International Journal of Ecotoxicology and Ecobiology
2016; 1(2): 49-58
http://www.sciencepublishinggroup.com/j/ijee
doi: 10.11648/j.ijee.20160102.14

Effects of Nitrates and Some Ecological Factors on Soil Macroinvertebrate Communities Inhabiting El-Minia Governorate, Egypt

Ahmad Hamed Obuid-Allah[1], Nasser Abd El-lateif El-Shimy[1], Zeinab Abd El-khalek El-Bakary[1], Mostafa Helmy Al-Sayed[2], Al-Shimaa Mohammed Adel[2, *]

[1]Department of Zoology, Faculty of science, Assiut University, Assiut, Egypt

[2]Department of Environment Research, Soil, Water and Environment Research Institute, Agriculture Research Center, Giza, Egypt

Email address:

aymnaraby82@gmail.com (Al-Shimaa M. A.)

[*]Corresponding author

To cite this article:

Ahmad Hamed Obuid-Allah, Nasser Abd El-lateif El-Shimy, Zeinab Abd El-khalek El-Bakary, Mostafa Helmy Al-Sayed, Al-Shimaa Mohammed Adel. Effects of Nitrates and Some Ecological Factors on Soil Macroinvertebrate Communities Inhabiting El-Minia Governorate, Egypt. *International Journal of Ecotoxicology and Ecobiology.* Vol. 1, No. 2, 2016, pp. 49-58.
doi: 10.11648/j.ijee.20160102.14

Received: June 25, 2016; **Accepted**: July 4, 2016; **Published**: August 4, 2016

Abstract: Soil invertebrates play a significant role in improving soil structures. Man uses nitrogenous fertilizers to improve growth of cultivated lands and provide plants with nutrients. The intensive addition of fertilizers accumulates soil nitrate which affects soil fauna. This investigation was designed to study the effects of nitrate concentration in the soil and some ecological factors on the soil macroinvertebrates inhabiting different agricultural lands at El-Minia governorate. Six sites were chosen for this study. Samples of soil and invertebrates were collected monthly during a period of one year extended from December 2013 till November 2014 using pitfall traps. The study revealed the occurrence of twenty six taxa in the investigated sites. The density of each taxon obviously varied in each site according to the season. The majority of collected macroinvertebrates assigned to phylum Arthropoda. The most dominant species at all sites belonged to order Isopoda then Orthoptera. Higher density of macroinvertebrates was recorded during spring and summer compared to their relevant numbers during winter and autumn. All collected macroinvertebrates exhibited negative correlation with nitrate concentration of soil in their habitat, especially isopods that showed strong significant correlation.

Keywords: Nitrate Concentration, Macroinvertebrates, Survey, El-Minia Governorate

1. Introduction

Soil invertebrates play essential roles in regulating ecological processes of nutrient cycling and energy flow in ecosystems [1]. In healthy soils, invertebrates are abundant and affect the delivery of ecosystem services by soils. They participate actively in the interactions that develop in soil among physical, chemical and biological processes. Soil invertebrates are the best biological parameters used to indicate pollutant impact on soil quality [2]. Macrofauna affect litter decomposition and soil chemistry directly through combination, fragmentation and transfer of organic materials deeper into substrate; that increases substrate surface area and litter decomposition [3, 4].

Ecological factors and seasonal fluctuations affect the presence of macroinvertebrates under different habitat structures. Temperature and humidity gradient affect the community of soil fauna and distribution pattern [5]. Soil quality and climate change including soil temperature and moisture affect greatly the survivorship and fecundity of most soil macroinvertebrates [1].

Nitrate ion (NO_3) is a naturally occurring form of nitrogen in soil. The atomic mass of NO_3 is 62.0049 $g \cdot mol^{-1}$. It is the most oxidized form of nitrogen (N) present in the environment with an oxidation state of +5. Nitrogen oxides have been recognized as the major acidifying pollutants in water. Once emitted into the atmosphere, they can undergo complex chemical reactions resulting in the formation of sulfuric acid (H_2SO_4) and nitric acid (HNO_3) [6]. The nitrate salts of all common metals, $NaNO_3$, KNO_3, Ca $(NO_3)_2$, $AgNO_3$ are highly soluble in water; while the resulting free nitrate ion is chemically unreactive as it has little tendency to form coordination complexes with other metal ions in solution. This form of nitrogen is created when nitrification occurs (the conversion of ammonium into nitrate) [7].

Nitrate is used as food by plants for growth and production. Nitrogen is essential to plant growth, yet the excessive use of fertilizers in agriculture is generally a major cause of nitrate pollution. Human intervention in the nitrogen cycle due to intensive agricultural activities leads to nitrogen saturation of many natural ecosystems, which caused nitrate pollution in natural and agricultural ecosystems. Egyptian cultivators and farmers fertilize the agricultural lands generally using urea 46.5% nitrogen, ammonium nitrate 33.5% nitrogen and ammonium sulphate 20.5% as main fertilizers in their fields. This causes a real problem resulting in excessive environmental risks of soil pollution that affects macroinvertebrates in their habitat. The overuse of nitrogen fertilizers results in diminishing crop returns and leads to diminished environmental quality and human wellbeing [8-10]. The analysis of groundwater and running water showed high values of nitrate concentrations as a result of agricultural activities [11].

The normal background level of nitrates in non-fertilized soil ranges from 5 to 10 parts per 1 million (ppm), according to [12]. Nitrate leaching depends on several factors; fertilization level, type and timing of fertilizer application, properties of soil, types of corps and their fertilizer requirement, weather conditions and the atmospheric deposition of inorganic nitrogen [11, 13, 14 and 15]. Also the huge combustion of fossil fuels has dramatically increased nitrate deposition [16-19].

Climatic conditions can directly affect the amount of nitrate in soil. Heavy rains after nitrogen applications can create considerable loss of soil nitrates and form a source of pollution. Soil nitrate levels are increased through rapid nitrification in well-aerated soils with a pH of 6 to 8 and temperatures greater than 50 degrees. Wet, cold or acidic soils do not contain high levels of nitrate. NO_3 in soil solution is determined by a number of agents, of which the accumulation of organic matter; soil pH; soil temperature; soil oxygenation status are the most important [20-22].

Ammonia gas is the main raw material used in making nitrogenous fertilizers. There are mainly four types of nitrogenous fertilizers; (1) Urea CO (NH_2), (2) Ammonium sulphate $(NH_4)_2SO_4$, (3) Ammonium nitrate (NH_4NO_3) and (4) Sodium nitrate $(NaNO_3)$

The present study was designed to carry out the following: 1- Survey of soil dwelling macroinvertebrates inhabiting different agricultural lands at El-Minia governorate. 2- Study the effects of nitrate concentration in the soil and some ecological factors on the density of the collected soil macroinvertebrates.

2. Materials and Methods

2.1. The Investigated Sites

The present study was carried out at El- Minia governorate, Egypt (28.1003N° and 30.7582E°), "Fig. 1, 2". Six sites were chosen which included: Bani-Mazar, Samalout, El-Minia, Abo-Korkas, Mallawi and Der-Mawas, "Fig. 3-8".

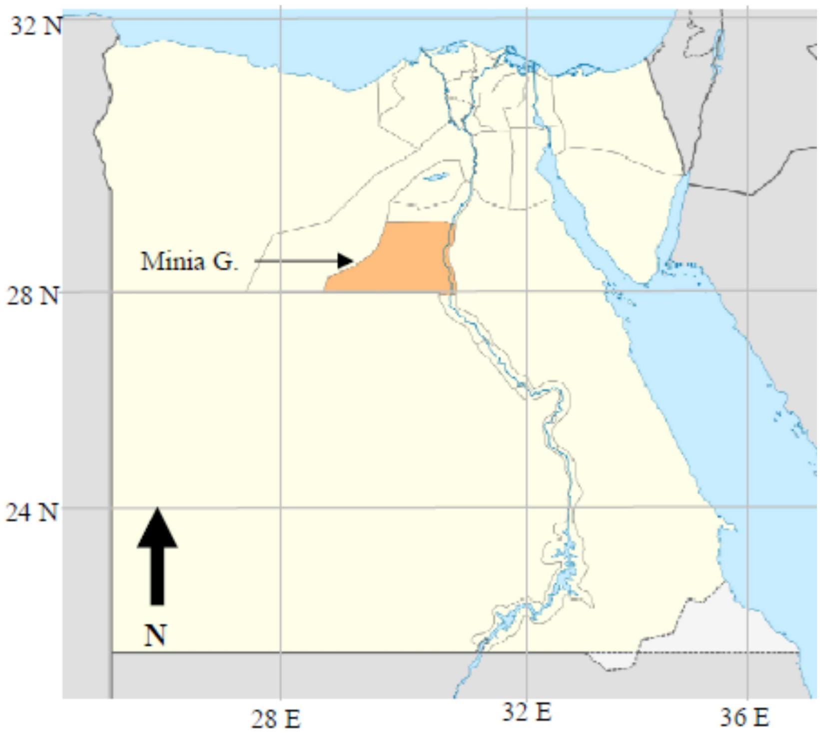

Figure 1. *Egypt map.*

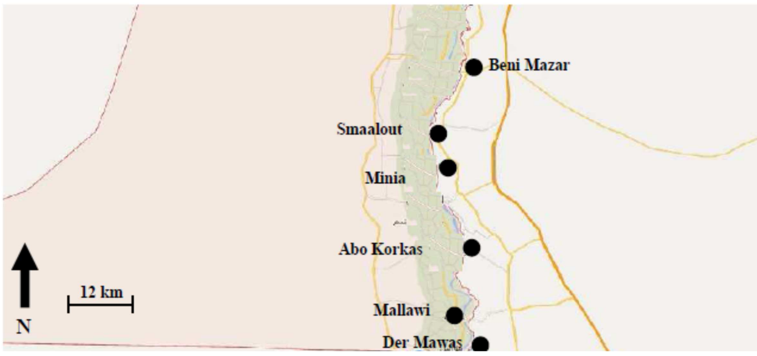

Figure 2. *El-Minia governorate map showing the six studied sites.*

Figure 3. *Site (1) Beni-Mazar.*

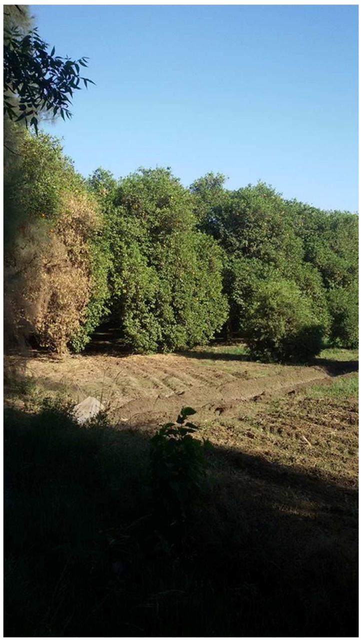

Figure 4. *Site (2) Samalout.*

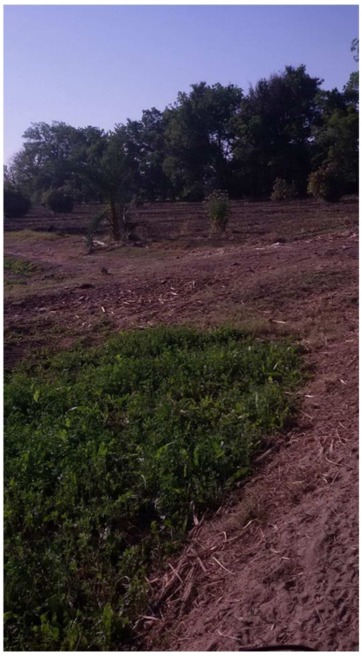

Figure 5. *Site (3) El-Minia.*

Figure 6. *Site (4) Abo-Korkas.*

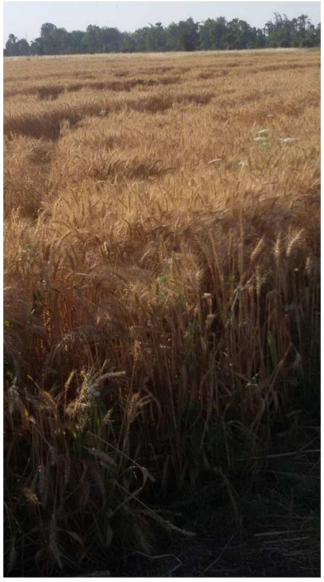

Figure 7. *Site (5) Mallawi.*

Figure 8. *Site (6) Der-Mawas.*

2.2. Soil Sampling and Nitrate Analysis

Three random soil samples were collected monthly from each site throughout the period of one year extended from December 2013 till November 2014. Soil samples were stored in labeled plastic bags and then transported to the laboratory. The macroinvertebrates within these samples were isolated. Soil samples were sieved through mesh sieves to remove small animals; while larger invertebrates were picked manually. Nitrate content within the soil samples was determined using the Salicylate method [23]. The concentration of nitrate-N was estimated from the standard curve. The wave length of nitrate was measured by the spectrophotometer (UNICO UV 2100 USA) at 420nm.

2.3. Survey of Macroinvertebrates and Identification

Soil dwelling macroinvertebrates were collected using pitfall traps. Five traps were randomly distributed at each investigated site; the traps then were covered by a holed paper sheet leaving the opening of the trap opened to protect it from fallen litter and predatory birds. Invertebrates were picked daily during one week. The collected animals were isolated, separated, sorted, identified, counted and recorded then stored in 70% ethanol until identification.

Collections were done monthly during the four seasons, and the data were standardized by the equation: $N/(D \times Tr)$

N= number of individuals in one sample in a habitat, D=number of days between two samplings, Tr = number of usable traps.

2.4. Statistical Analysis

Statistical analysis of the data was performed using SPSS 16 software package. Data were expressed in the form of mean ± SD. One way ANOVA was used to test the significance among treatments or groups and seasons. The multiple range test (Duncan's test) was used to detect differences between means. Pearson correlation and stepwise multiple regression were used to investigate relationships between macroinvertebrate densities and nitrate concentration and ecological factors. Figures were done using Microsoft Excel 2007.

3. Results

3.1. Survey of Soil Macroinvertebrates

The study revealed the occurrence of twenty six taxa in the investigated sites. The density of each taxon obviously varied in each site according to the current season. The majority of collected macroinvertebrates was assigned to phylum Arthropoda, and could be divided into ten orders: Araneae, Orthoptera, Isopoda, Dermaptera, Lepidoptera, Coleoptera, Geophilomorpha, Dictyopetra, Hymenoptera and Hemiptera. One taxon belonged to phylum Annelida (Haplotaxida). The above ten orders could be divided into two groups: The first one included the common orders, which occurred in considerable numbers: (Orthoptera, Coleoptera, Isopoda, Araneae, Hymenoptera, Lepidoptera), while the other group (included the rest of orders), which occurred in few numbers included under the "others" group (Table 1 and 2).

Table 1. *Taxonomy of the collected macroinvertebrate species collected from El-Minia governorate sites.*

Phylum	Class	Order	Family	Genus/Species
Arthropoda				
	Insecta			
		Orthoptera	Acrididae	*Locusta migratoria* (Linnaeus, 1758)

Phylum	Class	Order	Family	Genus/Species
			Gryllidae	*Acheta domestica* (Linnaeus, 1758)
			Gryllotalpidae	*Gryllotalpa gryllotalpa* (Linnaeus, 1758)
		Dermaptera	Labiduridae	*Labidura riparia* (Pallas, 1773)
		Lepidoptera	Lepidoptera	Lepidoptera larvae (Linnaeus, 1758)
				Lepidoptera pupae (Linnaeus, 1758)
		Coleoptera	Tenebrionidae	*Blaps polychresta* (Forskal, 1775)
				Coleoptera larvae (Forskal, 1775)
			Carabidae	*Bradycellus* sp. (Serville, 1821)
				Distichus planus (Bonelli, 1813)
			Tenebrionidae	*Gonocephalum rusticum* (Chevrolat, 1849)
			Coccinellidae	*Coccinella septempunctata* (Linnaeus, 1758)
				Coccinellidae Larva
		Lepidoptera	Noctuidae	*Spodoptera littoralis (*Boisduval, 1833)
		Dictyoptera	Blattidae	*Periplaneta americana* (Linnaeus, 1758)
	Chilopoda			
		Geophilomorpha	Himantariidae	*Stigmatogaster subterranean* (Shaw, 1789)
	Crustacea			
		Isopoda	Porcellionidae	*Porcellio laevis* (Latreille, 1804)
				Porcellionides pruinosus (Brandt, 1833)
			Armadillidae	*Armadillo officinalis* (Dumeril, 1816)
	Arachnida			
		Araneae	Lycosidae	*Hogna* sp. (Lucas, 1883)
				Wadicosa fidelis (O. P.-Cambridge, 1872)
				Pardosa sp. (C. L. koch, 1847)
		Hemiptera	Pentatomidae	*Euschistus* sp. (Linnaeus, 1763)
		Hymenoptera	Formicidae	*Pheidole* sp. (Westwood, 1839)
				Camponotus sp. (Mayr, 1861)
Annelida	Oligochaeta	Haplotaxida	Lumbricidae	*Allolobophora caliginosa* (Savigny, 1826)

Table 2. *Total numbers of macroinvertebrate groups collected from all sites during different seasons.*

Season / Group	Winter	Spring	Summer	Autumn
Orthoptera	16	87	121	47
Coleoptera	32	40	54	15
Isopoda	69	62	138	77
Araneae	15	41	34	10
Hymenoptera	22	30	50	23
Lepidoptera	19	51	43	18
Others	30	39	50	20
Total	203	350	490	210
Mean ± SD	29 ± 20.6	50 ± 33.3	70 ± 43.2	30 ± 25.6
Significance	C	B	A	C

One way ANOVA are used to test the significance among seasons.
Means with different letters (A, B, C) in the same row are significantly different.

The results indicated that the most dominant taxon at all sites belonged to order Isopoda. Higher abundance of macroinvertebrates was recorded during spring and summer compared with their relevant numbers during winter and autumn. The numbers of individuals collected are illustrated in table (2). The results illustrated that there was a significant ($p<0.01$) difference in the number of macroinvertebrates between winter and both summer and spring. Winter recorded the lowest value, while the highest value was recorded in summer.

The same trend of the previous results was observed in the total means of density of macroinvertebrates during the studied seasons (table 3) in which the mean densities were recorded during winter, spring, summer and autumn, with significant ($p<0.01$) difference in the abundance of macroinvertebrates between winter and other seasons. Winter and autumn recorded the lowest value with a mean density of 0.19, whereas the highest mean value was 0.46 and was recorded in summer.

Table 3. *Total density of macroinvertebrates (Indiv. /Trap/ day) at the studied sites during different seasons.*

Season / Group	Winter	Spring	Summer	Autumn
Orthoptera	0.10	0.58	0.80	0.31
Coleoptera	0.21	0.26	0.36	0.1
Isopoda	0.46	0.41	0.92	0.51
Araneae	0.1	0.27	0.22	0.06
Hymenoptera	0.14	0.2	0.33	0.15
Lepidoptera	0.12	0.34	0.28	0.12
Others	0.2	0.26	0.33	0.13
Mean ± SD	0.19 ± 0.14	0.33 ± 0.22	0.46 ± 0.29	0.19 ± 0.17
Significance	C	B	A	C

One way ANOVA are used to test the significance among seasons.
Means with different letters (A, B, C) in the same row are significantly different.

Table (4) illustrated the results of correlation between density of different taxa and the concentration of soil nitrate. These data indicated that there was a negative correlation between the densities of studied macroinvertebrate groups and the concentration of nitrate. Three of these correlations are non-significant (Coleoptera, Hymenoptera and

Lepidoptera). But in case of isopods, there is a high significance. Orthopetra, Araneae and others group also exhibited significant negative correlations.

The correlations between macroinvertebrate densities of the different groups and the measured ecological factors revealed that the air and soil temperatures are positively correlated with these densities, table (4); while soil pH and soil moisture show a non-significant correlation with the densities of the studied groups, except in case of Orthopetra and total density of collected taxa that displayed significant correlation with soil moisture.

Table 4. *Correlation coefficients between the invertebrate group densities and ecological factors and nitrate concentration.*

Eco. factor	Nitrate concentration		Air temperature (°C)		Soil temperature (°C)		Soil pH		Soil moisture	
Order	***(r)***	***Sig.***	***(r)***	***Sig.***	***(r)***	***Sig.***	***(r)***	***Sig.***	***(r)***	***Sig.***
Total density	-0.41	0.03*	0.84	<0.01**	0.86	<0.01**	-0.30	0.34^{NS}	0.44	0.05*
Orthopterans	-0.45	0.02*	0.78	<0.01**	0.80	<0.01**	-0.16	0.62^{NS}	0.41	0.03*
Coleopterans	-0.07	0.80^{NS}	0.77	<0.01**	0.78	<0.01**	-0.41	0.19^{NS}	0.37	0.23^{NS}
Isopods	-0.76	<0.01**	0.74	<0.01**	0.73	<0.01**	-0.19	0.65^{NS}	0.17	0.60^{NS}
Araneans	-0.51	0.04*	0.80	<0.01**	0.81	<0.01**	-0.30	0.34^{NS}	0.32	0.30^{NS}
Hymenopterans	-0.27	0.39^{NS}	0.90	<0.01**	0.88	<0.01**	-0.33	0.28^{NS}	0.39	0.20^{NS}
Lepidopterans	-0.06	0.85^{NS}	0.76	<0.01**	0.79	<0.01**	-0.27	0.39^{NS}	0.48	0.11^{NS}
Others	-0.51	0.04*	0.74	<0.01**	0.78	<0.01**	-0.24	0.44^{NS}	0.39	0.20^{NS}

Table (5) showed the regression equations for the relations between the densities of different groups of macroinvertebrates and ecological factors and nitrate concentration. It was observed from the model equations that temperature was the most effective factor among the measured ecological factors on taxa densities.

Table 5. *Regression equations for the relations between the invertebrate groups densities and ecological factors and nitrate concentration.*

Response	Selected variables	SE	P. v.	DF	F. v.	R^2	Reg. equation
Total No.	Constant S. temp	16.8	<0.01**	1	29.2	0.745	Total No. = -2.061+3.98 S. temp.
Orthoptera	Constant S. temp	25.7	<0.01**	1	17.8	0.640	Orth. = -33.4+ 4.76 S. temp.
Coleoptera	Constant A. temp	30.5	<0.01**	1	14.8	0.597	Coleo. = 18.4+ 3.71 A. temp.
Isopoda	Constant A. temp	22.3	<0.01**	1	14.1	0.586	Isopoda = 94.1-3.66 Nitrate + 1.94 A. temp.
	Nitrate A. temp	13.2	<0.01**	1	19.8	0.870	
Araneae	Constant S. temp	16.90	<0.01**	1	19.1	0.657	Arane. = -0.237+ 3.25 S. temp
Hymenoptera	Constant A. temp	11.07	<0.01**	1	46.4	0.823	Hymen. = 11.66+ 2.38 A. temp
Lepidoptera	Constant S. temp	9.55	<0.01**	1	16.9	0.628	Lepid. = 5.44+ 1.73 S. temp
Others	Constant S. temp	32.4	<0.01**	1	15.7	0.611	Others = 1.70+ 5.65 S. temp

A. temp: Ambient (air) temperature. S. temp: Soil temperature.
Nitrate: Nitrate concentration in soil.

Table 6. *Means of measured ecological factors in the different seasons.*

Eco. factor / Season	Air temperature (°C)	Soil temperature (°C)	Soil pH	Soil moisture %
Winter	14.3	12.6	6.66	15.17
Spring	21.0	19.0	7.56	6.21
Summer	35.3	28.7	7.30	4.91
Autumn	26.6	23.6	6.16	11.35

Table (6) represented the mean of different ecological factors during different seasons of the year during the study period. Air temperature recorded: 14.3, 21.0, 35.3 and 26.6°C for winter, spring, summer and autumn; respectively. Soil temperature recorded: 12.6, 19.0, 28.7 and 23.6°C for the four seasons; respectively. Regarding soil pH, it was 6.66 in winter, 7.56 in spring, 7.30 in summer and 6.16 in autumn. The percentage of the soil moisture content was 15.17, 6.21, 4.91 and 11.35 in the four seasons; respectively.

3.2. Differences in Nitrate Concentrations Among Different Sites in Different Seasons

Soil nitrate concentration exhibited significant differences in both cases: sites and seasons (table 7). The highest value (61.08) was recorded in site 3 during spring, while the lowest one (4.68) was recorded in site (1) during summer. Table (8) presented the results of soil nitrate concentration in different sites and seasons during the investigated period. Sites 1 and 2 showed the highest values of nitrate concentration during winter, while sites 3, 4 and 5 showed the highest concentration during spring and autumn. Site 6 showed the highest nitrate concentration during autumn and the lowest value during summer. Site 3 had relatively high soil nitrate concentration, especially during spring (61.08) and autumn (56.66).

Table 7. *Statistical results of two-way analysis of variance (ANOVA) for the nitrate concentration between sites and seasons.*

	DF	***F***	***P***
Sites	5	16.01	< 0.001**
Seasons	3	7.10	< 0.001**
Sites* Seasons	15	18.06	< 0.001**

Table 8. *Means of soil nitrate concentration (mg/kg of dry soil) in different sites and different seasons during the period of study from December 2013 till November 2014.*

Sites	**Site (1)**	**Site (2)**	**Site (3)**	**Site (4)**	**Site (5)**	**Site (6)**
Months	**Beni-mazar**	**Samalout**	**Minia**	**Abo-korkas**	**Mallawi**	**Der-mawas**
Winter	$24.62^{a} \pm 19.2$	$19.90\ ^{\alpha a} \pm 5.0$	$8.51\ ^{\beta b} \pm 7.9$	$14.56^{a} \pm 4.1$	$4.78^{b} \pm 3.2$	$10.22^{b} \pm 3.6$
Spring	$8.60^{b} \pm 5.2$	$8.57\ ^{\beta b} \pm 2.0$	$61.08\ ^{\alpha a} \pm 18.9$	$18.91^{b} \pm 5.6$	$11.19^{b} \pm 8.1$	$9.14^{b} \pm 5.6$
Summer	$4.68^{b} \pm 0.9$	$10.01\ ^{\beta b} \pm 1.2$	$8.02\ ^{\beta b} \pm 7.1$	$13.34^{a} \pm 4.1$	$6.63^{b} \pm 2.9$	$5.18^{b} \pm 2.6$
Autumn	$9.83^{a} \pm 3.5$	$9.31\ ^{\beta a} \pm 2.9$	$56.66\ ^{\alpha b} \pm 17.5$	$24.17^{a} \pm 8.1$	$11.40^{a} \pm 4.1$	$10.71^{a} \pm 2.5$

Similar characters mean no significant difference; (a, b) for differences between sites while (β, α) for differences between seasons.

4. Discussion

4.1. Survey of Macroinvertebrates in Relation to Measured Ecological Factors at El-Minia Governorate

Survey of macroinvertebrates in the present study recorded 26 taxa in the six studied sites. The low number of the collected taxa is mostly due to the nature of the surveyed sites, since the study was conducted in agricultural fertilized lands, contaminated with nitrate that negatively affected the presence and abundance of macroinvertebrates. [24] reported that the difference in the sensitivities of the various species increased as far as contaminants existence. Previous studies of soil invertebrates recorded different number of taxa. This can be attributed to many reasons: including the physical and chemical properties of soil, climate, the method of sampling and types of plants [25]. [26] recorded 13 orders of invertebrates in Estonia while [27] recorded 158 taxa in Granada. In Egypt, few studies were focused on the diversity of macroinvertebrates inhabiting different ecosystems and their relation to the environment [5, 28, 29, 30, 31, 32].

The present study indicated that the majority of collected macroinvertebrates were attributed to phylum Arthropoda and one species was attributed to phylum Annelida. This result agrees with [33] who mentioned that macroinvertebrates assemblage was amply dominated by arthropods, which comprised 94.7% of individuals. This can be attributed to the ability of arthropods to occupy many harsh ecosystems with hard and difficult climatic conditions, where they can adapt stressful ecological and nutrition conditions beside their capacity to prevent desiccation when exposed to heat stress [5, 34, 35, 36, 37]. Other studies emphasized this result and reported that arthropods are less constrained by extreme thermal environments than most other soil fauna [38-40].

The present survey revealed that Isopoda recorded the highest densities in all sites among different seasons then Orthoptera followed by Coleoptera. The isopod *Porcellio laevis* was the most abundant species among woodlouse in the six sites. [41] indicated that the most important taxa in macroinvertebrates are isopods (woodlice), larger Diplopoda, Isoptera (termites) and Coleoptera (beetles). Also [42] illustrated that *Porcellio laevis* was the commonest isopod inhabiting Ismailia region and *Porcellionides pruinosus* was less in number than *P. laevis*. [43] indicated that the biological diversity is not the same everywhere; there are almost infinite variations in patterns of diversity across and within the earth ecosystems.

In the present investigation, the number and density of the collected macroinvertebrate groups showed variations among seasons throughout the year. This result agrees with that of [40] who illustrated that seasonal changes cause variations in the density of the collected macroinvertebrate groups. The seasonal variation is a feature of most ecosystems, particularly in Mediterranean habitats, where the temperature and soil moisture fluctuation affect animal productivity and activity [44]. Furthermore, [45] indicated that arid ecosystems are characterized by low species diversity and consequently low diversity; the more diverse the species, the more stable the environment where soil fauna maintains soil formation.

In the present study, there was a high positive correlation between temperature and density of soil macroinvertebrates, where high densities occurred in summer and spring compared to their relevant values during winter and autumn. The clearly increasing of macroinvertebrates densities in summer were due to their positive correlation with air and soil temperatures, especially Isopoda and Orthoptera. This result coincided with [46] who recorded that high values of meteorological factors in summer months made some taxa appear. In contrast, [47] pointed that at high temperature soils are more desiccated because of faster evaporation, leading to soil drought that causes adverse effects on soil fauna.

In spring, the high densities of macroinvertebrates could be related to the presence of Orthoptera and Isopoda in high numbers in this period of the year. This result agrees with that of [28] who found that the greatest number of *Porcellio laevis* was in spring. [48] indicated that under favorable environmental conditions, plant growth is promoted and the weather conditions were suitable for high plant diversity; therefore, invertebrates were not subjected to the stress of temperature or humidity.

In winter, the data of the present study revealed that the richness of the collected taxa was low in all sites, especially both Orthoptera and Araneae orders. The decrease of the taxa in winter can be attributed to hibernation of some taxa. Also, this decrease can be justified by the view of [49], who showed that in winter there was a tendency towards higher occupancy of bird species feeding on soil invertebrates. It is well known that the migratory birds come to Egypt in winter. In autumn, the decline in the current data was related to the low densities of macroinvertebrate species, especially those that belonged to Coleoptera and Araneae. This result agrees with [50] who showed that the activity of ground beetles decreases in late autumn, becomes the lowest during mid-winter and then increases in early spring. Other reason may relate to that Carabidae are noted as an important food source in the diet of insectivorous mammals. For the decline in Araneae density, [51] revealed that the adult females of Araneae species have been recorded throughout the year, but both sexes peak in the autumn and winter.

The present study indicated that a non-significant correlation exists between soil moisture and density of most species except Orthoptera in the six sites. This may be due to the contamination of soil with nitrate in most of the surveyed sites, which decreased the number of species even in the well moisten soil. In this condition, even isopods and earthworm species, which prefer wet soil conditions, appeared to be restricted by low soil moisture [52, 53]. On the contrary, [54] indicated that most invertebrate taxa (75%) were more abundant in moist-soil.

It was observed from the above mentioned results, that climatic conditions contribute in controlling the density of soil macroinvertebrates. In the field, isopods stop feeding and migrate vertically into the soil, and the food consumption rates declined rapidly during November and December in response to the cold, while in spring and early summer the demand increased again during the period of rapid growth that preceded breeding [55-57].

4.2. The Effect of Soil Nitrate Concentration on the Density of Macroinvertebrates

In the present investigation, a negative correlation was found between soil nitrate content in the six studied sites and the density of most collected macroinvertebrates. This variation in macroinvertebrates density may be due to the effect of excessive addition of nitrogenous fertilizers during planting that lead to nitrate accumulation within the soil. [58] detected that fertilizers input in agricultural areas constitutes a significant contribution to the nitrate content in the soil and groundwater. In the present study, among the collected taxa, isopods were the most sensitive taxon to nitrate contamination. It exhibited strong negative correlation with nitrate concentration despite the ability of isopods to avoid the toxic action of the nitrate overdose. Terrestrial isopods select food on the basis of how rapidly they could absorb nutrients across the gut wall [59].

The density of collected macroinvertebrates in the present result decreased in soil with high content of nitrate concentration, while the sites with low or acceptable nitrate concentration contained a relatively high density of species. [60] reported that nutrition additions and site management have direct and indirect effects on the abundance and structure of soil fauna communities. The soil structure may play an important role in species abundance of invertebrates as pointed by [61].

The present study showed that in the six sites the concentration of NO_3 in soil exceeded the allowed international levels from (5 to 10 ppm), according to [12], especially in El-Minia site where the concentration of nitrate was too high in spring and autumn. This is mostly attributed to the presence of sewage source in this region, so the irrigation water was mixed and polluted with the drainage. In addition to the excessive use of nitrogenous fertilizers, especially in planting wheat that lasted to spring and corn that lasted to autumn, the two crops are gluttonous for nitrogen [62]. These two reasons (drainage and crop) cause massive accumulation of nitrate in this site, as illustrated in the above result, which lead to the elimination of macroinvertebrates and life barren soil, giving rise to a real problem and environmental risks of soil pollution. This result agrees with [11], who demonstrated that the highest nitrate concentrations were measured during spring time in the agricultural areas, particularly areas specialized in maize cultivation. Also [58] indicated that wheat and corn are increasingly important agricultural sources of nitrate contamination in the environment; other sources include human waste from sewage treatment plants and kitchen wastes. Recently, agriculture represents a major source of soil and water nitrate pollution, which is difficult to be eliminated [63, 64].

In the present study, Beni-mazar site, on the contrary, was observed to record the lowest concentration of nitrate in the soil during summer. The reason of reduction may refer to that the fertilizers applied to the field in this area were not in excess of plant needs, so the plant consumed the whole amount of added fertilizers entirely. This agrees with [11] who indicated that in many studied farms nitrogen concentration noted to be below the optimal values.

5. Conclusion

It could be concluded from the present study that the temperature seemed to be an effective stressor on the occurrence and density of soil macroinvertebrates. Nitrate concentration in the soil and fertilizers residues also contribute hardly to control the density of terrestrial macroinvertebrates, especially isopods. So the isopod populations could be adversely affected by the shortage of the best quality foods, or by the nitrate contaminated food, which proved that macroinvertebrates, especially isopods, are good indicators for soil quality.

Acknowledgments

Many thanks from the authors to all friends and colleagues in Zoology Dept., Faculty of Science, Assiut University, Egypt; especially Prof. Abd El-Wakeil for helping in the statistical analysis of the data.

References

[1] T. Kamin, "Factors that affect the make-up of soil invertebrate community," College of DuPage. Essai., vol. 8, pp 22, 2011.

[2] J. Cortet, A. Vauflery, N. Poinsot-Balaguer, L. Gomot, C. Texier, and D. Cluzeau, "The use of invertebrate soil fauna in monitoring pollutant effects," European Journal of Soil Biology, vol. 35, pp. 115-134, 1999.

[3] M. Witkamp, and D. Crossley, "The role of arthropods and microflora in the breakdown of white oak litter," Pedobiologia, vol. 6, pp. 293-303, 1966.

[4] M. Mitchell, G. Lawrence, D. Landers, and K. Stucker, "Role of a benthic invertebrate in affecting sulfur and nitrogen dynamics of lake sediments," In: Singer R (ed) Effects of acid precipitation on benthos. Proc symp Acidic Precipitation on Benthos, North American Benthological Society, Hamilton, New York, pp. 67-7, 1981.

[5] K. Abd El-Wakeil, H. Mahmoud, and M. Hassan, "Spatial and seasonal heterogeneity of soil macroinvertebrate community in Wadi Al-Arj, Taif, Saudi Arabia," Jökull Journal, vol. 64, pp. 180-196, 2014.

[6] J. Mason, "Introduction the causes and consequence of surface water acidification," Acid toxicity and aquatic animals, Cambridge: Cambridge University Press, 1989.

[7] C. Spencer, "The micronutrient elements," Chemical Oceanography, Academic Press, London, pp. 245-300, 1975.

[8] D. Tilman, K. Cassman, P. Maston, R. Naylor, and S. Polasky, "Agricultural sustainability and intensive production practices," Nature, pp. 418-671, 2002.

[9] J. Galloway, J. Aber, J. Erisman, S. Seitzinger, R. Howarth, E. Cowling, and B. Cosby, "The nitrogen cascade," Bioscience, pp. 53-341, 2003.

[10] J. Liu, and J. Diamond, "China's environment in a globalizing world," Nature, vol. 435, pp. 1179-1186, 2005.

[11] A. Lawniczak, J. Zbierska, B. Nowak, K. Achtenberg, A. Grzeskowiak, and K. Kanas, "Impact of agriculture and land use on nitrate contamination in groundwater and running water in central-west Poland," Environ. Monit. Assess., vol. 172, pp. 3-17, 2016.

[12] http://www.agvise.com/educational-articles/high-soil-nitrates-following-drought.

[13] M. Bechmann, "Nitrogen losses from agricultural in the Baltic Sea region," Agriculture, Ecosystems and Environment, vol. 198, pp. 13-24, 2014.

[14] R. Jiang, R. Hatano, Y. Zhao, K. Woli, K. Kuramochi, M. Shimizu, A. Hayakawa, "Factors controlling nitrogen and dissolved organic carbon exports across time-scales in two watersheds with different land uses," Hydrol. Process., vol. 28, pp. 5105-5121, 2014.

[15] K. Kyllmar, L. Forsberg, S. Andersson, and K. Martensson, "Small agricultural monitoring catchments in Sweden representing environmental impact," Agric. Ecosyst. Environ. vol. 198, pp. 25-35, 2014.

[16] P. Vitousek, J. Aber, R. Howarth, G, Likens, P. Matson, D. Schindler, W. Schlesinger, and D. Tilman, "Human alteration of the global nitrogen cycle, sources and consequences," Ecol. Appl., vol. 7, pp. 737–750, 1997.

[17] S. Carpenter, N. Caraco, D. Correll, R. Howarth, A. Sharpley, and V. Smith, "Nonpoint pollution of surface waters with phosphorus and nitrogen," Ecol. Appl., vol. 8, pp. 559–568, 1998.

[18] W. Moomaw, "Energy, industry and nitrogen: strategies for decreasing reactive nitrogen emissions," Ambio, vol. 31, pp. 184–1896, 2002.

[19] L. Boumans, D. Fraters, and G. Van Drecht, "Nitrate leaching by atmospheric deposition to upper groundwater in the sandy regions of the Netherlands in 1990," Environ. Monit., vol. 93, pp. 1–15, 2004.

[20] E. Rice, and S. Pancholy, "Inhibition of nitrification by climax ecosystems," Amer. J. Bot., vol. 59, pp. 1033–1040, 1972.

[21] R. Haynes, and Goh, K. "Ammonium and nitrate nutrition of plants," Biol. Rev., vol. 53, pp. 465–510, 1978.

[22] M. Lodhi, "Inhibition of nitrifying bacteria, nitrification, and mineralization of spoil soils as related to their successional stages," Bull. Torrey. Bot. Club., vol. 106, pp. 284–289, 1978.

[23] H. Caspers, "Deutsche Einheitsverfahren Abwasser-und Schlamm-Untersuchung Physikalische, chemische und bakteriologische Verfahren," Herausgeg. v. d. Fachgruppe Wasserchemie in der Gesellschaft Deutscher Chemiker. völlig neubearbeitete Aufl," Internationale Revue der gesamten Hydrobiologie und Hydrographie, vol. 46, pp. 494-494, January 1961.

[24] N. Van Straalen, "Chapter 6 The use of soil invertebrates in ecological surveys of contaminated soils," Developments in Soil Science, vol. 29, pp. 159–195, 2004.

[25] Z. Sylvain, and D. Wall, "Linking soil biodiversity and vegetation: Implications for a changing planet," Am. J. Bot., vol. 98, pp. 333-335, 2011.

[26] M. Ivaska, A. Kuua, M. Meristea, J. Truub, M. Truub, and V. Vaaterc, "Invertebrate communities (Annelida and epigeic fauna) in three types of Estonian cultivated soils," Eur. J. Soil. Biol., vol. 44, pp. 532-540, 2008.

[27] E. Doblas-Miranda, "Ecology of soil macroinvertebrates in a Mediterranean arid ecosystem," Ph. D. Thesis Universidad de Granada, Andalusia, Spain, 2007.

[28] K. Abd El-Wakeil, "Ecotoxicolgical studies on terrestrial isopods (Crustacea) in Assiut, Egypt," Ph. D. Thesis, Assiut Univ., Egypt, pp. 271, 2005.

[29] A. Al-Sanabani, "Biological studies on terrestrial slugs (Gastropoda) in Assuit, Egypt with special reference to their ecology," Ph. D thesis, University of Assuit, Egypt, 2008.

[30] A. Obuid-Allah, H, Abdel-Tawab, Z. El-Bakary, K. Abd El-Wakeli, and A. El-Sanabany, "A survey and population dynamics of terrestrial slugs (Mollusca, Gastropoda) at Assuit Governate, Egypt," Egypt. J. Zoo., vol. 51, pp. 585-608, 2008.

[31] R. Ramzy, "Biological and ecological studies on land snails at Assiut, Egypt. M. Sc. Thesis, Faculty of Science, Assiut University, Egypt," pp. 164, 2009.

[32] R. Ramzy, "Ecological Studies on Soil Macroinvertebrates Community in Different Ecosystem" ph. D. Thesis, Department of Zoology, Faculty of Science, Assiut University, 2015.

[33] E. Doblas-Miranda, F. Sánchez-Piñero, A. González-Megías, "Soil macroinvertebrate fauna of a Mediterranean arid system: composition and temporal changes in the assemblage," Soil. Biol. Biochem., vol. 39, pp. 1916–1925, 2007.

[34] J. Frouz, "Use of soil dwelling Diptera as bioindicators: a review of ecological requirements and response to disturbance," Agric. Ecosys. Environ., vol. 74, pp. 176-186, 1999.

[35] K. Tajovsky, "Impact of inundations on terrestrial arthropod assemblages in southern Moravian flood plain forests," Czech Republic. Ekol. Bratislava, vol. 18, pp. 177-184, 1999.

[36] J. Adis, and W. Junk, "Terrestrial invertebrates inhabiting lowland river flood plains of Central Amazonia and Central Europe: a review," Freshwater Biol., vol. 47, pp. 711-731, 2002.

[37] J. Frouz, J. Frouzova, and R. Lobinske, "Horizontal and vertical distribution of soil macroarthropods along a spatio-temporal moisture gradient in subtropical central Florida," Environ. Entomol., vol. 33, pp. 1282-1295, 2004.

[38] W. Whitford, "Subterranean termites and long term productivity of desert rangelands," Sociobiology, vol. 19, pp. 235-243, 1991.

[39] H. Heatwole, "Energetics of Desert Invertebrates," Springer, Berlin and NewYork, pp. 266, 1996.

[40] E. Miranda, F. Sanchez-Pinero, and A. Gonzalez-Megias, "Vertical distribution of soil macrofauna in an arid ecosystem: Are litter and belowground compartmentalized habitats?," Pedobiologia, vol. 52, pp. 361-373, 2009.

[41] N. Stork, and P. Eggleton, "Invertebrates as determinants and Indicators of soil quality," Am. J. Alternative Agr., vol. 7, 1992.

[42] M. Bedair, "Bioenergetics studies on some isopod species in Ismailia region" Ph. D. Thesis, Suez Canal University, 1991.

[43] D. Bardgett, D. Bowman, R. Kaufmann, and K. Schmidt, "A temporal approach to linking aboveground and belowground ecology," Ecology and Evolution, vol. 20, pp. 11, 2005.

[44] J. Blondel, and J. Aronson, "Biology and wildlife of the Mediterranean region," Oxford University Press, Oxford, New York, 1999, pp. 328.

[45] J. Smith, A. Chapman, and P. Eggleton, "Baseline biodiversity surveys of the soil macrofauna of london's green spaces," Urban Ecosyst., vol. 9, pp. 337-349, 2006.

[46] W. Mikhail, "Activity density of the epigeic soil mesofauna in northern Sinai, Egypt," Zool. Middle East, vol. 16, pp. 111-120, 1998.

[47] D. Hall, and R. Cherry, "Effect of temperature in Blooding to control the wireworm *Melanotus communis* (Coleoptera: Elateridae)," Fla. Entomol., vol. 76, pp. 155-160, 1993.

[48] T. Hsaio, "Plant response to water stress," Annu. Rev. Plant Physiol., vol. 24, pp. 519-570, 1973.

[49] W. Atkinson, J. Fuller, A. Vickery, J. Conway, B. Tallowin, N. Smith, A. Haysom, C. Ings, J. Asteraki, and K. Brown, "Agricultural management, sward structure and food resources on grassland field use by birds in lowland England," J. Appl. Ecol., vol. 42, pp. 932–942, 2005.

[50] R. Jaskuła, and A. Soszyńska-Maj, "What do we know about winter active ground beetles (Coleoptera, Carabidae) in Central and Northern Europe?," Zookeys, vol. 100, pp. 517–532, 2011.

[51] P. Harvey, D. Nellist, and M. Telfer, "Provisional atlas of British spiders (Arachnida, Araneae)," Huntingdon: Biological Records Centre, Vol. 1 & 2, 2002.

[52] O. Paris, "The ecology of *Armadillidium vulgare* (Isopoda: Oniscoidea) in California grassland: food, enemies, and weather," Ecol. Monogr., vol. 33, pp. 1–22, 1963.

[53] D. McCracken, G. Foster, and A. Kelly, "Factors affecting the size of leatherjacket (Diptera: Tipulidae) populations in pastures in the west of Scotland," Appl. Soil Ecol., vol. 2, pp. 203–213, 1995.

[54] J. Anderson, and L. Smith, "Invertebrate response to moist soil management of Playa Wetlands," Ecol. Appl., vol. 10, pp. 550–558, 2000.

[55] K. Al-Dabbagh, "Population dynamics and bioenergetics of the terrestrial isopod *Armadillidium vulgare* in grassland ecosystems," ph. D thesis, University of Leicester, 1976.

[56] R. Davis, M. Hassall, and S. Sutton, "The vertical distribution of isopods and diplopods in a dune grassland," Pedobiologia, vol. 17, pp. 320-329, 1977.

[57] M. Brody, and L. Lawlor, "Adaptive variation in offspring size in the terrestrial isopod, *Armadillidium vulgare*," Oecologia, vol. 61, pp. 55-59, 1984.

[58] M. Vithanage, T. Mikunthan, S. Pathmarajah, S., Arasalingam, and H. Manthrithilake, "Assessment of nitrate-N contamination in the Chunnakam aquifer system, Jaffna Peninsula, Sri Lanka," Springerplus, vol. 3, pp. 271, 2014.

[59] S. Rushton, and M. Hassall, "The effects of food quality on the life history parameters of the terrestrial isopod (*Armadillidium vulgare* (Latreille))" Oecologia, vol. 57, pp. 257-261, 1983.

[60] L. Cole, A. Bradford, J. Shaw, and D. Bardgett, "The abundance, richness and functional role of soil meso and macrofauna in temperate grassland—A case study," Appl. Soil. Ecol., vol. 33, pp. 186–198, 2006.

[61] K. Kliger, "Diplopods and chilopods of conventional and alternative (Biodynamic) fields in Hesse (FRG)," Ber. Nat. Med. Verein Innsbruck Suppl., vol. 10, pp. 243-250, 1992.

[62] G. Evanylo, and M. Alley, "Nitrogen soil testing for corn in Virginia," Virginia Coop. Ext. Publ., pp. 418-016, 1996.

[63] G. Billen, J. Garnierand, and L. Lassaletta, "The nitrogen cascade from agricultural soil to the sea: modeling nitrogen transfers at regional watershed and global scales," Phil. Trans. R. Soc., vol. 368, pp. 1-13, 2013.

[64] D. Fowler, M. Coyle, M. Skiba, U., Sutton, M., Cape, and S. Reis, "The global nitrogen cycle in the twenty-first century," Phil. Trans. R. Soc., pp. 368, 2013.