 doi:10.20944/preprints202202.0190.v1

Article

Arthropods in Two Organic Agro-Ecosystems; Biodiversity, Distribution, and Weeds Impacts

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Abstract: Due to a lack of knowledge about arthropod biodiversity in Egyptian organic agro-ecosystems; the study aimed to introduce information on the diversity, richness, and distribution of insect and mite species in two organic agro-ecosystems, also, to investigate the impact of plant-arthropod interactions. Samples collected from two organic farms, i) Shampoliah farm, Fayoum (GCS 29°21'07.4"N 30°44'17.8"E), and ii) SEKEM farm, Sharkia (GCS 30°22'56.1"N 31°39'17.4"E). Results shown 39 species recorded in Shampoliah farm, and 35 species in SEKEM of mite, insect, medicinal, and weed species. When 14 species shared among two cites. Study has measured the H', D and 1/D indices within each location, and the similarity/dissimilarity between locations. The study hypothesized the possible plant-arthropod interactions that explain why diversity differs from an ecosystem to another; due to; plant size, plant morphological characters, soil fertilization, plant nutritional content, and the prey-predator interactions. The added hypothesis; is to show that the importance of natural habitat is supporting natural enemies and distribution of arthropods, which could vary dramatically with the type of pest species, IPM, and landscape type considered.

Keywords: mites; insects; trophic relation; plant-arthropod interactions; SEKEM; fayoum

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Introduction

In Africa, there are two million hectares of certified organic agricultural land area. According to the Research Institute of Organic Agriculture FiLB; the first three countries with the most organic land area are; Tunisia (286,623 hectares), Tanzania (278,467 hectares), and Ethiopia (221,189 hectares) (FiLB, 2021). While, Egypt is in the top ten (116,000 hectares), and the fourth of the countries with the highest organic share of total agricultural land in 2019. In Egypt, the official information about the actual organic agricultural size is very scarce. According to the FiLB and The International Federation of Organic Agriculture Movements (IFOAM) reports from 2016 to 2019; the distribution of total organic land area among Egypt's governorates, Behera Governorate is the largest area (29,972 hectares), and Fayoum Governorate is the second (27,218 hectares), both governorates representing more than half of Egypt's total organic area (54%). While, Ismailia, New Valley, Beni Suif, Menia, Sharkia, and Sohag governorates are sharing about 15%. Medicinal and ornamental plants were representing 26.5% of the cultivated organic products (28,066 hectares) (Siam and Abdelhakim, 2019).

The official Egyptian biodiversity website stated that there is more than 15,000 insect species and more than 1,500 arachnid species of mites, ticks, scorpions and spiders as terrestrial fauna, and more than 1,800 invertebrate species in aquatic fauna (Available at: https://www.egyptheritage.com/BiodiversitySite/Biodiversity/index.html). Nevertheless, some studies have revealed arthropod biodiversity in different Egyptian agro-ecosystems (Abo-Shnaf *et al*., 2008; Sallam *et al*., 2010; Sawaby, *et al*., 2010; El-Sanady and Mohamed, 2013;

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Imam and Sawaby, 2013 a & b; Zaki *et al*., 2015; Abd El-Karim, *et al*., 2016; Abo-Shnaf *et al*., 2016; Rizk, *et al*., 2017; Zaki and Aly, 2018; 2019; Zaki and Abo-Shnaf, 2018; El-Sheikh, *et al*., 2020; Zaki, 2021). Also, genera of phylum Nematoda, *Meloidogyne* Göldi, 1889 was the most dominant genus, and *Xiphinema* Cobb, 1913 was the rarest genus recorded in SEKEM (Adam *et al*., 2013). Few studies indicated the definite biodiversity indices to understand the actual arthropod community's structure.

Biological diversity measured in two ways; actual and perceived biodiversity (Magurran, 2013), and recently there is a conceptual hypothesis of different pathways linking biodiversity to human health (Marselle *et al*., 2021). In addition, the agro-ecosystem (economic crops) and the surrounding landscape (spontaneous plants) are relevant to biodiversity conservation. That, the presence of various weed species contributes to informal biodiversity, even, in urban greenspaces (Phillips and Lindquist, 2021).

Organic agriculture supports the conservation of biodiversity, when arthropod (insects and mites) species richness and abundance in organic agricultural eco-systems increased, as well as, the richness of species within trophic guilds (phytophagous, predators, pollinators, and parasitoids) (Underwood *et al*., 2011). Thus, both the faunal and/or floral biodiversity in an agroecosystem have significant impacts on biodiversity conservation, contributing to ecosystem functioning, the recycling of nutrients, integrated pest management applications, and increasing crop health and productivity (Bengtsson *et al*., 2005; Tropek *et al*., 2010; Simoni *et al*., 2013; Montañez and Amarillo-Suárez, 2014; Gardarin *et al*., 2018; Alistair *et al*., 2021).

It was a shred of evidence in soil biodiversity and distribution, when Oribatida, Astigmata, Prostigmata, and Mesostigmata have the largest differences among different aged Italian organic farms (Simoni *et al*., 2013). Arthropod community structure varied across flowering plant species; it has resulted that a single flower species attracted a different group of beneficial arthropods, similarly, a mixture of plant species could attract several arthropod taxa (Bennett and Gratton, 2013). Therefore, the study was aimed to introduce new information about insect and mite species diversity in the Egyptian organic agro-ecosystems and to hypothesized new understanding of the Arthropod-Plant interactions.

Material and Methods

Locations

Samples were collected from two certified organic farms on Egypt, i) SEKEM farm, Sharkia Governorate (GCS 30°22'56.1"N 31°39'17.4"E), and ii) Shampoliah farm, Fayoum Governorate (GCS 29°21'07.4"N 30°44'17.8"E) (fig. 1: a, b & c).

Sampling

Fresh samples of different medicinal plant species were collected randomly. Samples of leaves, roots, debris, and weeds were collected bimonthly for each location, from Sep 2015 to May 2016 shown in Table 1. Samples were packaged in plastic coded bags and transferred to the laboratory for extraction. Extraction by modified Tullgren funnels, individuals were collected by fine brush, mounted on modified Hoyer's media. Specimens were dried for clearing and microscope identification.

Specimens confirmation

Mite specimens recognized and confirmed by Dr. A.K. Nasr, Pests and Plant Protection Department, NRC, and Dr. A.S. Sanad, Plant Protection Research Institute, Agricultural Research Center (ARC). Insect collections were confirmed by the Entomology unit in both the Faculty of Agriculture, Cairo University, and the Pests and Plant Protection Department, NRC. Weeds were identified and confirmed by Dr. B.A. Bakry, Field Crop Department, NRC.

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Statistical analysis

The number and abundance of each species per sample were used to estimate the species richness. Biodiversity Shannon-Wiener index (H'), Simpson's index (dominance D and species richness 1/D), and the similarity index between locations (Jaccard's index) were calculated for all samples using the BioDiversity Pro. ver. 2.0 software (McAleece *et al.*, 1997) and PAST ver. 4.03 software (Hammer *et al.*, 2001). Differences in the mean number of species within site and/or among the sites were evaluated using one-way analysis of variance (ANOVA) and were tested with Tukey's test at 95% confidence level using SPSS computer program ver. 20.0.

To compare the similarity (and dissimilarity) between the experimental location, Jaccard index (J') was applied following Jaccard, (1912); $\boldsymbol{SJ} = \frac{c}{(a+b+c)}$, and the coefficient of the community (CC) following Sørenson, (1948); $\boldsymbol{CC} = \frac{2c}{(a+b+2c)}$ where *c* is the number of shared species between two locations, and *a* and *b* are the number of species unique to each site.

Results

A Kruskal-Wallis test was conducted to detect the significant differences of the current study. Null hypothesis H_0 suggested that there is no significant differentiation of taxa diversity among selected organic locations. The alternative hypothesis H_1 was; there is significant differences in the diversity of living organisms among selected locations of the study. H_1 was accepted according to the collected sample results of the two experimental locations, there were significant impacts of fauna, flora distribution, and the diversity indices of resulted taxa.

Eleven weed species of seven families resulted in Shampoliah location (Table 2). While nine weed species belonging to six families found in SEKEM location (Table 3).

1. Biodiversity indices and distribution in Shampoliah Farm

The distribution of mites and insects was significant within plant samples. There were diverse groups of mites existed in Shampoliah farm; phytoseiid mites were represented by four genera, *Amblyseius* Berlese, 1914, *Cydnoseius* Muma, 1967, *Phytoseius* Ribaga, 1904, and *Typhlodromus* Scheuten, 1857. These genera presented in five predatory mite species in medicinal and weed plants. *Amblyseius swirskii* Athias-Henriot was in low distribution on eight plant samples (s= 8, χ^2 =194.354, *T*= 5.000, *P*=0.002). The diversity indices referred to moderate abundance and species richness (D=0.160, 1/D=6.250, H' =1.931), however, it was the highest number of phytoseiid individuals found (113 specimens/samples).

The rarest species recorded was *Aceria dioscorides* (Soliman and Abou-Awad), found on Ploughman's spikenard *Pluchea dioscoridis* (L.) DC., the eriophyid mite recorded the highest dominance and richness indices, with no diversity index (H') recorded, however, its highest number of individuals (900 specimens/ single sample, *T*=1.000, *P*=0.332). (Tables 3 & 5).

The lowest dominance (D) recorded was *Tydeus californicus* (Banks)= 0.078 which distributed over 14 plant samples, and different in habitat (soil, debris, leaves, and some weeds), found in few numbers (33.00 ± 2.70 specimens/sample, *T*=12.207, χ^2=147.939, *P*=0.000, 1/D=12.877, H' =2.588, evenness= 0.951) (Table 5).

The highest distribution recorded by *Orius* sp which collected on 15 plant samples, resulting in low dominance (D=0.090) and high species richness (1/D) =11.121, low diversity index H'=2.443, (χ^2=422.340, *T* =11.800, *P*= 0.000) at the probability level =95% (Table 5). Similar result was observed in *B. tabaci* (D= 0.090, $\chi 2$=117.534, t=6.348, *P*=0.000) distributed on 12 samples, oribatid mite species *Zygoribatula syidi* (S=14, D=0.091, $\chi 2$=17.192, t=6.870, *P*=0.000), acarid mite species *Tyrophagous* sp (S=12, D=0.096, $\chi 2$=260.983, t=8.38, *P*=0.000), the Collembola (S=12, D=0.096, t=8.352, *P*=0.000), and the mesostigmatid species

Cosmolaelaps keni Hafez, El-Badry and Nasr (S=13, D=0.090, $\chi 2$=52.970, t=8.308, *P*=0.000) (Tables 7, 8 & 9).

Shampoliah location has much diversity of plant species, the most diverse records of arthropods was on the nettle-leaved goosefoot *C. murale* (S=21), low dominancy (D=0.106) highest species richness (1/D)= 9.421, highest diversity index H'=1.092 ($\chi 2$=1086.585, *P*=0.000), A similar result in case of Slender amaranth *A. viridis* (Amaranthaceae), 860 individual representing 18 taxa of mite and insect species were found on the *A. viridis* habitat whether on the plant itself or in debris and soil (H'=1.049, D =0.114, 1/D =8.783, $\chi 2$=131.549, *P*=0.000). The highest distribution recorded on *A. viridis* in case of *Cenopalpus* sp (Tenuipaplidae), *T. urticae* (Tetranychidae) *Aphis* sp (Aphididae) and *B. tabaci* (Aleyroididae) (Tables 3, 4 & 5).

Oppositely, the lowest arthropod distribution recorded in case of the camel-thorn *A. maurorum* (Fabaceae), only five species recorded, *Laelaspis astronomicus* (Koch) (Laelapidae), *Z. syidi* (Oribatulidae), and *Collembola* sp (Collembolla), and the highest dominance recorded was (D= 0.216), $\chi 2$=414.528 at a probability level of 95%. Fleabane *C. aegyptiaca* recorded the second lowest place in arthropod distribution, eight species representing seven families, (4 mite families and 3 insect families), diversity indices were significantly recorded as D=0.153, 1/D=6.54, H'=0.849, $\chi 2$=476.887, *P*=0.000 (Tables 3, 4 & 5).

2. Biodiversity indices and distribution in SEKEM farm

The diversity indices of arthropods in both medicinal and weed plants were significantly differed; the highest (D) value recorded in case of Egyptian crowfoot grass *Dactyloctenium aegyptium* (L.) Wild. (Poaceae) (D= 0.388) representing by ten species of mites and insects, followed by the Common Cocklebur *Xanthium strumarium* L. (Astraceae) (D = 0.301) represented by eight arthropod species, while the lowest dominance record was Salvia *S. divinorum* (D= 0.146). Oppositely, Salvia recorded the highest species richness (Simpson index 1/D) which was 6.829, and the lowest was resulted in case of *D. aegyptium* (1/D= 2.575) (Tables 6 & 7).

Arthropod taxa and individual distribution gave significant interactions within plant samples. In case of *L. astronomicus* (0.81 ± 0.23 specimens/sample, D= 0.136, 1/D= 7.348, H'= 2.098, χ^2= 15.308), presented on nine plant samples in few numbers. *Kleemania* Oudemans 1930, found on five plants with few numbers (1.00 ± 0.00 individual/sample, D= 0.200, 1/D= 5.000, H'= 1.609, χ^2 = 11.000), and *Collembolla* Lubbock, 1871 which found on 13 samples, represented by 29 individuals (D= 0.106, 1/D= 9.452, H'= 2.384, χ^2= 20.103). These three genera have no significant impact within plant samples on the probability level of 95% (Tables 8 and 9).

The heights mean number of individuals recorded was 18.13 ± 6.67 specimens/sample, in case of *Aphis* sp which found in eight samples (D= 0.189, 1/D= 5.283, H'= 1.828, χ^2= 588.235) at $P \leq$ 0.05, *T. urticae* recorded 12.13 ± 6.38 individual/sample found in five plant leaves with few, moderate and high distribution (D= 0.322, 1/D= 3.108, H'=1.292, χ^2=804.433, *P*= 0.000).

Although, *Typhlodromus* sp1 (11 specimens, 4 samples), *Oldealaps* sp (14 specimens, 5 samples), *Spinibdella* sp (14 specimens, 5 samples), *Amblyseius* sp1 (27 specimens, 8 samples), *Amblyseius* sp2 (23 specimens, 6 samples), *Parasitus* sp (34 specimens, 5 samples) and *Hemicheyletia wellsina* (27 specimens, 6 samples) were found in few numbers and narrow distribution, but were significantly different among the whole community (χ^2 = 39.91, 38.57, 86.57, 39.96, 48.65, 141.06, and 76.70, respectively) at $P \leq 0.05$ (Tables 8 and 9).

3. Similarity index between experimental locations

Jaccard index (J') and Sørenson coefficient of community (CC) were applied, where the total species recorded in the Shampoliah farm was 39 species of mite, insect, medicinal, and weed species, and SEKEM was 35 species. Shared species were 14 species, and the similarity indices were J'= 0.233, and CC= 0.378 (Table 10).

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Few immatures belonging to Oonopidae, Simon, 1890, and only one individual of wasp spider *Argiope* Audouin, 1826 (Araneidae: Araneae) found during the experiment was running (Appendix). Also, ants, beetles, lacewing eggs, caterpillars, and bees were observed while sampling, but were statistically ignored.

Discussion

It is hard to find an individual species/organism within an ecosystem in nature (BBC https://www.bbc.co.uk/ bitesize/guides/zctwgdm/revision/5; Malmstrom, 2010). Simpson's index (D) measures community diversity, it's value ranges from 0 to 1, which the larger the value, the lower the diversity (Magurran, 2013; Kiernan, 2020). It giving evidence, when an only species with no diversity; the eriophyid mite *A. dioscorides*, that found in huge numbers (900.00 ± 0.00, *P*= 0.332) on *P. dioscoridis*. Eriophyid mites have specialization to their hosts, also, *A. dioscorides* feeding on plant tissues causes galls in the plant, these galls are considered shelters to protect the phytophagous eriophyid away from natural enemies and to guarantee maximum feeding source (Jeppson *et al*., 1975; Lindquist *et al*., 1996), so that, this would explain why this species found in huge numbers with no diversity indices.

The diversity indices H', D, and 1/D values indicating diversity within a tested location. We are usually interested not just in the biodiversity of a single site, but also in comparing biodiversity levels across sites. Also, measuring the similarity between two sites would help to understand the fraction of species they share (Magurran, 2013).

The differences in an arthropod community hypothesized that numbers, diversity, and biology may be affected by different impacts such; host plant nutritional contents, morphological, and domatia structure of organic plant cultivars (Akyazı *et al*., 2021; Abou-Elella *et al*., 2021). It should be noted that a single factor is not responsible for the abundance and diversity of arthropods but the combination of factors. Since the effect of cultivars on the mite population is time-consuming, such results caould only observed in the long term (Camporese and Duso, 1996; Krips *et al*., 1999; Kretier *et al*., 2002; Ali *et al*., 2015).

It was noticed that old organic farms are characterized by fewer individuals and taxa than young ones. It was suggested that arthropod communities in the old system, reached their maximum balance, the abundance of specimens and biodiversity tended to be lower than in the younger systems. To accept this hypothesis, it is required to have more information about soil nutrient analysis, plant-arthropod relations, farming systems, and biogeographical distribution (Simoni *et al*., 2013).

Spontaneous plants have wide dispersal and common distribution in all eco-systems (Neto *et al*., 2015; Deghiche-Diab *et al*., 2016; 2020), but do they consider pests for crops? Weeds are good habitat for predacious species (Valdes, 2016), some researchers studied how weeds could be a good refuge for predators, however, they are carrying various phytophagous pests (less in importance), this mini-environment called the "Banker plant" (Parolin *et al*., 2001 and 2002; Xiao *et al*., 2012).

To accept this hypothesis, we measured the diversity indices of weeds; which are shared among two locations. Cheese weed *M. parviflora,* has the highest species diversity indices in SEKEM (S= 16, total individuals= 307 individuals, D= 0.217, 1/D= 4.614, H'= 0.788) (Table 7), while the nettle leaf goosefoot *C. murale* was the highest in Shampoliah (S= 21, total individuals= 799 individuals, D= 0.106, 1/D= 9.421, H'= 1.092) (Table 4) (fig. 2). These plants were rich in their arthropod community; however, their trophic group, either predator or phytophagous species was recorded, but the density of populations were not the same (Tables 3 & 8). Also, their distribution along experimental cites borders and overlapping with the medicinal crops, would definitely help increasing the arthropod distribution that measured (Appendix). Similar indices of *A. viridis*, *P. major* in both locations of our study, were resulted in case of Quinoa *Chenopodium quinoa* Willd. (Deghiche-Diab *et al*., 2021), and the findings of Bennet and Garton (2013), and Deghiche-Diab *et al*., (2016 & 2020).

The study hypothesized understanding the Arthropod-Plant interactions; which suggested based on soil fertilization effect. Using organic fertilizers (manure) could adjust the available micronutrients by changing both physical and biological characteristics of either the plant or the soil; organic fertilization increasing P levels in soil, which caused an increase in protein, K, Fe, Mn, and Zn in plant contents (Zeidan and EL Kramany, 2001; Zeidan, 2007; Zeidan *et al*., 2010), which led to increasing in mite diversity (Abo-Shnaf *et al*., 2016). Plants in the organic systems have better predacious mite species richness and distribution (El-Banhawy *et al*., 1998). Plant size; the hypothesis suggested that large sized plants are more attractive for correlative species richness of arthropods (predacious or phytophagous) than smaller plants (Schlinkert *et al*., 2015).

Although, there is several Egyptian literatures dealt with insect, mite, and spider species biodiversity, but these studies do not discuss the actual plant-arthropod relations, neither di-trophic (plant-herbivore) nor tri-trophic (plant-predator-herbivore) relations. Interactions been also suggested; the plant responds to phytophagous activities, by producing volatiles that attract predators (McCormick *et al*., 2012). Also, duo to plant morphological characters (Lawton, 1983). Some changes in Nitrogen contents with ammonium nitrate stimulated the fecundity of the whitefly *B. tabaci*, which attracted more individuals to oviposit on treated plants. Nitrogen fertilization may decrease plant resistance to insect pests by improving the nutritional quality of host plants and reducing the secondary metabolite concentrations (Bentz *et al*., 1995; Yardım and Edwards, 2003). Nutritional contents of plants in organic ecosystems have positively increased. Increasing in Nitrogen (N), Phosphor (P), Potassium (K), Sodium (Na), and Calcium (Ca), had significantly affect the life table parameters and biological behaviors of *T. urticae*, which may reflect on the prey-predator relations (Ali *et al*., 2015; Abou-Elella *et al*., 2021).

Conclusion

In conclusion, there are many examples in the literature where the amount and configuration of natural/organic and semi-natural biodiversity in agro-ecosystems could help to enhance pest control and reduce the probabilities of pest outbreaks. In the current study we could proposed explanations for the faunal and floral diversification. The added hypothesis; is to show that the relative importance of natural habitat (organic ecosystems) is supporting natural enemies and natural pest control, which could vary dramatically with the type of crop, pest species, habitat, management designed, and landscape type considered. The Shannon-Wiener (H'), and Simpson (D and 1/D) values indicating diversity within a tested location. We are interested not just in the biodiversity of a single site, but also in comparing biodiversity levels across sites. Also, measuring the similarity/dissimilarity between experimental sites, which helps to understand the fraction of species they share. A further study needed to detect the climate change impacts through 5-10 years in the same tested locations, to find if the population structure, taxa variability, and the biodiversity indices had changed.

Disclosure

Funding: This study has funded by The National Research Centre (NRC).

Conflicts of interest: The authors declare that they have no conflict of interest.

Acknowledgments: The authors are like to express their deep gratitude and respect to Prof. Abdel Rady K. Nasr, Pests and Plant Protection Department, NRC, and Dr. Ahmed S. Sanad, Plant Protection Research Institute, Agricultural Research Center (ARC), for their help in mites group identification. Thanks are due to Dr. Bakry A. Bakry, Field Crop Dept., NRC for identifying and confirming the weed collections. Thanks also due to SEKEM, and the Association of Small Crops and Biological Products (Kamal Shampoliah) management for their help while this study was running.

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Table 1. Samples of the medicinal plants collected of the experimental organic locations.

Plant name	Scientific name	Family	Sampling parts	Location
Moringa	*Moringa oleifera* Lam.	Moringaceae	leaves, weeds, debris, soil	2
Pot marigold	*Calendula officinalis*	Asteraceae	leaves, weeds, debris, soil	1, 2
Chamomile	*Chamaemelum nobile* (L.) All.		leaves, weeds, debris, soil	1, 2
Lemongrass	*Cymbopogon schoenanthus* (L.) Spreng.	Poaceae	leaves, weeds, debris, soil	2
Sage	*Salvia officinalis* L.	Lamiaceae	leaves, weeds, debris, soil	2
Basil	*Ocimum basilicum* L.		Total herb, weeds	2
Spearmint	*Mentha spicata* L.		Total herb, weeds, debris, soil	1
Saudi mint	*M. officinalis* L.		Total herb, weeds, debris, soil	1
Rosemary	*Rosmarinus officinalis* L		Total herb, weeds, debris, soil	1
1: Shampoliah, and 2: SEKEM				

Table 2. Weed species of Shampoliah farm.

Weeds		Family	Geographic Coordinate System (GCS)	
Common Name	Scientific name		Latitude	Longitude
Camelthron	*Alhagi maurorum* Medic.	Fabaceae	29°21'04.9"N	30°44'24.7"E
Pigweed	*Amaranthus cruentus* L.	Amaranthaceae	29°21'04.6"N	30°44'23.8"E
Slender amaranth	*Amaranthus viridis* L.	Amaranthaceae	29°21'04.6"N	30°44'23.8"E
Spanish needles	*Bidens biponnata* L.	Asteraceae	29°21'03.5"N	30°44'31.1"E
Shepherd's purse	*Capsella bursa-pastoris* (L.) Medik.	Brassicaceae	29°20'59.6"N	30°44'27.2"E
Nettle-leaved goosefoot	*Chenopodium murale* L.	Amaranthaceae	29°21'03.5"N	30°44'31.1"E
Fleabane	*Conyza aegyptiaca* (L.) Aiton.	Asteraceae	29°21'00.1"N	30°44'33.4"E
Cheese weed	*Malva parviflora* L.	Malvaceae	29°20'59.6"N	30°44'27.2"E
Broadleaf plantain	*Plantago major* L.	Plantaginaceae	29°20'57.3"N	30°44'16.6"E
Ploughman's spikenard	*Pluchea dioscoridis* (L.) DC.	Asteraceae	29°21'05.4"N	30°44'26.5"E
Giant pigweed	*Trianthema portulacastrum* L.	Aizoaceae	29°21'04.9"N	30°44'24.7"E
Common Cocklebur	*Xanthium strumarium* L.	Asteraceae	29°21'00.1"N	30°44'33.4"E

Table 3. Abundance and distribution of the Arthropod species at Shampoliah farm plants.

Taxa		Samples																
Family	Genera/Species	Sp	C	Ch	SM	B	CHW	PlS	CT	PW	SA	SPN	SHP	NlG	F	BlP	HoP	CC
Phytoseiidae	*Amblyseius swirskii*			+		+	+	+			+			+		+	+	
	Cydnoseius negevi				+		+			+	+			+		+		+
	Typhlodromus sp.			+			+			+				+	+		+	+
	Amblyseius sp.	+	+		+			+			+			+		+		+
	Phytoseius finitimus					+	+	++		+			+	+		+		
Macrochelidae	*Macrocheles* sp.		+	+		+	+	+			+		+	+	+	+		
Laelapidae	*Cosmolaelaps keni*			+	+	+	+	+			+	+	+	+	+	+	+	+
	Laelaspis astronomicus		+						+				+	+			+	+
Tenuipalpidae	*Cenopalpus* sp.	++	+	+	+++	+++		+		++	+++	+	+	++				++
Tetranychidae	*Tetranychus urticae*	++	++		++	++	+++			+++	+++			+++		++		++
	Oligonyghus aferstiacus			+	+	+++		+			++	++	+++	+++			+++	+
Stigmaeidae	*Agestimus exsertus*		+	+	+		+	+		+	+	+	+	+		+		+
Tydeidae	*Tydeus californicus*	+	+	+	+	+	+	+		+	+	+	+	+		+	+	
Eriophyidae	*Aceria dioscorides*							+++										
Oribalutidae	*Zygoribatula syidi*	+				+	+	+	+	+	+	+	+	+	+	+	+	+
Acaridea	*Rhizogliphus robini*		++		+				+		+	++	+	+	+	+	++	
Acaridea	*Tyrophagus putrescentiae*	+		+	+	+		+	+	+	++		+	++		+	++	
Aphididae	*Aphis* sp.		++		++		+++			++	+++	++		++		+++		+++
Aleyroididae	*Bemisia tabaci*	++	++			++	++	+			+++		++	++	+	++	++	++
Anthocoridae	*Orius* sp.	+		+	+	+	+	+		+	+	+	+	+	+	+	+	+
Thripidae	*Thrips tabaci*		+	+		+	++			+	++			+		+	++	+++
Collembola	Collembola	+	+		+		+	+	+		+		+	+	+		+	+

(+) low distribution 1-45, **(++)** moderate distribution 46-90, **(+++)** common species >90. **Sp**: Spearmint, **C**: Calindula**, Ch**: Chamomile, **SM**: Saudi mint, **B**: Basil, **CHW**: Cheeseweed, **PlS**: Ploughmans spikenard, C**T**: Camelthron, **PW**: Pigweed, **SA**: Slender Amaranth, **SPN**: Spanish needles, **SHP**: Shepherd's Purse, **NlG**: Nettle-leaved goosefoot, **F**: Fleabane, **BlP**: Broadleaf Plantain, **HoP**: Horse Purslane, **CC**: Common Cocklebur.

doi:10.20944/preprints202202.0190.v1

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Table 4. Diversity indices of medicinal and weed plants at Shampoliah farm.

Sample	S	Total individuals	Mean/ 10 samples ± SE	H'	(D)	(1/D)	χ^2
Spearmint	9	283	12.86 ± 5.21 e	0.764	0.199	5.022	974.421*
Calendula	12	381	17.32 ± 5.78 d	0.899	0.149	6.695	889.745*
Chamomile	11	160	7.27 ± 2.22 f	0.938	0.129	7.766	312.450*
Saudi mint	13	412	18.73 ± 6.56 d	0.918	0.161	6.226	1062.214*
Basil	13	553	25.14 ± 8.01 c	0.950	0.141	7.108	1177.521*
Cheese weed	15	644	29.27 ± 10.65 c	0.928	0.171	5.862	1791.304*
Ploughman's spikenard	15	1230	55.91 ± 40.32 a	0.543	0.541	1.847	13433.018*
Camelthorn	5	106	4.82 ± 2.08 g	0.674	0.216	4.634	414.528*
Pigweed	12	478	21.73 ± 7.43 c	0.918	0.155	6.437	1174.209*
Slender Amaranth	18	860	39.09 ± 10.54 b	1.049	0.114	8.783	1313.549*
Spanish needles	9	300	13.64 ± 5.04 e	0.820	0.172	5.823	851.627*
Shepherd's Purse	14	487	22.17 ± 7.25 c	0.959	0.146	6.851	1095.690*
Nettle-leaved goosefoot	21	799	36.32 ± 9.42 b	1.092	0.106	9.421	1086.585*
Fleabane	8	194	8.82 ± 3.02 f	0.849	0.153	6.544	476.887*
Broadleaf Plantain	16	564	25.64 ± 9.40 c	0.944	0.172	5.804	1592.156*
Horse Purslane	13	437	19.86 ± 6.08 d	0.939	0.133	7.521	860.396*
Common Cocklebur	15	612	27.82 ± 8.05 c	0.997	0.124	8.062	1077.327*

Chi square ($\chi 2$) values; * significant, at $P \le 0.05$, df= 16
Means followed by similar letters are not significantly different (Tukey HSD), at $P \le 0.05$, F= 44.86, df= (15, 159), P= 0.000

Table 5. Diversity indices and analysis of variances of arthropod species at Shampoliah farm.

Species	Taxa (S)	Total individuals	Mean/10 samples ± SE	D	1/D	(H')	Evenness	χ^2	T-value	*P*
Amblyseius swirskii	8	113.00	14.13 ± 2.82 e	0.160	6.250	1.931	0.862	194.354	5.000	0.002
Cydnoseius negevi	7	102.00	14.57 ± 1.31 e	0.150	6.676	1.922	0.976	157.667	11.151	0.000
***Typhlodromus* sp.**	7	80.00	11.43 ± 2.26 e	0.176	5.672	1.812	0.875	159.700	5.066	0.002
***Amblyseius* sp.**	8	50.00	6.25 ± 1.73 f	0.192	5.208	1.834	0.783	113.200	3.614	0.009
Phytoseius finitimus	7	110.00	15.71 ± 5.04 e	0.231	4.327	1.709	0.789	322.109	3.117	0.021
***Macrocheles* sp.**	10	50.00	5.00 ± 1.17 f	0.150	6.684	2.050	0.777	77.160	4.260	0.002
Cosmolaelaps keni	13	99.00	7.62 ± 0.92 f	0.090	11.074	2.465	0.905	52.970	8.308	0.000
Laelaspis astronomicus	6	44.00	7.33 ± 1.73 f	0.213	4.699	1.667	0.883	115.182	4.250	0.008
***Cenopalpus* sp.**	12	750.00	62.50 ± 10.34 c	0.108	9.225	2.326	0.853	632.168	6.047	0.000
Tetranychus urticae	10	1131.00	113.10 ± 18.60 b	0.124	8.045	2.185	0.889	1259.747	6.080	0.000
Oligonyghus aferstiacus	10	724.00	72.40 ± 14.01 c	0.134	7.479	2.132	0.843	921.619	5.168	0.001
Agestimus exsertus	12	240.00	20.00 ± 3.45 e	0.111	9.042	2.286	0.820	211.208	5.799	0.000
Tydeus californicus	14	462.00	33.00 ± 2.70 d	0.078	12.877	2.588	0.951	147.939	12.207	0.000
Aceria dioscorides	1	900.00	900.00 ± 0.00 a	1.000	1.000	0.000	1.000	14.000^{ns}	1.000^{ns}	0.332

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Table 5. Cont.

Species	Taxa (S)	Total individuals	Mean/10 samples ± SE	D	1/D	(H')	Evenness	χ^2	T-value	*P*
Zygoribatula syidi	14	250.00	17.86 ± 2.60 e	0.091	10.977	2.478	0.851	137.192	6.870	0.000
Rhizogliphus robini	10	376.00	37.60 ± 5.08 d	0.116	8.591	2.215	0.917	368.112	7.405	0.000
Tyrophagus putrescentiae	12	409.00	34.08 ± 4.06 d	0.096	10.378	2.404	0.922	260.983	8.389	0.000
Collembola	12	154.00	12.83 ± 1.54 e	0.096	10.366	2.406	0.924	98.571	8.352	0.000
Aphis sp.	9	945.00	105.00 ± 15.28 b	0.130	7.698	2.119	0.925	1142.330	6.873	0.000
Thrips tabaci	10	489.00	48.90 ± 7.64 d	0.122	8.203	2.190	0.894	524.708	6.404	0.000
Bemisia tabaci	12	799.00	66.58 ± 5.64 c	0.090	11.121	2.443	0.959	422.340	11.800	0.000
Orius sp.	15	223.00	14.87 ± 2.34 e	0.090	11.132	2.532	0.838	117.534	6.348	0.000

Chi square (χ^2) values are significant at $P \leq 0.05$, df= 16
The means followed by similar letters are not significantly different (Tukey HSD), at $P \leq 0.05$
Species diversity analysis of variance (ANOVA) is significant at probability level = 95%, where; F= 2.454, df= (21, 234), *P*= 0.000

Figure 6. Weed species of SEKEM farm, Belbis, Ash Sharqia.

Weeds		Family	Geographic Coordinate System (GCS)	
Common Name	Scientific name		Latitude	Longitude
Nettle-leaved goosefoot	*Chenopodium murale* L.	Amaranthaceae	30°22'58.5"N	31°39'31.1"E
Egyptian crowfoot grass	*Dactyloctenium aegyptium* (L.) Wild.	Poaceae	30°22'57.8"N	31°39'38.7"E
Cockspur grass	*Echinochloa crus-galli* (L.) Beauv.	Poaceae	30°22'54.8"N	31°39'41.5"E
Cogon grass	*Imperata cylindrica* (L.) Beauv.	Poaceae	30°22'57.6"N	31°39'33.6"E
Cheese-weed	*Malva parviflora* L.	Malvaceae	30°22'48.0"N	31°39'48.5"E
Green foxtail	*Setaria viridis* (L.) Beauv.	Poaceae	30°23'00.9"N	31°39'29.9"E
Broadleaf plantain	*Plantago major* L.	Plantaginaceae	30°22'58.5"N	31°39'31.1"E
Giant pigweed	*Trianthema portulacastrum* L.	Aizoaceae	30°22'48.0"N	31°39'48.5"E
Common Cocklebur	*Xanthium strumarium* L.	Asteraceae	30°22'48.0"N	31°39'48.5"E

Table 7. Diversity indices of medicinal and weed plants at SEKEM.

Plant	Taxa (S)	Individuals	D	1/D	H'	Evenness
Rm	11	78	0.148	6.748	0.881	1.041
Mo	8	62	0.222	4.513	0.712	0.903
Ch	11	77	0.149	6.711	0.909	1.041
Sa	9	63	0.146	6.829	0.852	0.954
La	7	22	0.160	6.243	0.758	0.845
B	11	141	0.147	6.826	0.897	1.041
Le	9	28	0.156	6.407	0.828	0.954
NG	12	206	0.217	4.612	0.785	1.079
EGC	10	71	0.388	2.575	0.616	1.000
CG	7	43	0.213	4.703	0.722	0.845
CO	7	16	0.250	4.000	0.677	0.845
Che	16	307	0.217	4.614	0.788	1.204
Grf	7	23	0.233	4.288	0.679	0.845
BlP	12	146	0.214	4.677	0.809	1.079
GP	7	17	0.162	6.182	0.748	0.845
CC	8	18	0.301	3.326	0.666	0.903

Rm: Rosemary, **Mo**: Moringa, **Ch**: Chamomile, **Sa**: Salvia, **La**: Lavender, **B**: Basil, **Le**: Lemongrass, **NG**: Nettle-leaved goosefoot, **EGC**: Egyptian Crowfoot grass, **CG**: Cockspur grass, **CO**: Cogon grass, **Che**: Cheesweed, **Grf**: Green foxtail, **BIP**: Broadleaf Plantain, **GP**: Giant Pigweed and **CC:** Common Cocklebur

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Table 8. SEKEM biodiversity and taxa distribution.

Taxa	Samples																χ^2
Genera/Species	**Rm**	**Mo**	**Ch**	**Sa**	**La**	**B**	**Le**	**NG**	**EGC**	**CG**	**CO**	**Che**	**Grf**	**BlP**	**GP**	**CC**	
Zygoribatula syidi	++		+	+	+			+	+	+	+	+	+	+	+	+	**75.642***
Sheloribates sp.	+		+			+		+	+		+	+	+	+	+	+	**48.444***
Rhizogliphus robini	++	+		++			+	++	+	+	+	+	+	+	+	+	**42.500***
Typhlodromus athiasea	+	++				+	+	+	+	+	+	+		+	+	+	**74.612***
Typhlodromus sp. 1			+	+	+							+					**39.909***
Parasitus sp.	+		+	+		++						+					**141.059***
Macrocholes sp.	+	++	+		+	+	+	+	+		+		+				**190.667***
Laelaspis astronomicus	+	+	+		+		+		+			+		+		+	**15.308ns**
Kleemania sp.					+		+				+		+			+	**11.000ns**
Amblyseius sp. 1				+			+	+			+	+	+	+	+		**39.963***
Amblyseius sp. 2	+		+			+		+		+				+			**48.652***
Ololealaps sp.		+			+				+	+	+	+			+	+	**38.571***
Spinibdella sp.			+				+	+				+		+			**86.571***
T. urticae		+		+		++		+++				+++					**804.433***

Table 8. cont.

Taxa	Samples																χ^2
Taxa	**Rm**	**Mo**	**Ch**	**Sa**	**La**	**B**	**Le**	**NG**	**EGC**	**CG**	**CO**	**Che**	**Grf**	**BlP**	**GP**	**CC**	
Hemicheyletia wellsina	+	+				+		+				+		+			**76.704***
Collembola	+	+	+	+	+	+	+		+	+		+	+		+	+	**20.103ns**
Thrips tabaci				++		+	+		+	++		++		++			**290.429***
Bemisia tabaci			++			++		+				+++		+			**609.565***
Aphis sp.	++		+	+		++		+++	++			+++		+++			**588.235***

(+) Few specimens 1-10, (++) moderate specimens 11-40, (+++) common specimens >40 individuals/sample

* Significant, ns not significant at probability level = 95%

Rm: Rosemary, **Mo**: Moringa, **Ch**: Chamomile, **Sa**: Salvia, **La**: Lavender, **B**: Basil, **Le**: Lemongrass, **NG**: Nettle-leaved goosefoot, **EGC**: Egyptian Crowfoot grass, **CG**: Cockspur grass, **CO**: Cogon grass, **Che**: Cheese-weed, **Grf**: Green foxtail, **BIP**: Broadleaf Plantain, **GP**: Giant Pigweed and **CC**: Common Cocklebur.

Table 9. Diversity indices of the arthropod species in SEKEM farm.

Genera/Species	Mean/10 leaves ± SE	Taxa (S)	Individuals	(D)	(1/D)	(H')	Evenness
Zygoribatula syidi	5.06 ± 1.26 c	12	81	0.121	8.271	2.297	0.828
Typhlodromus athiasea	4.20 ±1.14 c	12	67	0.132	7.570	2.203	0.755
Typhlodromus sp 1	0.69 ± 0.34 d	4	11	0.289	3.457	1.295	0.912
Parasitus sp	2.13 ± 1.12 cd	5	34	0.322	3.108	1.261	0.706
Macrocholes sp	2.25 ± 1.34 cd	10	36	0.394	2.541	1.487	0.443
Laelaspis astronomicus	0.81 ± 0.23 d	9	13	0.136	7.348	2.098	0.906
Tetranychus urticae	12.13 ± 6.38 b	5	194	0.322	3.108	1.292	0.728
Kleemania sp	0.31 ± 0.12 d	5	5	0.200	5.000	1.609	1.000
Sheloribates sp	2.25 ± 0.67 cd	11	36	0.147	6.821	2.136	0.769
Amblyseius sp 1	1.70 ± 0.53 cd	8	27	0.155	6.452	1.967	0.893
Amblyseius sp 2	1.44 ± 0.45 cd	6	23	0.195	5.136	1.714	0.925
Ololealaps sp	0.88 ± 0.38 d	8	14	0.235	4.261	1.772	0.735
Spinibdella sp	0.88 ± 0.56 d	5	14	0.449	2.227	1.128	0.618
Rhizogliphus robini	8.00 ± 1.19 c	13	128	0.083	12.012	2.524	0.960
Hemicheyletia wellsina	1.69 ± 0.74 cd	6	27	0.240	4.165	1.592	0.819
Collembola	1.81 ± 0.40 cd	13	29	0.106	9.452	2.384	0.835
Thrips tabaci	6.56 ± 2.82 c	7	105	0.235	4.248	1.659	0.751
Bemisia tabaci	11.50 ± 5.41 b	5	184	0.270	3.709	1.437	0.842
Aphis sp	18.13 ± 6.67 a	8	290	0.189	5.283	1.828	0.777
F-value	**2.311***						

The means followed by similar letters are not significantly different (Tukey HSD), df= (15, 151), *P*= 0.001 at 95%

Table 10. Biodiversity similarity indices between the study locations.

Experimental location	Total species	Shared species
Shampoliah farm	39	14
SEKEM	35	
Jaccard Index J'	0.233	
Sørenson Coefficient CC	0.378	

Figures

(a)

(b)

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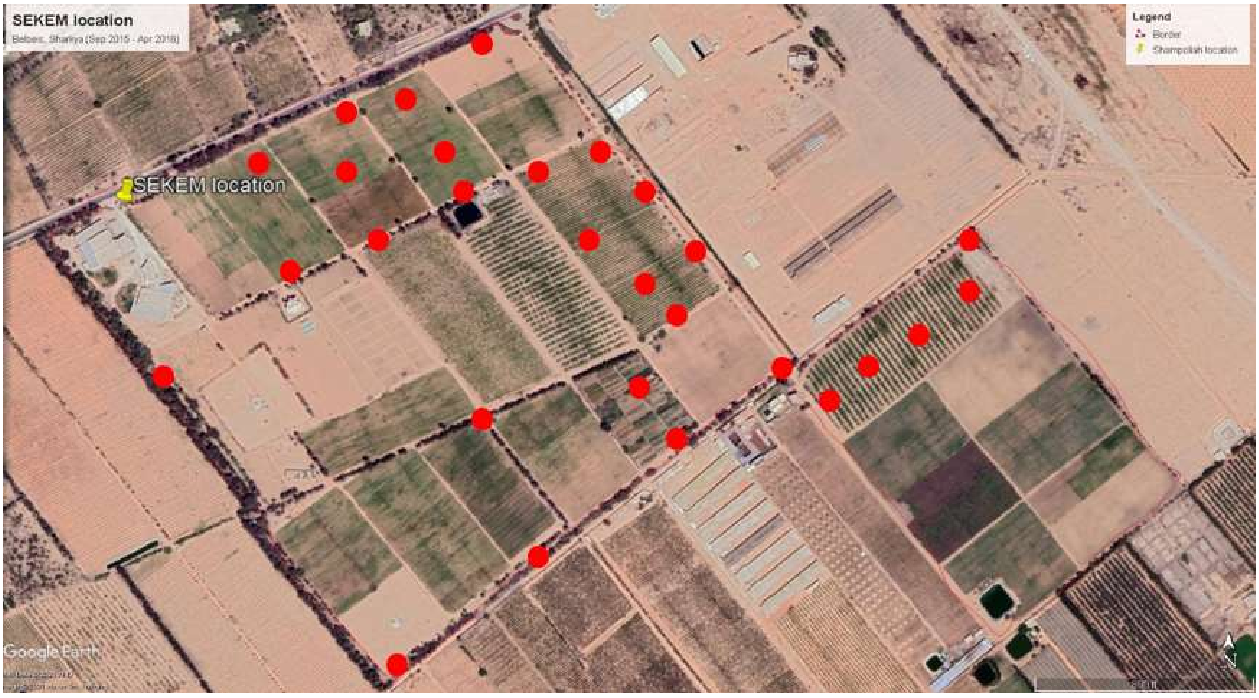

（c）

Figure 1. Experimental locations, a) within the Egypt's map, b) Shampoliah farm, Fayoum (GCS 29°21'07.4"N 30°44'17.8"E), and c) SEKEM farm, Sharkia (GCS 30°22'56.1"N 31°39'17.4"E). .

（a） （b）

Figure 2. Cheese weed *Malva parviflora*, a) with Calendula in Shampoliah, and b) with Chamomile in SEKEM.

Figure 3. Weeds on boarders hypothesized a positive impact on arthropod distribution.