ACARINES, 17:57-67. 2023

Population fluctuation of mites inhabiting soil cultivated with wheat and soybean crops and their relationships to the chemical properties of the soil in Sharkeia and Beheira governorates, Egypt

Fatma Sh. Kalmosh[1,2*] & Mohamed A. AbdelRahman[3,4]

[1]Cotton and Filed Crops Mites Department Plant Protection Research Institute, Agricultural Research Centre, Dokii, Giza, Egypt. E-mail: fatma.kalmosh@arc.sci.eg, Bkalmosh@yahoo.com
[2]Laboratory of predatory mites, Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing, China.
[3]Division of Environmental Studies and Land Use, National Authority for Remote Sensing and Space Sciences (NARSS), Cairo 1564, Egypt.
[4]State Key Laboratory of Efficient Utilization of Arid and Semi-arid Arable Land in Northern China (the Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China).
*[*]**Corresponding author:** Bkalmosh@yahoo.com*

ABSTRACT

The current study targeted the numerical abundance of some species of soil mites living in soil cultivated with wheat and soybean crops in Sharkeia and Beheira governorates. A total of 54 species belonging to 41 genera and 22 families from four Acari groups were identified. The most widespread species observed were: *Sheloribatus laevigatus*, *Tyrophagous putrescentiae*, *Rhizoglyphus robini*, *Dermatophagoides farina*, *Chiropturopoda bakeri*, *Neothoria niloticus*, *Apostigmaeus navicella*, and *Haemogamasus pontiger*. Interestingly, *Sheloribatus laevigatus*. The highest densities of these species were recorded during the two studied seasons (2021 and 2022) in Sharkeia governorate, which indicates a high level of soil fertility. The Oribatida mites are commonly used as important indicators of soil quality and health due to their role in breaking down soil by feeding on microbes, debris, and plant material. The obtained results revealed that the total numbers of individuals in the four mite groups were 708 and 638 in wheat and soybean crops in Sharkeia governorate, while in Beheira governorate, total numbers of 629 and 499 were recorded in wheat and soybean fields. In addition, the current study extended to the analysis of the soil components beneath both crops in order to study their effect on some Acari mite species.

Keywords: Population abundance; Oribatida; crop field; soil properties; soil fertility.

INTRODUCTION

Soil is an essential natural component in assessing the sustainability of land use, with an emphasis on the preservation of natural resources and ecosystem biodiversity (Hou et al., 2020; Critchley et al. 2023). Factors including the quality of plant litter, soil water balance, microclimate, root activity, and microbiota influence soil formation and fertility, and they also affect the functioning of underground ecosystems. Among the various arthropods found in the soil beneath cultivated plants, mites are considered one of the most abundant members, representing about 95% of the soil fauna that contribute significantly to soil fertility, decomposition, and structure (Behan et al., 1978; Seastedt, 1984; Steffen et al., 2012). Their role in soil fertility is well established (Crossley, 1977; Heneghan et al. 1999; Amani et al. 2020). Additionally, mites influence soil decomposition by consuming microbes and debris, acting as predators, omnivores, and plant feeders (Kethley 1990; Potapov et al. 2022). Mites are responsible for soil structure, an indicator of the health of the soil system, and important interactions with nematodes and microbes during decomposition processes (Walter and Proctor 1999). In Egypt, favorable weather during the four seasons of the year helps the mites in the soil, especially those cultivated with crop plants. Additionally, different groups of soil mites have varying responses to particular plant species, which affects their activities and habitats (Wasylik 1978; Abo-Korah and Osman 1979; Alatalo et al. 2017). Mites can be metaphorically characterized as the engineers of soil structure, and they play an important role in assessing soil health and maintaining ecological balance. Through their activities, they significantly influence various ecological processes, thus establishing their importance as integral components of terrestrial ecosystems. The presence of host plants is of paramount importance in the food chain because they form the basic elements of underground ecosystems. Numerous studies have indicated that several factors, including the quality, quantity, and timing of plant litter, soil water balance, surface layer microclimate, and root activity, significantly influence the functioning of these vital ecosystems (Hairiah et al. 2001; Kalmosh and Yassin 2018). Furthermore, environmental factors such as temperature, humidity, availability of organic matter, and nutrients have a considerable influence on the abundance of mite populations in the soil (Tousignant and Coderre 1992; Yin et al. 2023). Vertical distribution and abundance of oribatid mite populations in soil, which showed notable differences depending on factors such as temperature, moisture levels, matter content, organic matter, and nutrient availability (Frouz et al. 2004; Zhou et al. 2022). Therefore, these various environmental factors must be studied in order to gain a comprehensive understanding of the complex dynamics of ecosystems beneath the soil surface. The main objective of the current investigation was to study the population fluctuations of some soil mites that inhabit wheat and soybean crops in Sharkeia and Beheira governorates, Egypt. As well as to explore the relationships between the abundance of soil mites and various surrounding factors, whether climatic and certain physical and chemical properties of the soil in which wheat and soybean crops are grown.

MATERIALS AND METHODS

Samples collection:

The current study was conducted in two distinct locations, in Sharkeia and Beheira governorates, over two consecutive seasons (2021–2022). The soil samples are located at coordinates (30° 40' 3" N; 31° 33' 29" E), as well as (30° 52' 18" N; 30° 40' 54" E) respectively.

Population fluctuation of some species of soil mites:

This study was conducted using three random samples of the topsoil layer (0–20 cm) in soybean and wheat fields by using a steel core with a diameter of 5 cm following Gilyarov (1975). Soil samples were collected beneath the crops of both wheat and soybean and placed in the modified Tullegren extractor apparatus. The Acari species were cleared up in lactic acid, mounted in Hoyer's medium on a clean glass slide, dried on a hot plate, ringed with nail polish, and then examined under a phase contrast research microscope. Samples were taken four times a month. The extracted mite species were identified based on illustrated keys provided by Krantz (2009), Zaher (1986a and b), and Evans (1992).

Soil analysis:

Soil samples were analyzed for total carbon using the calorimetric method (Andrson and Ingram 1993) and for total nitrogen using the Kjeldahl method (Hinga et al. 1980 and Page et al. 1982) after the extraction of mites from the soil. Additionally, water pH (Hinga et al. 1980) and acidity percentage were determined.

Statistical analysis:

The statistical analysis of variance (ANOVA) procedure and graphics package are essential tools in data analysis to compare the means of multiple groups and determine whether there are significant differences between them. Differences between means were tested by using COSTAT Statistical Software (2005). On the other hand, graphics software provides a visual representation of data to gain a comprehensive understanding of the data and make informed decisions based on the results. The relationship between the population of the mite species, temperatures and relative humidity as correlation (Abou-Setta 2020).

RESULTS AND DISCUSSION

Population fluctuation of different mite species inhabiting soil beneath wheat and soybean crops:

The data in Table (1) clearly demonstrate that wheat soil had significantly the highest average numbers of mite species as compared with soybean soil. Specifically, the average numbers of mites recorded in wheat soil in Beheira and Sharkeia were 32.05 and 25.65. On the contrary, the average numbers of mites in soybean soil in Sharkeia and Beheira were found to be 29.17 and 23.47/500 g of soil, respectively. Wholly in agreement with the results obtained by Mahmoud (1999) and Embarak and El-Saad (2010), they observed variations in soil mite density between different crops in different fields. On the other side, the current results showed that the number of oribatid mites in the soil under soybean is the highest (41.79 individuals/ 500 g of soil), followed by

Mesostigmta (29.06), then Prostigmata (23.26), with significant differences between the first and third orders. While the lowest number was recorded for the Astigmata mites (10.82 individuals/500 g of soil), this may be due to the dependence of some predatory species on them for feeding. Comparing the results of the presence of mite group average populations on the soil beneath wheat, it was also found that the presence of the mite Oribata was higher (42.42 individuals/500g of soil) than that of Mesostigmata (34.40), Prostigmata (28.94), and Astigmata (9.63). These results are consistent with those obtained by Walia and Mathur (1994).

The average monthly population of soil mites in wheat and soybean plants in Sharkeia and Beheira governorates during the 2021–2022 seasons is indicated in Table 1. The results indicated the soil mites associated with soybean fields were the most abundant, with 42.39 and 32.45 individuals per 500 g of soil in September and 31.04 and 24.57individuals per 500 g of soil in August in Sharkeia and Beheira, respectively.

However, in April and March, the majority of wheat soil mites were extracted, with 48.81 and 40.75 individuals per 500 g of soil recorded in Beheira and 38.09 and 28.36 individuals per 500 g of soil recorded at Sharkeia. The lowest numbers of soil mites (25.63 and 13 individuals per 500 g of soil) were recorded in February and January, with no significant differences observed in the two localities.

Many researchers have studied fluctuations in soil mite populations (Nour et al. 1985; Sanyal and Sarkar 1993; Shoker and Eraky 1994). The results obtained are in agreement with those obtained by Mahmoud (1999), who found that the highest density of soil mites occurred in spring and autumn, while the lowest density was observed in summer and winter. Consistent with these results, Banerjee (1988) and Krantz and Walter (2009) reported that Cryptostigmata mites (Oribatida) were the most prevalent group in heavily vegetated soil patches, outperforming other mite groups such as Mesostigmata, Prostigmata, and Astigmata. This dominance could potentially be attributed to the presence of specific host plants.

Table1. Monthly mean numbers of the soil mites inhabiting soybean cultivated season 2021, and wheat plants cultivated season 2022 at Sharkeia and Beheira governorates

Order	Location	Soybean						Wheat					
		Jun.	Jul.	Aug.	Sep.	Mean		Jan.	Feb.	Mar.	April	Mean	
Mesotigmata	**Sharkeia**	15	28.5	28.67	55.86	32.01^{b}	29.06^{b}	17.5	22	30.5	55.67	31.42^{b}	34.40^{b}
	Beheira	14.5	22.5	26.78	40.66	26.11^{b}		16.5	39.5	52	41.56	37.39^{b}	
Prostigmata	**Sharkeia**	23	25	27.5	32.5	27bc	23.63^{bc}	16.5	26	30	34	26.63^{bc}	28.94^{bc}
	Beheira	22.5	20.5	22	16	20.25^{bc}		14.5	25.5	34.5	50.5	31.25^{bc}	
Oribatida	**Sharkeia**	35.5	36.5	58.5	67.67	49.54^{a}	41.79^{a}	20.5	28	49.5	59.67	39.42^{a}	42.42^{a}
	Beheira	24	25.5	34	52.65	34.04^{a}		16.5	29.5	57	78.66	45.42^{a}	
Astigmata	**Sharkeia**	4.5	5.00	9.5	13.54	8.14^{c}	10.82^{c}	7.00	6.00	4.5	3.00	5.13^{c}	9.63^{c}
	Beheira	3.5	14.5	15.5	20.5	13.5^{c}		4.5	8	19.5	24.5	14.13^{c}	
Mean	**Sharkeia**	**19.5^{cd}**	**23.75^{ab}**	**31.04^{b}**	**42.39^{a}**	**29.17^{a}**		**15.38**	**20.50**	**28.63**	**38.09**	**25.65**	
	Beheira	**16.13$_{abc}$**	**20.75$_{ab}$**	**24.57^{b}**	**32.45^{a}**	**23.47^{b}**		**13^{cd}**	**25.63^{ab}**	**40.75^{b}**	**48.81^{a}**	**32.05^{a}**	

Means followed by different letters are significantly different at the 5% level.

The relationships between soil mites and some weather factors:

Data collected on soil mites presented on Soybean plants in Beheira governorate (Table 2 and Figure 1) showed that there was a significant negative correlation between the population of the three mite groups (Mesostigmata, Oribatida and Astigmata), r = -0.94, -0.96, and -0.79, respectively. However, it should be noted that there is significant positive correlation with the Prostigmata group (r = 0.75). Additionally, mean soil relative humidity showed significant negative correlation with the three aforementioned mite groups Prostigmata, Oribatida, and Astigmata (r = -0.93, -0.95, and -0.93), but insignificant negative correlation with Mesostigmata (r = -0.45). In contrary, when examining wheat plants with Sharkeia, significant positive correlations were observed between the population of Mesostigmata, Prostigmata, and Oribatida (r = 0.74, 0.83, and

0.94), while, significant negative correlation was found with Astigmata (r = -0.88). Additionally, the correlation between average relative humidity and mite groups revealed interesting trends. There were insignificant positive correlations between relative humidity and Mesostigmata, Prostigmata, Oribatida, and Astigmata (r = 0.33, 0.34, 0.34, and 0.29, respectively). The combination of temperature and relative humidity with soil mites in wheat soil showed a significant effect, the explained variance (E.V) ranged from 57.76 to 94.54% in Beheira governorate, and ranged from 79.38 to 99.88% in Sharkiea governorate. These results showed light on the relationships between soil mite populations, environmental factors, and different locations of wheat plants.

Statistical analysis of data on soil mites in wheat plants in Beheira governorate (Table 2 and Figure 2) recorded significant correlation between the population of the three mite groups (Prostigmata, Oribatida and Astigmata), with temperature (r = 0.97, 0.98, and 0.97, respectively). However, insignificant correlation was found with the Mesostigmata population (r = 0.58). Additionally, mean soil relative humidity showed a significant negative correlation with Prostigmata, Oribatida, and Astigmata populations, with correlation coefficients of -0.93, -0.95, and -0.93, respectively. On the other hand, insignificant negative correlation was observed with the Mesostigmata population (r = -0.45). In the case of Sharkeia wheat plants, a significant positive correlation was found between the populations of Mesostigmata, Prostigmata, and Oribatida, with temperature (r = 0.74, 0.83, and 0.94, respectively. However, significant negative correlation was observed with the Astigmata population (r = -0.88). Regarding the correlation between average relative humidity and different mite groups, a significant negative correlation was found with Mesostigmata, Prostigmata, and Oribatida, with correlation coefficients of -0.91, -0.79 and -0.95, respectively. However, significant positive correlation was observed with Astigmatism (r = 0.93). Furthermore, the analysis revealed that the combination effect of temperature and relative humidity showed a significant indicated explained variance (E.V) ranged from 92.79 to 99.28% in Beheira governorate, and ranged from 70.09 to 94.87% in Sharkiea governorate.

Table 2. Multiple and simple correlation coefficients and E.V % values between soil mite groups on soybean and wheat plants and certain climatic factors (average temperature and R.H. %) during the season of 2021/ 2022 at Sharkeia and Beheira governorates

Factors		Plant crop	Sharkeia				Beheira			
			Meso-stigmata	Pro-stigmata	Oribatid	Astig-mata	Meso-stigmata	Pro-stigmata	Oribatid	Astig-mata
Temperature	r	Soybean	-0.89	-0.97	-0.99	- 0.99	-0.94	0.75	-0.96	-0.79
		Wheat	0.74	0.83	0.94	-0.88	0.58	0.97	0.98	0.97
	p	Soybean	0.1094	0.0251	0.0071	0.0023	0.0596	0.2400	0.0305	0.2096
		Wheat	0.2534	0.1661	0.0536	0.1114	0.4124	0.0236	0.0113	0.0249
	b	Soybean	-9.61	-2.53	-10.15	-2.75	-6.86	1.67	-9.83	-2.62
		Wheat	-1.90	0.97	1.50	-0.06	19.28	7.82	12.72	4.41
R.H.	r	Soybean	0.33	0.34	0.34	0.29	0.59	-0.34	0.38	0.86
		Wheat	-0.91	-0.79	-0.95	0.93	-0.45	-0.93	-0.95	-0.93
	p	Soybean	0.6682	0.6536	0.6522	0.7097	0.4035	0.6502	0.6122	0.1380
		Wheat	0.0816	0.2070	0.0412	0.0608	0.5446	0.0663	0.0476	0.0627
	b	Soybean	0.11	0.01	0.02	-0.06	0.50	0.004	-0.25	1.03
		Wheat	-2.72	-0.15	-1.15	0.15	8.22	1.99	2.84	1.03
	E.V	Soybean	79.38	95.05	98.59	99.88	91.59	57.76	94.54	93.51
		Wheat	89.72	70.09	94.87	88.74	92.79	98.65	99.28	97.39

r = correlation, P = probability, b = slope, E.V= Explained variance (R^2 X 100)

Population fluctuation of the most dominant species of soil mites at Sharkeia and Beheira governorates:

Data presented in Figure (1) illustrated the fluctuation of mite populations among specific soil mite species associated with soybean cultivation in Skarkeia and Beheira governorates throughout the year of 2021. The population numbers varied not only from month to month but also between the two governorates. Among the observed species, *Sheloribatus laevigatus* exhibited the highest numbers throughout the season in both governorates. Conversely, *Tyrophagous putrescentiae* had the lowest population density in Sharkeia, while *Rhizoglyphus robini* held that position in Beheira. The population of *Sheloribatus laevigatus* experienced an increase from June, reaching its peak number in July, and subsequently decreased until September in both governorates.

Moving on to Figure 2, which focused on the population fluctuations of certain soil mite species associated with wheat cultivation in Skakia and Beheira governorates, it can be observed that in Sharkeia governorate, *Sheloribatus laevigatus* was the most dominant species recorded the highest number of individuals (106) in March. On the other hand, Beheira governorate recorded three dominant species, with population counts of 282, 252, and 242 in April, March, and February, respectively. The lowest population density was observed for *Dermatophagoides farinae* in Sharkeia, while *Tyrophagus putrescentiae* held that position in Beheira. The population of *Sheloribatus laevigatus* gradually increased from January, reaching its peak number in March with 106 mite individuals, then decreased in April in Sharkeia. The obtained results agree with Kalmosh and Yassin (2018) who studied the biodiversity of different soil mites associated with wheat and soybean crops during two successive seasons, they found that the oribatid and mesostigmatid mite species exhibited the highest numbers of soil mites in wheat soil followed by prostigmatid and astigmatid ones, while the lowest numbers of mites were recorded in soil cultivated by soybean plants. El-Kawas et al. (2011) examined in their study, the presence and distribution of soil mites on onion and garlic plants in Sharkeia governorate. They identified a total of 23 species belonging to four mite groups. The researchers observed that prostigmata were represented by six families, while mesostigmata were represented by five families and Oribatida by three families. The results revealed that prostigmatic and Oribatid mites were the most prevalent mite groups in onion and garlic soils, accounting 35.16% and 41.38% of the total mite species collected, respectively, Abd-Elwahab et al (2022) reported that the interaction between *M. pacifica* and soil temperature recorded highly significant differences in Zagazig district, followed by *P. geotrupi* recorded significant differences in Diarb-Nigm district (Sharkeia governorate), while *A. bilinear* recorded insignificant one. The *N. pacifica* was the most dominant species recorded during the 1st season, followed by *P. geotrupi* during the 2nd season in both districts, while *A. bilinear* was the lowest one.

Soil analysis:

The physical and chemical characteristics of soils cultivated with soybeans and wheat are presented in Table (3). Data indicated that the soil texture classes in the Beheira and Sharkeia zones are clayey, although the percentage of clay differs between the two zones. These variations in clay content can have an impact on mite populations and distribution. Overall, the soil tested had low levels of organic matter, nitrogen, potassium, and phosphorus. To improve the physical and chemical properties of the soil, it is necessary to add organic matter and the necessary fertilizers. Previous studies by Leetham and Milehunas (1985) and Zaki (1992), showed that the distribution of soil mites is influenced by two direct factors related to environmental conditions and soil quality, and indirect factors such as microhabitat selection, food availability, and presence of roots. Biomass and interactions between individuals. Additionally, Sjursen et al. (2005) reported that prostigmatic and astigmatic mite populations increased in soils with high fertilization levels when used N.P.K.

The landforms in the investigated areas were identified through a combination of Digital Elevation Models (DEM), satellite images, and land surveying techniques. Data obtained revealed that, the studied area can be divided into one main landscape unit. The selected sites were specifically chosen from the fringes of the Nile Delta, and both sites share the same geological structure, which is composed of Nile silt. The soil taxonomy in both areas also exhibits similar characteristics, as depicted. The texture of the alluvial soil is predominantly fine-textured, ranging from clay loam to clay, and the water table is found at depths between 120 and 160 cm. The depth of the soil profile varies, with the southern part of the alluvial soil having the deepest profile, while the depth decreases towards the north.

Overall, the majority of the alluvial areas in Beheira exhibited a high clay texture, ranging from 48.78% to 60.41%, and 45.6% in Sharkeia. Soils in these areas are not significantly affected by salinity, and their pH levels tend to be close to neutral. Pedological studies revealed that the parent materials of these soils are alluvial deposits located in various geomorphological positions, such as plains in both areas. From a conceptual standpoint, it is crucial to identify and understand the characteristics of these soils in order to ensure the long-term preservation of resources, particularly for field crops, which are the main agricultural activities in these areas. By focusing on both pedological and agronomical traits, it was possible to gather evidence regarding the soil qualities and characteristics that are conducive to the growth of the main crops.

In general, the area exhibited a wide range of soil types, and it is worth noting that marginal lands have traditionally been dedicated to cultivation. The alluvial soils in this region provide deep and fertile conditions for the cultivation of field crops. In this context, chemical soil qualities and effective drainage play crucial roles in determining soil quality. The findings indicated that the characteristics of the parent material and the ongoing pedogenetic processes have a significant influence on the soil order. According to soil taxonomy, the identified soil properties correspond to the presence of arid soils in the area.

Table 3: Physical and chemical properties of soil at two studied governorates.

Properties		**Beheira**		**Sharkeia**	
		Soybean	**Wheat**	**Soybean**	**Wheat**
Sand %		23.69	7.09	25.96	25.3
Sailt %		27.53	32.5	28.36	29.1
Clay %		48.78	60.41	45.68	45.6
Texture		Clay	Clay	Clay	Clay
$CaCO_3$ %		7.0	3.15	6.3	8.1
pH*		7.98	7.7	8.17	7.96
Organic matter, (g kg-1)		10.5	0.68	11.2	10.2
E.C dS/m		0.58	1.93	0.62	1.20
Available nutrient (mg/kg)	**N**	62.3	41.78	68.36	76.9
	P	11.02	2.66	12.26	14.6
	K	74.11	74.11	198	198
Soluble cations and anions, (mmol L^{-1})**	**Ca^{++}**	1.52	6.12	1.78	3.6
	Mg^{++}	1.85	3.54	0.98	4.5
	K^{+}	1.10	1.56	1.33	1.5
	Na^{+}	2.45	8.17	2.11	2.4
	Cl^{-}	2.45	10.11	2.91	3.4
	HCO_3^{--}	1.95	0.85	2.27	4.5
	SO_4^{--}	1.40	8.43	1.12	4.1

*** Soil-water suspension 1: 2.5** **** Soil water extract 1: 5**

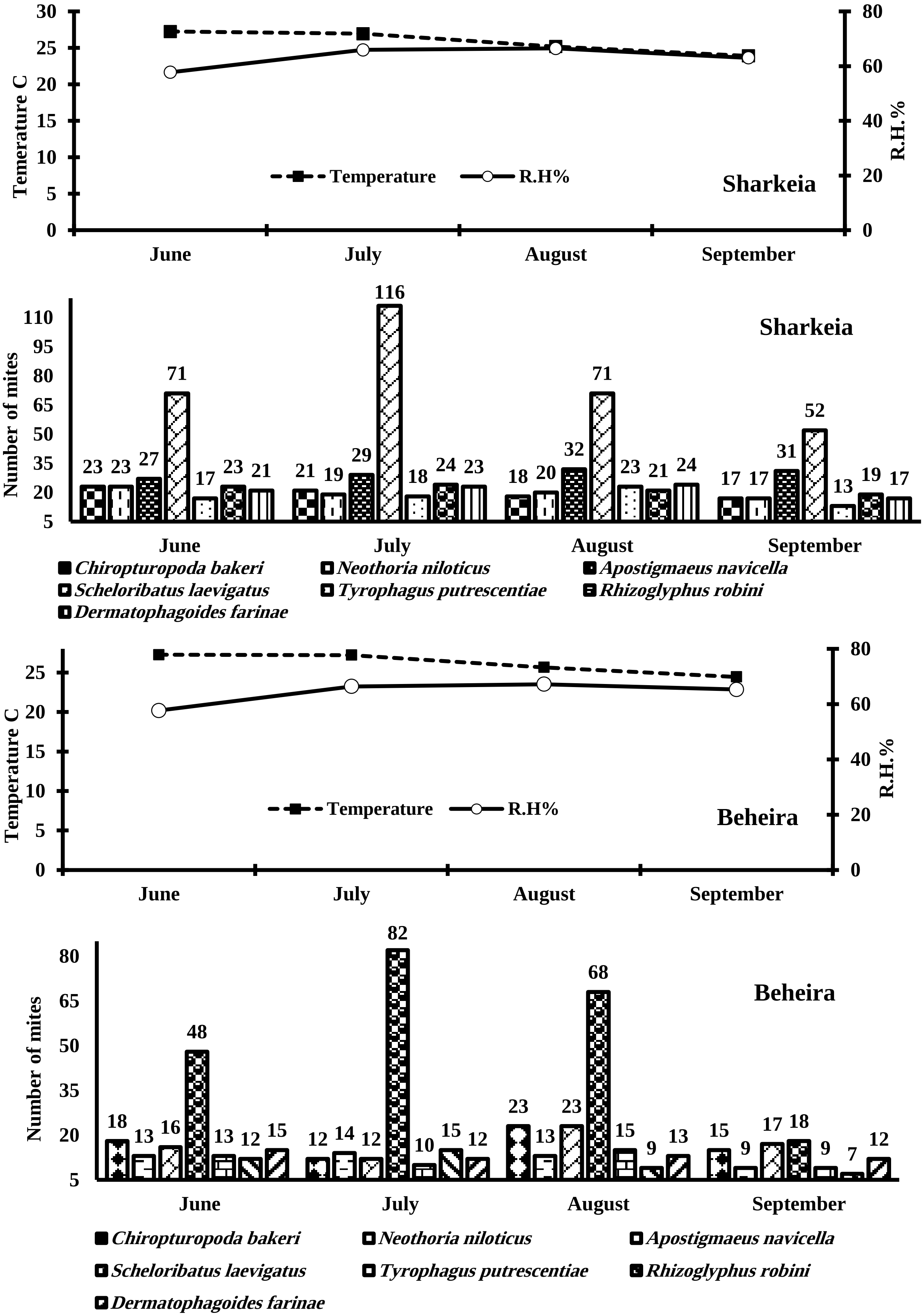

Figure 1. Population fluctuation of soil mite species at Sharkeia and Beheira in Soybean crops.

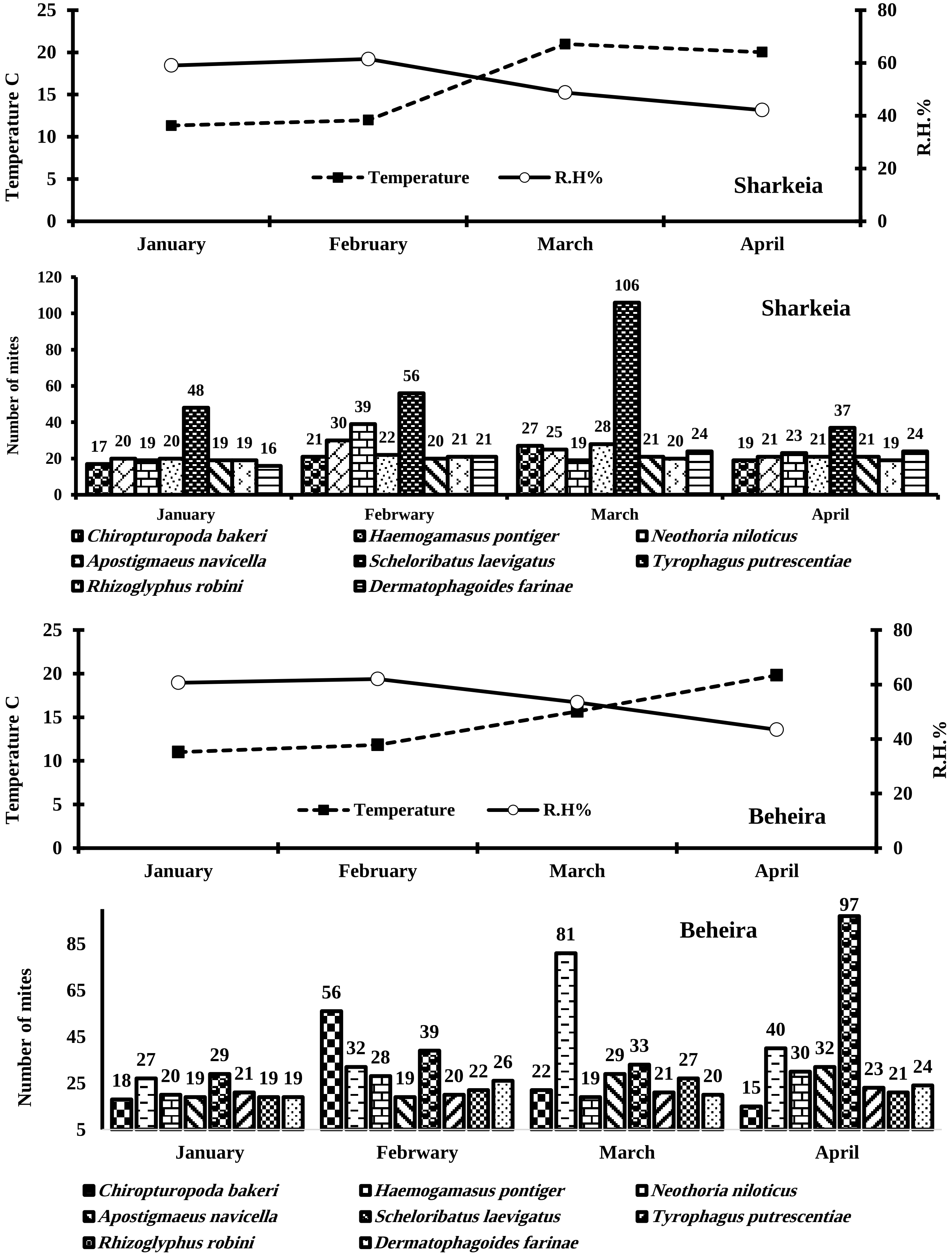

Figure 2. Population fluctuation of soil mite species at Sharkeia and Beheira on wheat crops.

The application of fertilizers, the leaching of nutrients, and the continuous practice of agriculture have a significant impact on the properties of soil in croplands. To prevent the degradation of these cultivated soils, it is crucial to address these effects through adequate and forward-thinking farming techniques. Decisions regarding soil management should consider all relevant research factors to ensure sustainable and productive agricultural practices.

There is a prevalent scarcity of primary nutrients, soil secondary nutrients, and micronutrients. To uphold and improve soil carbon levels, it is recommended to implement soil management techniques such as conservation tillage, crop residue management and incorporation, and soil conservation practices. These measures will not only address nutrient deficiencies but also enhance soil health. Additionally, the use of chemical fertilizers containing nitrogen (N), phosphorus (P), sulfur (S), boron (B), and copper (Cu) is advised. In areas where potassium (K) shortages are induced by magnesium (Mg), the application of K fertilizer is recommended. Furthermore, further investigation will be conducted to determine crop- and variety-specific nutrient delivery rates. Currently, landform is considered the primary aspect of unit management in agricultural practices.

CONCLUSIONS

The results of the current study indicated that the abundance and variation of soil mites depend on the cultivated crop plant. The oribatid mite, *Sheloribatus laevigatus*, was the most abundant species in soil cultivated with the two crop plants (soybean and wheat) in both of the studied locations. The physical and chemical properties of this soil indicated the highest values of organic matter, resulting in high soil fertility in Sharkeia governorate during the cultivation of soybeans and wheat. These findings show the important role of soil mites as the best bio-indicator in terms of soil quality and soil health.

ACKNOWLEDGEMENTS

The authors thank Prof. Abdeen Khalil, Plant Protection Research Institute, A.R.C., Dokii, Giza, Egypt, for his help in classifying the mite species collected through the current study. We are also grateful to Prof. Edward Ueckermann (Forestry and Agricultural Biotechnology Institute, University of Pretoria, South Africa), and Prof. Sayed Eraky (Plant Protection Department Faculty of Agriculture, Assiut University) for reviewing the earlier draft of the manuscript and for constructive suggestions in the manuscript.

REFERENCES

Abd-Elwahab A, Kandee M, Omar N. 2022. Population dynamics of soil mites inhabiting under wheat at Sharkeia governorate, Egypt. *Journal of Productivity and Development*, 27(4), 463–475. DOI:10.21608/jpd.2022.296462

Abo-Korah SM, Osman AA. 1979. Seasonal variation of mites population density under certain field crops. 3rd Pest Conf. *Tanta Univ*ersity, 1, 377–381.

Abou-Setta MM. 2020. Nutritional ecology bridgesthe gap between mites' biological and ecological research results under Mediterranean environment. *ACARINES: Journal of the Egyptian Society of Acarology*, 14:45–52. DOI: 10.21608/ajesa.2020.180888

Alatalo JM, Jägerbrand AK, Juhanson J, Michelsen A, Ľuptáčik P. 2017. Impacts of twenty years of experimental warming on soil carbon, nitrogen, moisture and soil mites across alpine/subarctic tundra communities. *Scientific Reports*, 7(1), 44489. DOI: 10.1038/srep444.

Amani M, Khajehali J, Moradi-Faradonbeh M, Macchioni F. 2020. Species diversity of soil mites (Acari: Mesostigmata) under different agricultural land use types. *Persian Journal of Acarology*, 9(4), 353–366. DOI: 10.22073/pja.v9i4.59610

Anderson JM, Ingram JS. 1994. Tropical soil biology and fertility: a handbook of methods. *Soil Science*, 157(4), 265. DOI:10.2307/2261129.

Banerjee S. 1988. Distribution of acari in relation to soil conditions in 24-parganas, west Bengal, India. *Progress in Acarology*, 7(1), 451.

Behan VM, Hill SB, Kevan DM. 1978. Effects of nitrogen fertilizers, as urea, on Acarina and other arthropods in Quebec black spruce humus. *Pedobiologia*, 18(4), 249–263.

Costat statistic Software 2005. Microcomputer program analysis. Version, 6.311. CoHort Software, Monterey, California.

Critchley W, Harari N, Mollee E, Mekdaschi-Studer R, Eichenberger J. 2023. Sustainable Land Management and Climate Change Adaptation for Small-Scale Land Users in Sub-Saharan Africa. *Land*, 12(6), 1206. DOI: 10.3390/land12061206.

Crossley Jr DA. 1977. The roles of terrestrial saprophagous arthropods in forest soils: current status of concepts. *In*: *The role of arthropods in forest ecosystems* (pp. 49–56). Berlin, Heidelberg: Springer Berlin Heidelberg. DOI: 10.1007/978-3-642-88448-1_6.

Ducarme X, Lebrun P. 2004. Spatial microdistribution of mites and organic matter in soils and caves. *Biology and Fertility of Soils*, 39, 457–466. DOI: 10.1007/s00374-004-0730-x.

El-Kawas HM, Mead HM., El-Sharabasy HM. 2011. Occurrence of Soil Mites in Relation to Soil Analysis at Sharkeia Governorate. *ACARINES: Journal of the Egyptian Society of Acarology*, 5(1), 41–46. DOI:10.21608/ajesa.2011.163607.

Embarak MZ, Aiman K, Abou El-Saad. 2010. Survey of insects and mites inhabiting leaves and soil of Lantana camara L. in Assiut Governorate. *Assuit University Bulletin for Environmental Researches*, 13(1), 35–44.

Evans GO. 1992. *Principles of Acarology*. C.A.B. International Walling Ford, 522pp.

Frouz J, Ali A, Frouzova J, Lobinske RJ. 2004. Horizontal and vertical distribution of soil macroarthropods along a spatio-temporal moisture gradient in subtropical Central Florida. *Environmental entomology*, 33(5), 1282–1295. DOI:10.1603/0046-225X-33.5.1282.

Gilyarov MS. 1975. *An Identification Keys of Soil Living Mites (Sarcoptiformes*). Science, Moscow.491pp. (In Russian).

Hairiah K, Williams SE, Bignell D, Swift M, van Noordwijk M. 2001. Effects of land use change on belowground biodiversity (p. 32). ICRAF.

Heneghan L, Coleman DC, Zou X, Crossley Jr DA, Haines BL. 1999. Soil microarthropod community structure and litter decomposition dynamics: a study of tropical and temperate sites. *Applied Soil Ecology*, 9(1–3), 33–38. DOI: 10.2307/176665.Hinga G, Muchena FN, Njihia CM. (Eds.) 1980. Physical and chemical methods of soil analysis. *National Agricultural Research Laboratories, Nairobi, Kenya*.

Hou D, Bolan NS, Tsang DC, Kirkham MB, OC'onnor D. 2020. Sustainable soil use and management: An interdisciplinary and systematic approach. *Science of the Total Environment*, *729*, 138961. DOI: 10.1016/j.scitotenv.2020.138961.

Kalmosh FS. Yassin EM. 2018. Biodiversity of soil mites associated with wheat and soybean crops in Sharkeia and Beheira Governorates. *Egyptian Journal of Agricultural Research*, 96(3), 955–965. DOI: 10.21608/ejar.2018. 138820.

Kethley JB. 1990. Acarina: Prostigmata (Actinedida). *Soil biology guide*, pp. 667–756.

Krantz GW, Walter DE. 2009. *A Manual of Acarology*. Texas Tech UniversityPress, 807 pp.

Mahamoud NA. 1999. *Ecological and toxicological studies on some groups of soil fauna*. Ph.D. Thesis, Faculty Agriculture, Al-Azhar University, 232pp.

Leetham JW, Milehunas DG. 1985. The composition and distribution of soil microarthropods in the shortgrass steppe in relation to soil water, root biomass and grazing by cattle. *Pedobiologia*, 28, 311–325. DOI:10.1016/s0031-4056(23)06597-6.

Nour AH, Maareg MF, El-Manhaly MA. 1985. Studies on the soil fauna of sugar crops. Part I: Number and category of the soil arthropods fauna in sugar cane fields. P*roc. 6th Arab Pesticide Conf. Tanta University*, 11, 391–405.

Page AL, Miller RH, Keeney DR (Eds.). 1982. Methods of soil analysis. Part2. 2nd ed Madison Winconsin, USA, *American Society of Agronomy*, 595–622pp.

Potapov AM, Beaulieu F, Birkhofer K, Bluhm SL, Degtyarev MI, Devetter M, Scheu S. 2022. Feeding habits and multifunctional classification of soil-associated consumers from protists to vertebrates. *Biological Reviews*, 97(3), 1057–1117. DOI: 10.1111/ brv.12832.

Sanyal AK, Sarkar BJ. 1993. Ecology of soil oribatid mites in three contrasting sites at botanical garden, Howrah, West Bengal. *Environment and ecology. Kalyani*, 11(2), 427–434.

Seastedt TR. 1984. Microarthropods of burned and unburned tallgrass prairie. *Journal of the Kansas Entomological Society*, pp.468–476. http://www.jstor.org/stable/25084545.

Shoker NI, Eraky SA. 1994. Incidence of some predaceous mesostigmatid mite species at animal farm, Assiut, Upper Egypt. *El-Minia Sciences Bulletin*, 7(1), 57–65.

Sjursen H, Michelsen A, Jonasson S. 2005. Effects of long-term soil warming and fertilisation on microarthropod abundances in three sub-arctic ecosystems. *Applied Soil Ecology*, 30(3), 148–161. DOI: 10.1016/j.apsoil. 2005.02.013.

Steffen JF, Palincsar J, Funk FM, Larkin D J. 2012. Activity and diversity of Collembola (Insecta) and mites (Acari) in litter of a degraded midwestern oak woodland. *The Great Lakes Entomologist*, 45(1 -2), 1.-18. DOI: 10.22543/0090-0222.2234.

Tousignant S, Coderre D. 1992. Niche partitioning by soil mites in a recent hardwood plantation in Southern Quebec, Canada. *Pedobiologia (Jena)*, 36(5), 287–294.

Walia KK, Mathur S. 1994. Acarine fauna of arable soils and their screening for nematophagy. *Indian Journal of Nematology*, 24(1), 69–79.

Walter DE, Proctor HC. 1999. *Mites: Ecology, Evolution, and Behaviour*. Springer, Dordrecht, Netherlands, 494.

Wasylik A. 1978. The mites (Acarina) of potato and rye fields in the environs of Choryn. *Polish Ecological Studies*, 1, 83–91.

Woods FW. 1960. Biological antagonisms due to phytotoxic root exudates. *The Botanical Review*, 26, 546–569.

Yin X, Gong T, Liu W, Chen H, Fei Y. 2023. Community structure of soil mites under different crops and its response to environmental factors in the buffer zone of Shibing Karst World Natural Heritage. *Environmental Research Communications*, 5(6), 065004. DOI:10.1088/2515-7620/ acda1b.

Zaher MA. 1986a. *Survey and ecological studies on phytophagous, predaceous and soil mites in Egypt. I- Phytophagous mites in Egypt (Nile valley and Delta)*. PL-480 Program. USA Project No. EG- ARS-30. Grant No. FGEG-139, 228 pp.

Zaher M.A. 1986b. *Survey and Ecological Studieson Phytophagous, Predaceous and Soil Mites in Egypt. II-A: Predaceous and Nonphytophagous Mites (Nile Valley and Delta)*. Text. PL 480 Programme U.S.A., Project No. EG-ARS-30, Grant No. FGEG-139, 567 pp.

Zaki AM. 1992. Population dynamics of mites associated with some stone fruit trees in Menoufia, Egypt. *Acta phytopathologica et entomologica hungarica*, *27*(1-4), 679– 685.

Zhou Y, Wei Q, Xiao N, Huang J, Gong T, Fei Y, Chen H. 2022. Characteristics of soil Mites communities structure under vegetation vertical gradient in the Shibing World Natural Heritage Property, China. *Forests*, 13(4), 598. DOI:10.3390/f13040598.