Pak. J. Agri. Sci., Vol. 60(2), 385-390;2023
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI:10.21162/PAKJAS/23.27
http://www.pakjas.com.pk

Population diversity of soil macro-fauna in cauliflower (*Brassica oleracea*) fields

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Soil macro-fauna regarded as a fundamental indicator, responsive to water pollution's impact on agricultural systems' management options. They are an essential part and hence contributing to the pivotal role in all the agro-ecosystems. In the present study, soil macro-faunal diversity was estimated from cauliflower fields (treated and control) in Faisalabad, district, Pakistan. Soil macro-fauna belonging to three phyla were recorded from cauliflower treated and control fields. The maximum relative abundance was recorded for phylum Mollusca (58.18%) from cauliflower control fields. In cauliflower control fields, the macro-fauna population consisted of 52 species, 44 genera and 24 families and nine orders. The cauliflower treated fields consisted of 58 species, 51 genera and 60 families, and 12 orders. Highest diversity index was found in cauliflower treated fields (3.451); the higher dominance was in cauliflower control fields (0.526). Evenness was recorded higher (0.474) in control cauliflower fields, while richness in cauliflower treated fields was recorded higher (8.855) than in control fields (6.499). These agro-farming practices are destroying important organisms, soil texture, hydrological procedures, detoxification, and nutrients recycling. Presently, it is dire need to make conservation strategies for the survival of fauna.
Keywords: Agroecosystems, environmental pollution, impact, soil fauna.

INTRODUCTION

Soils are multifocal component and diversified systems which reflect the series of "regulating services" as structure maintenance, decomposer's population, nutrient cycling, that results in a sustainable ecosystem. Soil macro-fauna have a substantial impact on soil components, their processes (Barrios 2007, Bayon and Milleret, 2009), principal constituents of soil ecosystem which accelerate the decomposition of organic matters and the availability of nutrients for ideal functioning (Xin *et al.,* 2012). They further affect decomposition either directly by fragmentation of litter organic matter or indirectly by changing microbial function (Lavelle *et al.*, 2006). Macro-invertebrates play many crucial roles in sustaining the soil composition and richness in natural and man-customized habitats. They are useful indicators that showed the soil health status, regulation of the ecological behavior and decomposer's population to upgrade soil (Bautista-Cruz *et al.,* 2012). Whereas xenobiotically directed soils control the soil macro-invertebrate populations that lead to unwanted alteration in soil execution (Barros *et al.,* 2002, Lavelle *et al.*, 2006, Ruiz *et al.*, 2008).

During the last few decades, the contamination of soils by heavy metals has increased dramatically. Land degradation affected via heavy metals reflected the significant adverse impacts on the environment, ecosystem, and biological processes (Morgan, 2013, Chibuike and Obiora, 2014, Chen *et al.*, 2016). Under these adverse and extreme soil conditions, macro-fauna has become the potential indicator of soil disturbances (Jolly *et al.,* 2013). Soil pollution by heavy metals is notorious for boasting negative impacts on soil macro-fauna. Ants are considered the excellent indicators of industrial pollution and successful remedy of degraded regions. High abundance, species richness, ease of sampling, division into morpho-species, and particular taxa are perceivable environmental alterations (Nahmani *et al.*, 2005, Tessaro *et al.*, 2016).

It has been recorded that diversity and abundance of macro-fauna have been used as tension index for soil (Menandro *et al.,* 2019). However, polluted water results in long-term soil degradation and reduces the number of soil macro-fauna through changes of microhabitats (Ruiz *et al.,* 2008). They endorsed the present findings that soil pollution in any way is hazardous for soil macro-faunal diversity. Anthropogenic activities such as (physical and chemical), forestry and agriculture disturbances adversely to soil faunal diversity (Tilman, 2000). Keeping in view, the present study was designed to check the impact of soil pollutants on the variety and fauna occurrence.

Kanwal, S., N. Rana, W. Majeed and S. Maqsood. 2023. Population diversity of soil macro-fauna in cauliflower (*Brassica oleracea*) fields. Journal of Agricultural Sciences 60:385-390.
[Received 12 Jan 2021; Accepted 23 may 2023; Published 27 Jun 2023]

MATERIALS AND METHODS

***Study area*:** In the current study, cauliflower fields with parallel topography were randomly selected from a similar area of Faisalabad district, Punjab, Pakistan. Fields were named as control; those were irrigated with tube well water and the fields irrigated with untreated sewage wastewater irrigation were taken as treated. The average rainfall in Faisalabad is 346 mm. The coordinates of the districts are 31.4504° N, 73.1350° E. The soil texture is composed of sand 59 %, silt 19 %, clay 22 %, generally, soil is sandy clay loam (Khan *et al*., 2010).

Sampling strategy: The sampling was done from the selected cauliflower fields, pre to post harvesting, for two successive seasons from each vegetable field on a fortnightly basis. Soil samples were taken from both the treated and control fields with three replications. A total of nine quadrat samples was taken from each field. To maintain the reliability of the experiment, three samples were collected right from the boundary, middle and center of each selected field. The specimens were collected and sorted by handpicking, forceps and Berlese funnel respectively (Magurran, 1988, Rana *et al.*, 2010) and preserved in separate glass jars with laboratory-grade alcohol and glycerin. Each specimen was marked indicating the date of collection, name of the locality, micro-habitat (boundary/middle/center) and field name. Identification of soil macro-fauna was made up to species level based on the taxonomic keys/literature (Pocock and Blanford, 1900, Holloway *et al.*, 1992, Rafi *et al.*, 2005, Triplehorn *et al.*, 2005).

***Statistical analysis*:** Data were analyzed statistically to determine species diversity and abundance, species richness and species evenness with Shannon-Weiner diversity index (Shannon, 1948). The comparisons of both sampling sites were made by using t-test and correlation was used to find the effect of temperature and humidity on soil-macro fauna. The data recorded were analyzed by SPSS and Microsoft excel, and all the analyses were performed at a level of significance $\alpha = 0.05$.

RESULTS

Among the two fields, total 2879 specimens were collected during the entire sampling and the higher population was recorded from 76.06% (n = 2190) in cauliflower control fields. The lesser population of soil macro-fauna 24.24% (n = 698) was recorded from cauliflower treated fields. During the present study, the diversity index was found higher in cauliflower treated fields (3.451) in contrast to control fields (1.864). The dominance was higher in cauliflower control fields (0.526) when compared with treated fields (0.153). Evenness was higher in cauliflower and (0.474) in control cauliflower fields. The richness in cauliflower fields, was recorded higher in treated fields (8.855) than in control fields (6.499). t-test analysis was significant (t = 28.14; $p < 0.001$) among cauliflower control fields and treated fields cultivations; furthermore, t-test analysis was highly significant among boundary (t = 7.83; $p < 0.001$), middle (t = 20.28; $p < 0.000$) and center (t = 11.12; $p < 0.001$) between control fields and treated fields cultivations (Table 1).

Table 1. Analysis of species diversity difference between the control and treated fields of cauliflower crop by t-test.

Sampling point	Treatment	Shannon diversity (H)	t-value	P-value
Boundary	Treated	2.421	7.83***	0.0000
	Control	1.586		
Middle	Treated	3.007	20.28***	0.0000
	Control	1.345		
Center	Treated	2.838	11.12***	0.0000
	Control	1.910		
Total	Treated	3.451	28.14***	0.0000
	Control	1.864		

** = Significant (P<0.05); *** = Highly significant (P<0.01)

Diversity: Subjected to cauliflower control fields, maximum (H′) was calculated 2.103 during 6th sampling, followed by 1.578 (2nd), 1.514 (3rd), 1.414 (7th), 1.062 (5th), 1.054 (5th) and the least (H′) 1.005 was determined for1st sampling (Table 1). In cauliflower treated fields, maximum (H′) was recorded 2.459 during (7th) sampling, followed by 2.436 (6th), 2.135 (3rd), 2.039 (4th), 1.925 (5th), 1.809 (2nd) whereas, the least (H′) 1.782 was calculated for 1st sampling (Table 2).

Dominance: In the case of cauliflower control fields, maximum dominance (D) 0.5858 was determined in (4th) sampling, followed by 0.5424 (1st), 0.4934 (5th), 0.4103 (7th), 0.3148 (5th), 0.2859 (6th) sampling and least dominance (D) 0.2220 was determined in 3rd sampling (Table 1). In cauliflower treated fields, maximum (D) 0.3057 was calculated in (5th) sampling, followed by 0.2454 (2nd), 0.2000 (6th), 0.1796 (4th), 0.1678 (3rd), 0.1650 (7th) sampling and least (D) 0.0842 was determined in 1st sampling (Table 2).

***Evenness*:** In cauliflower control fields, maximum Evenness (E) 0.778 was determined in (3rd) sampling, followed by 0.714 (2nd), 0.685 (3rd), 0.590 (7th), 0.507 (5th), 0.458 (6th) sampling and least Evenness, 0.414, was calculated in 7th sampling (Table 1). In the case of cauliflower treated fields, utmost evenness (E) 0.916 was calculated in (1st sampling), followed by 0.835 (7th), 0.832 (3rd), 0.820 (4th), 0.800 (5th), 0.755 (3rd) sampling and least Evenness (E) 0.694 was detected in 7th sampling (Table 2).

***Richness*:** In the case of cauliflower control fields, maximum (R) (2.961) was determined during (6th) sampling, followed by 1.961 (4th), 1.814 (2nd), 1.676 (7th), 1.509 (1st) 1.175 was calculated in (5th) sampling and least richness (R) 1.154 in 3rd sampling (Table 1). In the case of cauliflower treated fields, maximum (R) (3.881) was documented during (6th) sampling,

Table 1. Sampling wise Shannon diversity indices of soil macro-fauna recorded from Cauliflower control fields

Samplings	Sample1	Sample2	Sample3	Sample4	Sample5	Sample6	Sample7
Diversity(H´)	1.005	1.578	1.514	1.062	1.054	2.103	1.414
Evenness (J)	0.458	0.685	0.778	0.414	0.507	0.714	0.590
Dominance (D)	0.542	0.315	0.222	0.586	0.493	0.286	0.410
Richness (R)	1.509	1.814	1.154	1.961	1.175	2.961	1.676

(Note: Sample 1 means the 1st collection of individuals and so on up to 7th)

Table 2. Sampling wise Shannon diversity indices of soil macro-fauna recorded from Cauliflower treated fields

Samplings	Sample1	Sample2	Sample3	Sample4	Sample5	Sample6	Sample7
Diversity (H´)	1.782	1.809	2.135	2.039	1.925	2.436	2.459
Evenness (J)	0.916	0.755	0.832	0.820	0.694	0.800	0.835
Dominance (D)	0.084	0.245	0.168	0.180	0.306	0.200	0.165
Richness (R)	1.627	2.234	2.746	2.698	3.087	3.881	3.692

(Note: Sample 1 means the 1st collection of individuals and so on up to 7th)

followed by 3.692 (7th), 3.087 (5th), 2.746 (3rd), 2.698 (4th) 2.234 was determined in (2nd) sampling and the least richness (R) 1.627 in 1st sampling (Table 2).

Impact of temperature and humidity: The present investigation demonstrated the impacts of climatic conditions (temperature and humidity) on the soil macro-fauna populations' diversity indices among cauliflower (control and treated fields).

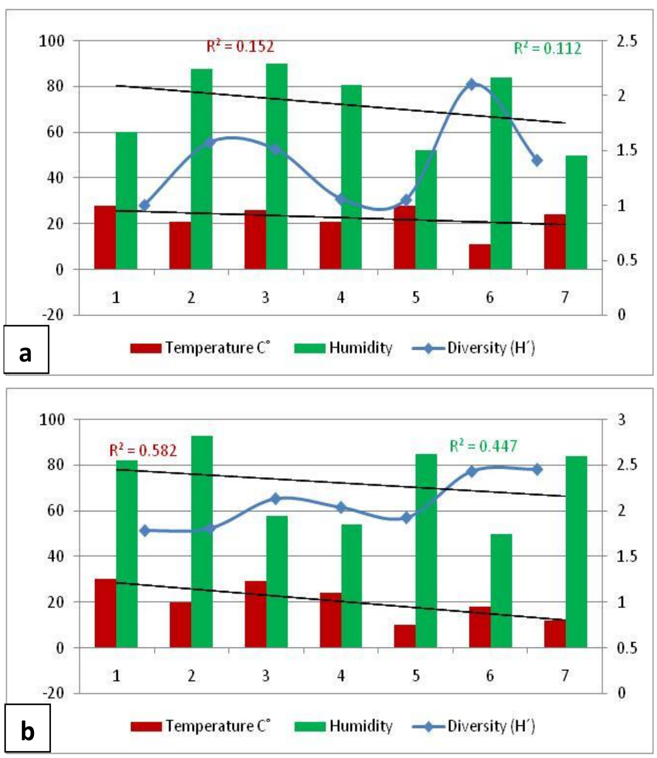

Figure 1. Effect of temperature and humidity correlation on diversity of soil macro-fauna diversity in cauliflower field (a) Control (b) Treated. Figure showing the linear curve with adjusted r^2 value.

In cauliflower control fields, the least diversity was recorded (1.005) at the pre-harvest stage, and utmost diversity (2.103) was recorded during the 6th sampling (Fig. 1a). In case of cauliflower treated fields (Fig. 1b), the least diversity (1.782) was recorded in pre-harvest sampling. Similarly, maximum diversity (2.459) was recorded during post-harvest sampling. The lowest dominance (0.2220) was determined during the 3rd sampling, whereas the highest dominance was calculated in the 4th sampling (0.5858) (Fig. 2a). Likewise, least dominance (0.0842) was observed during the pre-harvest stage (the 1st sampling) while, the highest dominance was determined during the 5th sampling (Fig. 2b).

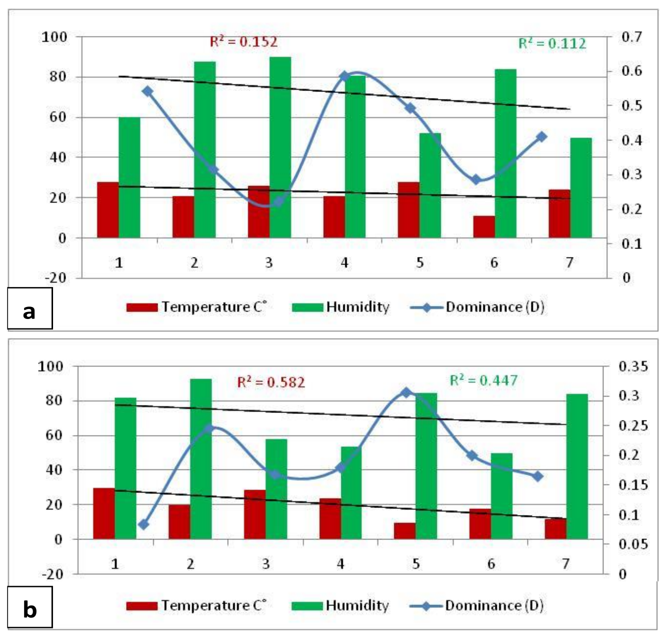

Figure 2. Effect of temperature and humidity correlation on diversity of soil macro-fauna dominance in cauliflower field (a) Control (b) Treated. Figure showing the linear curve with adjusted r^2 value.

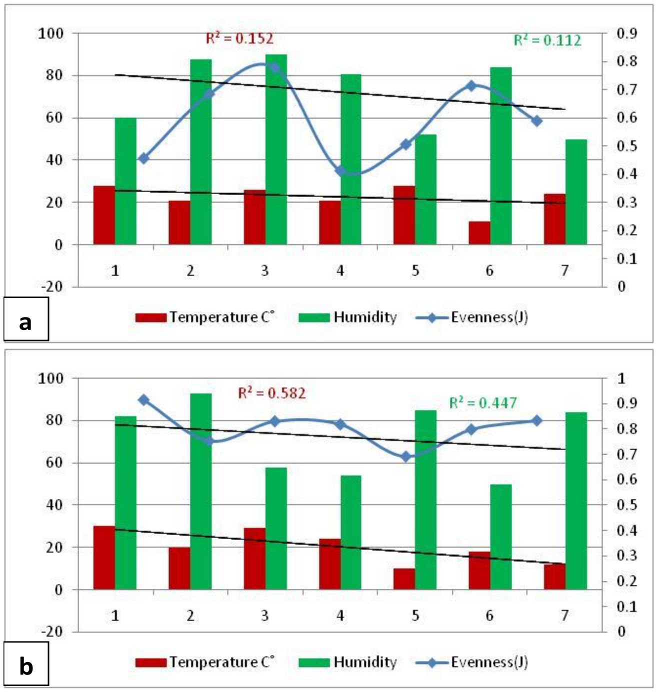

Figure 3. Temperature and humidity correlation effects on soil macro-fauna Evenness in cauliflower fields (a) Control (b) Treated. Figure showing the linear curve with adjusted r^2 value.

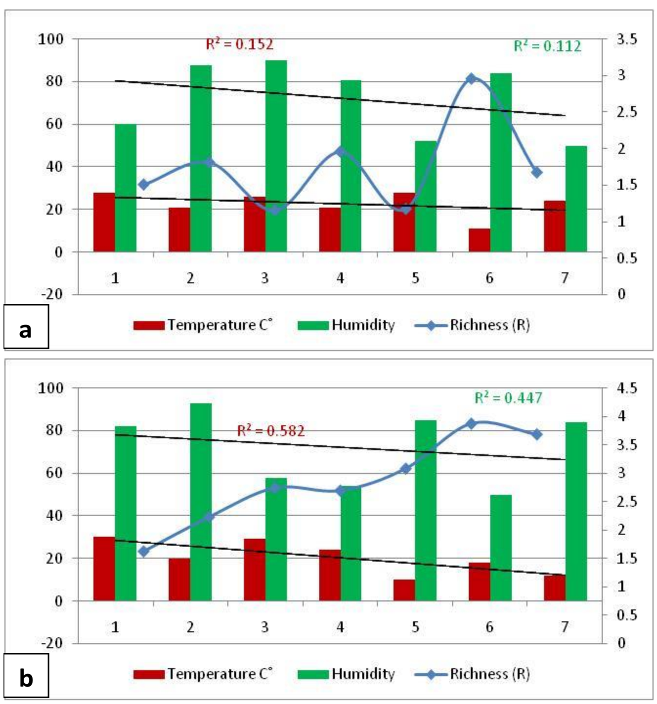

Figure 4. Temperature and humidity correlation effects on soil macro-fauna Richness in cauliflower fields (a) Control (b) Treated. Figure showing the linear curve with adjusted r^2 value.

In (Fig. 3a) data presented, the least evenness (0.414) was observed in the 4th sampling, while high (0.778) evenness was observed during 3rd sampling. In continuation, the least evenness (0.694) was observed in 5th sampling, while maximum evenness (0.916) was observed at pre-harvest sampling- depicting the hardness of treatments (Fig. 3b).

The lowest richness (1.54) was observed during the 3rd sampling, whereas the maximum richness was recorded during 6th sampling (2.961) (Fig. 4a). In the same way, richness was recorded lowest (1.627) at the pre-harvest stage and highest (3.881) was recorded at 6th sampling (Fig. 4b).

DISCUSSION

Soil being a supreme diverse and imperative habitat has species-rich communities and includes one of the optimum combinations of soil fauna and flora with variable diversity indices (Khodashenas *et al.,* 2012). Among them, soil macro-fauna has distinct diversity and, in some ecosystems, local variations about them are much superior (Lavelle *et al.,* 2006). In the present study, the present study, the soil chemical and biological properties trend was reflected by their abundance and density, better than their taxa richness (Fig. 3a&b), also addressed by (Siqueira *et al.,* 2014). Therefore, it is supposed that soil organisms' abundance and density are more affected by soil properties than taxa richness, as also reported by (Nahmani and Lavelle, 2002). The abundance and diversity of macro-fauna were also used as a tension-time index for soil profile (Menandro *et al.*, 2019); having great importance in litter decomposition and nutrients cycle, also accounts to depict the current status of the area and could be used as the best factor in the determination of soil quality as well (Xin *et al.*, 2012, Moghimian and Kooch, 2013). They are one of the ecosystem's main constituents because they perform an essential role in accelerating organic matter decomposition and moving nutrients (Mathieu *et al.,* 2004, Ruiz *et al.,* 2008, Xin *et al.,* 2012, Moghimian and Kooch, 2013).

Determination of diversity, richness, evenness, and abundance indices of fauna is required for ecological studies, habitat management and conservation programs for ecosystem evaluation (Nahmani *et al.,* 2005). The current study aimed to address the indices of diversity and density of soil macro-fauna in cauliflower treated and control fields. Anthropogenic activities adversely overstate soil fauna through agriculture and forestry disturbances (physical and chemical) (Tilman, 2000). Other threats to them include climate change, landslides, and toxic wastes such as heavy metals and untreated wastewater irrigation in agricultural lands. However, polluted water results in long-term soil degradation and reduces the number of soil macro-fauna by altering the microhabitats (Ruiz *et al.,* 2008). They endorsed the present findings that soil pollution in any way is hazardous for soil macro-fauna.

The present study results supported scientist's research that explained that temperature is a primary factor in influencing ants' diversity globally (Diamond *et al.,* 2012). Moreover, many scientists observed that climate change sturdily influenced the soil macro-faunal physiology through shifting the soil temperature and moisture (Brose *et al.,* 2012, Lurgi *et al.,* 2012). Ants exhibited prominent species dominance level with variation in elevation (Sanders, 2002, Burwell and Nakamura, 2011), indicating that their distribution patterns were probable susceptible to overall temperature change (Deutsch *et al.*, 2008, Del Toro *et al.*, 2015). A higher abundance of Coleoptera beetle was associated with high temperature and low humidity, such as beetles prefer the warm and dry environment. *Dermaptera* sp. abundance was somewhat correlated to low temperature, high humidity and a higher soil humidity level. (Briones *et al.,* 1997) described the impacts of temperature alterations on macro-fauna, while further studies were also concerned about the effects of changed moisture regimes.

Conclusion: Conclusively, soil macro-fauna correlates with soil habitat and appropriate conditions that directly or indirectly affect its populations. The treated field showed minimum diversity and maximum dynamic in population was recorded, which described that wastewater had exerted pressure on the fauna. Moreover, soil macro-fauna is cost-effective, functionally important, and a pivotal role in establishing the decomposer population in our environment. Soil fauna is greatly affected by anthropogenic activities; besides these, further threats to them may include climate change, landslides, and toxic heavy metals present in untreated wastewater that has been a source of irrigation in agricultural lands.

Conflict of Interest: The Authors declare that there is no conflict of interest.

Authors' Contribution Statements**:** SK and NR designed the field research. SK, WM, SM did field work, whereas, SK, WM, SM did laboratory work. NR supervised the work and NR, WM provide the editorial advice.

Acknowledgement**:** Authors acknowledge the Department of Zoology, Wildlife and Fisheries, University of Agriculture, Faisalabad for providing facilities of research work.

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