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IMPACT OF SOME EDAPHIC AND ECOLOGICAL FACTORS ON THE BIODIVERSITY OF SOIL FAUNA FROM VEGETABLE FIELDS

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ABSTRACT

This study explained different numbers of soil arthropods in response to some edaphic and ecological factors. The sampling was done by using a soil sampler (corer) from vegetable fields, of the University of Agriculture, Faisalabad, Pakistan. The extraction of soil arthropods from samples was done by Berlese-Tullgren funnel. Results showed a significant variation in soil fauna abundance. Out of total samples collected, 54-56% fitted to Springtails followed by Mites 18-20%, Proturans 4.0-4.06%, Symphylans 3.0-4.2%, Ants 3-4%, Soil beetles 2%, Spiders 3%, Parasitic wasp 1.8-2.0%, Woodlouse 1.0-1.3%, Pseudoscorpions 0.0-0.5% and miscellaneous 4.8-5.0%. Mean comparison numbers of arthropod population were categorized into four groups i.e., most abundant (Collembola, Acari), moderately abundant (Protura, Symphyla, Hymenoptera), least abundant (Araneae, Coleoptera, Isopods) and rare (Pseudoscorpions). The findings also showed highest population of springtails and mites with mean value of 59.67±8.76 and 22.33±1.76 respectively, while lowest abundance was in pseudoscorpions with mean value of 0.001±0.00. The soil temperature had a positive and highly significant correlation with springtails (0.774**) and proturans (0.714*). Soil moisture content had a positive and significant relationship with proturans (0.612*). Organic matter had a positive and remarkable relationship with pseudoscorpions (0.634*), while negative and significant association with soil beetles (-0.651*) and proturans (-0.679*). Soil fauna was also correlated with macronutrients and it was found that available phosphorous and potassium had a significant correlation with soil micro-arthropods except soil beetles. Mites and springtails had highly significant and positive correlation with temperature (0.837**, 0.863** respectively), while negatively significant with relative humidity (-0.798**, -0.704** respectively). Other arthropod guilds did not show any significant correlation with edaphic and meteorological factors.

Keywords: *Biodiversity, soil fauna, arthropods, edaphic factors, ecology.*

INTRODUCTION

Soil has been reported as the most diverse and complex ecological community worldwide (Kopittke *et al*., 2019) and contains a significant pool of biodiversity.

Indeed, in terms of species diversity, it is one of the richest abodes of terrestrial ecosystem. Approximately one-fourth of all living species on Earth are found in soil. The significance of biodiversity has already been discussed about the physiological action that soil biota play a pivotal role in managing ecological processes (Geisen *et al*., 2019). The soil mesofauna consists mainly of the phyla Arthropoda and Nematoda (Roversi *et al*., 2012).

From forests to deserts, soil micro-arthropods are present in nearly every habitat (Chesworth *et al*., 2008). Arthropods participate in the decomposition of dead animal and plant tissues. Additionally, they convert organic matter into a substance that is readily decomposed by the microbes present in the soil. These living species also influence aeration, infiltration, porosity and dispersion of organics within the soil (Bird *et al*., 2004). They have been reported to impact the mineralization of organic material and conversion of parent rock into soil over time (Bisset *et al.,* 2003). In a microcosm experiment, it was described that the release of nutrients from soil and plant debris is enhanced with increasing microarthropod abundance. Microarthropods in soil are considered effective biological indicators of soil condition (Menta *et al.,* 2017). The diversity and abundance of soil microarthropods in agroecosystems are influenced by climatic and soil physicochemical factors. Their activity, nutrition, and habitat are directly and indirectly affected by soil temperature, pH, and moisture content (Killham, 1994). The relatively distinct combination of precipitation and temperature determines the set of viable species and defines characteristics of community type. The soil characteristics that lead to distinctions in abundance of soil arthropods in agroecosystems are affected by changes in weather (Shakir and Ahmed, 2014). The developmental stages of the microarthropods are highly susceptible to change in edaphic factors, which greatly limit their distribution (Schowalter, 2011). The edaphic variables provide a heterogeneous condition for the allocation and abundance of soil arthropods. The distribution and variety of soil biota, including microarthropods, may be influenced by seasonal variation (Meloni *et al*., 2020). In India and abroad, the soil arthropods have been studied in response to various biological and abiotic elements, specifically either in grassland, forest, cultivated, arid fields or at a certain height in a mountainous region (Gosh and Roy, 2004). The relationship among arthropod diversity and abundance, environmental factors and agronomic practices have been determined by many studies (Gkisakis *et al.,* 2016). The impact of different abiotic factors against abundance and distribution of soil biota is elaborated by numerous studies. Several studies are a combination of climatic and edaphic parameters consisting of soil pH and type (Rentao *et al*., 2013), soil moisture (Wallwork, 1970), soil temperature (Usher, 1976) and rainfall (Anu *et al*., 2009). Soil fauna need to be emphasized in agroecosystems for the study of probable effects of Plant Protection Products on their communities. This investigation will recommend that there is an extensive range of studies on these parameters with respect to soil microarthropods to anticipate the confrontations of changes in climate. The present study aims to determine the groups of arthropods that are soil inhabiting and their response to different edaphic and meteorological factors.

MATERIAL AND METHODS

Soil sampling was done from the vegetable field area, University of Agriculture, Faisalabad. Random sampling of soil microarthropods was from October to March 2022-23. Sampling was done fortnightly with the help of soil sampler or (corer) having the length of 7 inch and 4.5 inch in diameter. The samples were placed in polyethene bags and taken to workroom for extraction of micro-arthropods, their count and analysis.

Extraction by Berlese-Tullgren Funnel: Microarthropods were extracted by Berlese-Tullgren apparatus (Crossley and Blair, 1991). 75-80% ethylene alcohol was used as preservative material. The extracted samples were transferred to vials for their count and identification. The extracted samples were mounted on glass trays and carefully observed under stereo microscope. The soil fauna was counted and identified by using taxonomic keys (Krantz and Walter, 2009).

Soil Temperature measurement: To read the temperature underground, a hole was made by using a dowel for the insertion of thermometer. For one minute, thermometer was put into the hole, detached and temperature was noted after one minute. This technique was repetitive five times and then readings were gathered up to obtain average temperature (Srivastava, 2009).

Determination of Soil pH: The dried soil sample of 10 grams taken from 7inch depth was put in a beaker and 20ml of purified water was added to sample and kept to stand for half an hour. The mixture was stirred and then the electrode of pH meter was dipped in solution and readings were recorded (Bates, 1954).

Measurement of Soil Moisture: First, the weight of jar was recorded as W_1. Then, approximately 30-40 gm of soil sample was placed in beaker, then reweight the beaker with sample as W_2. The beaker was microwaved for 10-15 minutes. The soil sample was weighed and after that returned to the oven for 5 minutes. The soil sample was weighed again and if the weight was changed, it was again sited in the microwave range for further 5 minutes. The procedure was performed several times until the mass (Wt) was uniformed. The final uniform weight (W_3) of the beaker containing dry samples was measured (Reynolds, 1970).

$$\text{Soil Moisture (\%)} = \frac{(W2 - W3)}{(W3 - W1)} \text{ X } 100$$

Measurement of organic matter and micronutrients: Analysis of organic matter and micronutrients such as available potassium and phosphorous was obtained from soil fertility research laboratory, Ayub Agricultural Research Institute, Faisalabad. 1kg soil sample from vegetable research area was collected and submitted to laboratory without any delay. Samples were kept alright to avoid the escape of moisture content and labelled properly according to sampling plan.

Measurement of Meteorological (ecological) Factors: Data regarding temperature, relative humidity and rainfall was obtained from Ayub Agricultural Research Institute, Faisalabad.

RESULTS AND DISCUSSION

Biodiversity of soil fauna: The abundance of different soil fauna groups was studied from October to March. Analysis of variance regarding the biodiversity of soil fauna revealed a significant difference in soil fauna abundance among different species ($p \leq 0.05$). Out of 1643 soil samples recorded, 56% of the population was related to Springtails accompanied by 20% Mites, 4% Proturans, 3% Symphylans, 4% Ants, 2% Soil beetles, 3% Spiders, 2% Parasitic wasp, 1% Woodlouse and 0-0.05% Pseudoscorpions and 5% Miscellaneous as shown in (Figure 1). The findings showed that highest mean population was of soil fauna i.e., springtails 59.67 (±8.76) and mites 22.33 (±1.76) while the lowest mean population was of pseudoscorpions 0.05 (±0.00) during month of October. Least abundance of soil fauna such as springtails, mites and pseudoscorpions with mean value of 5.33 (±1.48), 5.00 (±0.76) and 0.17 (± 0.16) respectively, was observed during January as shown in (Figure 2).

Zhimomoi *et al*. (2009) reported that soil microarthropod activity in rice fields peaked between May and September, with Collembola being the most abundant, followed by Acari, Hymenoptera, Coleoptera, and Araneae. Similar seasonal trends were observed under Bt cotton fields by Williams (1999), Ospina *et al*. (2003), Brahman *et al*. (2010), and Abbas (2012). Pérez-Bote and Romero (2012) found Formicidae dominant, accompanied by Coleoptera, Araneae, Collembola, Acari, and Hymenoptera. McIntyre *et al*. (2001) noted that Acari, Hymenoptera, and Collembola comprised 92% of the total soil fauna, while Anu *et al*. (2009) highlighted Coleoptera as the most prevalent group.

Correlation regarding edaphic factors: Correlation analysis as shown in Fig 3&4 revealed that edaphic and meteorological factors exhibited significant associations with specific soil microarthropod groups. Among edaphic variables, soil temperature showed a highly significant positive correlation with springtails ($r = 0.7774^{**}$) and proturans ($r = 0.714^{*}$), while soil moisture content was positively associated with proturans ($r = 0.612^{*}$). Organic matter had a positive correlation with pseudoscorpions ($r = 0.634^{*}$) but a significant negative relationship with soil beetles ($r = –0.651^{*}$) and proturans ($r = –0.679^{*}$). Available phosphorus was positively correlated with pseudoscorpions ($r = 0.615^{*}$) and negatively with soil beetles ($r = –0.751^{*}$), whereas available potassium showed a positive association with soil beetles ($r = 0.674^{*}$). Other soil fauna groups did not exhibit significant correlations with edaphic factors. Regarding meteorological parameters, mites ($r = 0.752^{**}$) and springtails ($r = 0.903^{**}$) showed highly significant positive correlations with temperature, while relative humidity had a significant negative association with mites ($r = –0.798^{**}$) and springtails ($r = –0.704^{*}$). Rainfall was positively correlated with miscellaneous specimens ($r = 0.641^{*}$), whereas other groups showed no significant relationships with meteorological variables.

Regression analysis against edaphic factors:

Regression analysis indicated that both edaphic and meteorological factors significantly influenced soil microarthropod populations, with mites, proturans, and springtails showing the highest responsiveness. Mite populations were strongly affected by edaphic factors (86.4%), positively correlating with soil temperature, pH, moisture, and organic matter, and negatively with potassium and phosphorus. Meteorological factors explained 87.72% of mite variation, with positive associations to minimum and maximum temperature and humidity, and negative to average temperature and rainfall. Springtails were most influenced by meteorological conditions (89.47%) and also showed substantial sensitivity to edaphic factors (80.94%), with similar correlation patterns. Proturans followed closely in both categories (82.78% and 83.01%). Spiders exhibited the least response to both edaphic (48.55%) and meteorological (22.90%) factors, showing negative associations with moisture, organic matter, and average temperature, and positive with other variables. These results highlight the differential ecological responses of soil microarthropods to abiotic drivers (Table 1&2).

Among edaphic factors, soil temperature emerged as the most influential in enhancing microarthropod diversity, particularly Collembola and mites (Table 2). This contrasts with earlier studies (Fujikawa, 1970; Anderson, 1988; Santos *et al*., 1978; Scheu & Schulz, 1996; Klausman, 2006; Tripathi *et al*., 2007) that emphasized organic matter as the key determinant. Soil pH showed no significant correlation, opposing findings by Klausman (2006) and Cancela Da Fonseca (1995). Similarly, soil moisture had limited impact, aligning with Tsiafouli *et al*. (2005), but contradicting Gbarakoro *et al*. (2010) and Badejo (1982), who reported increased Acari and Collembola densities during wet seasons. Organic matter showed a strong positive correlation with pseudoscorpions, consistent with Taneja and Duta (2023). Temperature fluctuations significantly affected Collembola, mites, and ants, with winter declines and spring recoveries (Wallwork, 1970; Asikidis & Stamou, 1991; Sulkava & Huhta, 2003; Uvarov, 2003). Relative humidity exhibited a strong negative correlation with Collembola and mites, while rainfall showed no significant effect (Cakir & Makineci, 2013; Anu *et al*., 2009). Temperature and humidity were confirmed as key drivers of Collembolan distribution (Joosse & Groen, 1970; Verhoef, 1981; Verhoef & Van Selm, 1983).

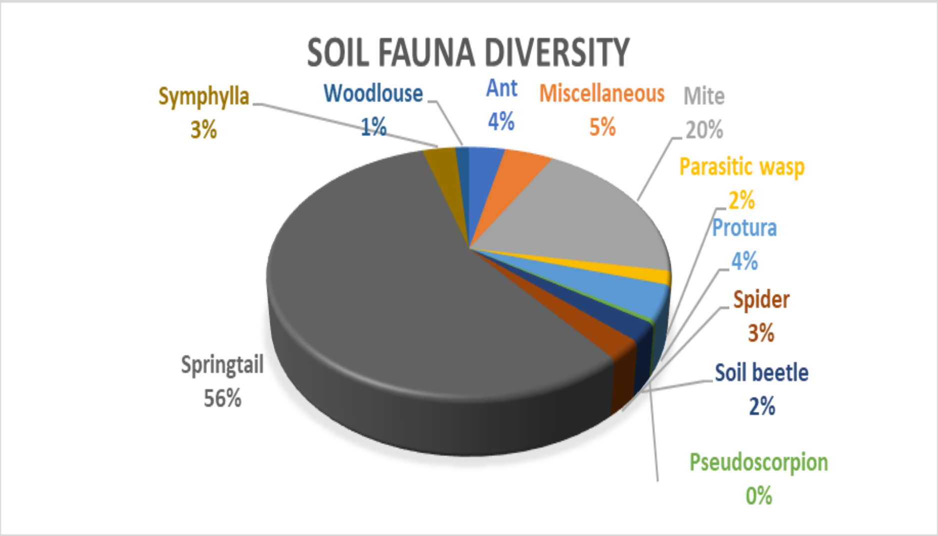

Fig 1: % Population of different groups of soil fauna

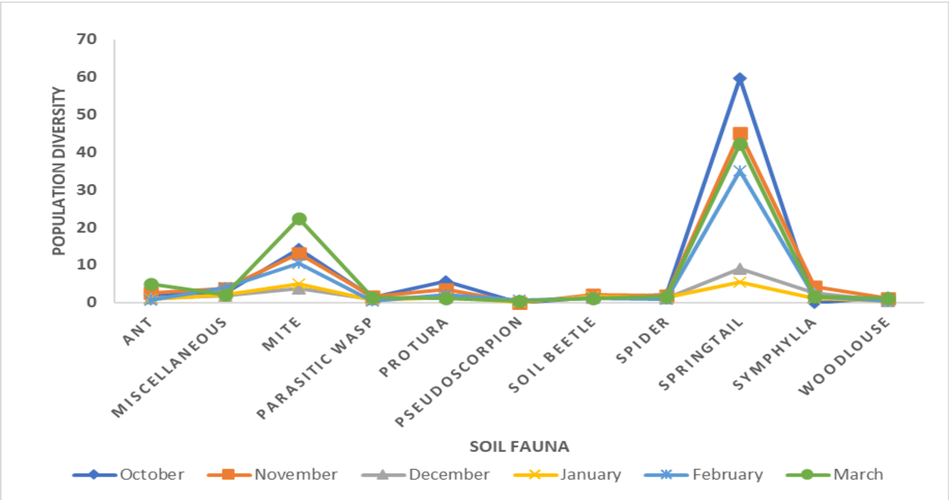

Fig 2: Mean population of soil fauna

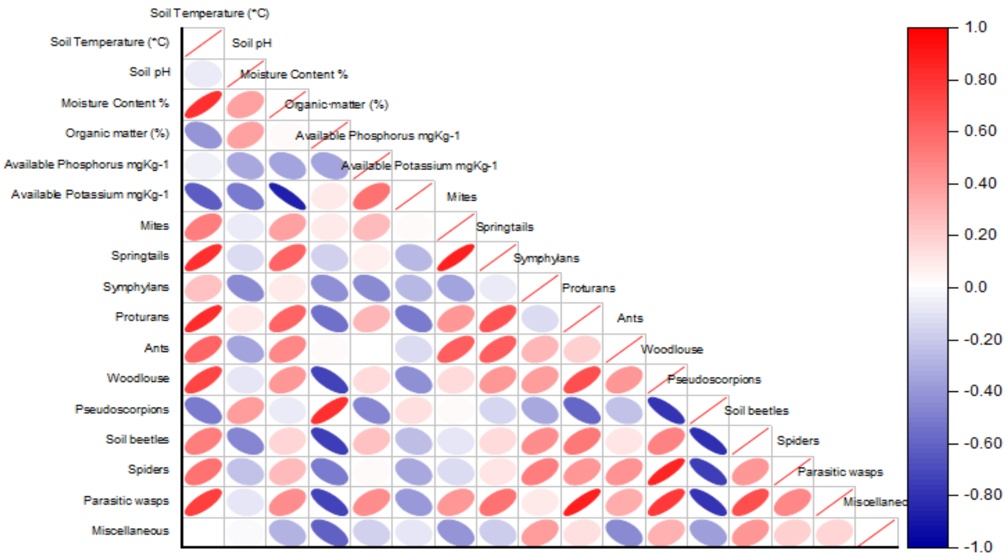

Fig 3: Correlation analysis of edaphic parameters and soil fauna (Red and Blue color showed highly positive and negative correlation, respectively)

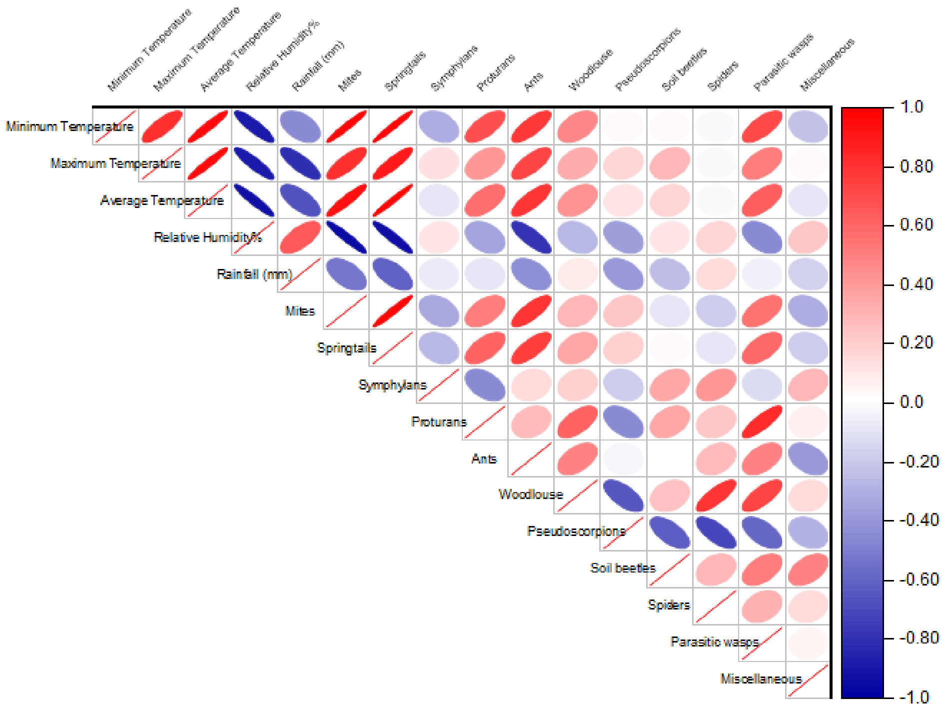

Fig 4: Correlation analysis of meteorological parameters and soil fauna (Red and Blue color showed highly positive and negative correlation, respectively)

Table 1. Regression analysis of soil fauna against edaphic parameters (soil temperature, pH, moisture content, organic matter, available potassium and phosphorous)

Treatments	Regression Equation	R^2
Mites	$T_1 = -299 + 4.09X_1 + 13.0X_2 + 2.62X_3 + 187X_4 - 0.00X_5 - 1.053X_6$	86.4%
Springtails	$T_2 = - 409 + 12.70X_1 + 37X_2 - 1.10X_3 + 179X_4 - 0.26X_5 - 1.65X_6$	80.94%
Symphylans	$T_3 = 18 + 0.026X_1 - 6.4X_2 - 1.80X_3 - 8.7X_4 + 0.885X_5 + 0.139X_6$	69.44%
Proturans	$T_4 = 160.2 + 0.369X_1 - 5.01X_2 + 0.190X_3 - 30.6X_4 - 0.695X_5 - 0.253X_6$	82.78%
Ants	$T_5 = - 117 + 0.524X_1 + 4.9X_2 + 0.56X_3 + 25.6X_4 + 0.515X_5 + 0.216X_6$	59.01%
Woodlouse	$T_6 = 0.1 + 0.238X_1 - 4.91X_2 - 0.494X_3 - 9.5X_4 - 0.079X_5 - 0.055X_6$	75.30%
Pseudoscorpions	$T_7 = - 16.9 - 0.0226X_1 + 0.06X_2 + 0.042X_3 + 2.93X_4 - 0.060X_5 + 0.0417X_6$	71.92%
Soil beetles	$T_8 = - 24.2 - 0.096X_1 + 3.62X_2 + 0.049X_3 - 5.1X_4 + 0.023X_5 - 0.0321X_6$	68.15%
Spiders	$T_9 = 35.6 + 0.016X_1 + 0.74X_2 - 0.353X_3 - 25.9X_4 + 0.000 X_5 + 0.147 X_6$	48.55%
Parasitic wasp	$T_{10} = 69.4 + 0.187X_1 - 4.0X_2 + 0.084X_3 - 0.4X_4 - 0.241X_5 - 0.189X_6$	66.99%
Miscellaneous	$T_{11} = 32 + 0.420X_1 - 0.9X_2 - 2.08X_3 - 4.1X_4 + 0.446X_5 – 0.133X_6$	57.42%

X_1: Soil temperature X_2: Soil pH X_3: Moisture Content X_4: Organic Matter X_5: Available potassium X_6: Available phosphorous. (R^2= Goodness of fit of the model)

Table 2. Regression analysis of soil fauna against meteorological parameters (Min. temperature, Max. temperature, Avg. temperature, Relative humidity, Rainfall)

Treatments	Regression Equation	R^2
Mites	$T_1 = 30.8 + 28.4 Z_1 + 27.2 Z_2 - 55.1 Z_3 - 0.291 Z_4 - 2.51 Z_5$	87.72%
Springtails	$T_2 = - 61.1 + 191 Z_1 + 190 Z_2 - 377 Z_3 + 0.322 Z_4 - 5.97 Z_5$	89.79%
Symphylans	$T_3 = - 3.44 - 18.3 Z_1 - 18.0 Z_2 + 36.4 Z_3 + 0.0291 Z_4 - 0.41 Z_5$	51.44%
Proturans	$T_4 = - 13.37 + 29.7 Z_1 + 29.6 Z_2 - 59.0 Z_3 + 0.1313 Z_4 + 0.179 Z_5$	83.01%
Ants	$T_5 = 1.21 - 1.8 Z_1 - 2.1 Z_2 + 4.1 Z_3 - 0.0069 Z_4 - 1.424 Z_5$	58.92%

Woodlouse	$T_6 = - 0.58 + 6.91 Z_1 + 6.91 Z_2 - 13.8 Z_3 + 0.0053 Z_4 + 0.214 Z_5$	35.54%
Pseudoscorpions	$T_7 = 3.54 - 2.26 Z_1 - 2.23 Z_2 + 4.43 Z_3 - 0.0328 Z_4 + 0.129 Z_5$	44.30%
Soil beetles	$T_8 = - 3.57 + 0.14 Z_1 + 0.19 Z_2 - 0.25 Z_3 + 0.0415 Z_4 - 0.191 Z_5$	55.02%
Spiders	$T_9 = - 2.88 + 9.7 Z_1 + 9.8 Z_2 - 19.5 Z_3 + 0.0372 Z_4 + 0.037 Z_5$	22.90%
Parasitic wasp	$T_{10} = - 1.03 + 7.21 Z_2 + 7.16 Z_2 - 14.3 Z_3 + 0.0130 Z_4 - 0.205 Z_5$	38.81%
Miscellaneous	$T_{11} = 0.37 - 7.5 Z_2 - 7.2 Z_2 + 14.7 Z_3 - 0.0140 Z_4 + 2.696 Z_5$	74.12%

Z_1: Min. Temp: Z_2: Max. Temp: Z_3: Avg. Temp: Z_4: Relative Humidity: Z_5: Rainfall. ($R^{2=}$ Goodness of fit of the model)

CONCLUSION

High soil temperature and low relative humidity were more suitable for an increase in the abundance of micro-arthropods, while other abiotic and edaphic factors could not bring a drastic change in their numbers during study periods from the vegetable field areas.

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