sp. and *Allonothrus* sp. were exclusive.

Conclusion

The correlation coefficient data as mentioned in the study indicated the sixteen variables viz., organic carbon, available (nitrogen, zinc, iron, manganese and copper), porosity of soil and soil moisture were significant to highly significant positively correlated with the oribatid as well as with different oribatid species. In respect to other variables however, a difference was marked between the sampling sites. The pH, electrical conductivity and bulk density appeared to show significant to highly significant negative correlation with the oribatid as well as with different oribatid species in the studied agroecosystems. Similarly, available (phosphorus, potassium and sulphur), particle density of soil and soil temperature though indicated non-significant correlation with the population in all the agroecosystems. The values of dominance, abundance, diversity, evenness, and species richness were analyzed in the present investigation. The available results showed the highest value of abundance

in banana (2.1272), while the lowest was found in fallow land (0.9630). The results of Simpson's index showed the lowest in banana (0.1385) which makes the greater species diversity (0.8615) while, the lowest species diversity was found in fallow land (0.4213) (0.5787). The highest evenness found in fallow land (1.1868), while lowest was in teak (0.5218). Bio-

diversity park (10 species) showed highest species richness while, lowest species richness was found in fallow land with 2 species.

Conflict of Interest

The authors declare that they have no conflict of interest.

Table 5: The impact of soil properties on oribatid mite abundance, distribution and diversity at Navsari Agricultural University campus

Sr. No.	Agroecosystem	Shannon index	Simpson index	Simpson index of diversity	Evenness	Species richness
1	Sugarcane	1.5390	0.2272	0.7728	1.1004	4
2	Rice	1.5055	0.2442	0.7558	1.0238	4
3	Pigeon pea	1.8995	0.1775	0.8225	0.8048	7
4	Lucerne	2.0326	0.1520	0.8480	0.8224	8
5	Castor	1.8722	0.1856	0.8144	0.7697	7
6	Okra	1.3627	0.3144	0.6856	0.7952	4
7	Mango	1.6108	0.2504	0.7496	0.6656	6
8	Coconut	1.5585	0.2647	0.7353	0.6296	6
9	Banana	2.1272	0.1385	0.8615	0.8022	9
10	Teak	1.3808	0.3194	0.6806	0.5218	6
11	Organic farm	1.9256	0.1863	0.8137	0.6710	8
12	Turmeric	1.6641	0.2110	0.7890	0.9479	5
13	Aloe vera	1.6033	0.2311	0.7689	0.8654	5
14	Greenhouse soil	1.7049	0.1944	0.8056	1.0288	5
15	Vermicompost bed	1.7618	0.2022	0.7978	0.8243	6
16	Biodiversity park	1.9335	0.2176	0.7824	0.4596	10
17	Fallow land	0.9630	0.4213	0.5787	1.1868	2

Acknowledgement

The Authors are thankful to Principal and Dean, N. M. College of Agriculture, Navsari Agricultural University, Navsari and Director of Research and Dean, Post Graduate Studies, Navsari Agricultural University, Navsari for providing all the necessary facilities during the present study.

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How to Cite This Article

Patel AT, Shukla A, Patel KM, Darji, R T. Influence of soil properties on soil oribatid mites in different agroecosystems. *J Soil Future Res.* 2026;7(2):85-98.
doi:10.54660/JSFR.2026.7.2.85-98.

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