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Diversity and Community Composition of Soil Macro-Arthropods under Contrasting Irrigation Regimes in Tomato Fields of Okara, Pakistan

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Email: mislamashfaq786@gmail.com**ARTICLE INFO****ABSTRACT****Received:**

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Soil macro-arthropods are important components of agroecosystems and may respond to changes in irrigation-associated soil conditions. This study compared the abundance, community composition and diversity of soil macro-arthropods in tube-well-irrigated and wastewater-irrigated tomato fields in Okara, Punjab, Pakistan. Sampling was conducted from February to May at fortnightly intervals, with seven sampling events under each irrigation condition. Macro-arthropods were collected using quadrat sampling, hand sorting, forceps and Berlese funnel extraction and were identified using morphological characteristics and standard taxonomic keys. A total of 1,031 individuals were recorded, including 351 (34.04%) from the tube-well-irrigated field and 680 (65.96%) from the wastewater-irrigated field. The tube-well-irrigated field supported 63 species belonging to 53 genera, 33 families and 10 orders, whereas the wastewater-irrigated field contained 42 species belonging to 33 genera, 24 families and 7 orders. Isopoda was the dominant order under wastewater irrigation, accounting for 75.59% of individuals, with *Porcellio scaber* alone representing 53.09% of the total wastewater-irrigated community. Shannon diversity ($H' = 3.6514$), Pielou evenness ($J = 0.8813$) and Margalef richness ($R = 10.5788$) were higher in the tube-well-irrigated field, while Simpson dominance was higher under wastewater irrigation ($D = 0.3149$). These findings indicate that wastewater irrigation was associated with greater total abundance but stronger dominance by a limited number of taxa, whereas tube-well irrigation supported a richer and more evenly distributed soil macro-arthropod community.

Introduction

Tomato (*Solanum lycopersicum* L.) is an economically important vegetable crop widely cultivated for fresh consumption and processing. Successful tomato production depends considerably on irrigation because both water availability and irrigation-water quality can influence soil fertility, salinity, nutrient availability and rhizosphere conditions. Recent studies have shown that wastewater reuse in tomato production can modify soil nutrient availability and microbial community structure, while alternative irrigation sources are increasingly being considered in regions where freshwater resources are limited (Muscarella

et al., 2024; Shahmoradi *et al.*, 2025). Such changes in the soil environment may also influence organisms inhabiting tomato-field soils, including soil macro-arthropods.

Soil macro-arthropods are important components of agricultural ecosystems because they contribute to organic-matter decomposition, nutrient cycling, soil-structure development and trophic interactions. Through fragmentation of plant residues and interactions with soil microorganisms, many soil-faunal groups facilitate decomposition and nutrient release, while predators and other functional groups contribute to below-ground food webs. Their abundance and community composition can therefore provide useful information on changes in soil conditions and agricultural management (Mamabolo *et al.*, 2024; Shehzad *et al.*, 2024). Recent evidence also indicates that crop type and management practices can influence soil arthropod abundance, diversity and community structure (Remelli *et al.*, 2025).

Wastewater is increasingly used for agricultural irrigation in areas where freshwater availability is limited. It can provide an additional source of water and nutrients for crop production. However, untreated or inadequately treated wastewater may also introduce salts, pathogens, heavy metals and other contaminants into agricultural soils. Its effects may therefore include both improved nutrient availability and deterioration of soil quality depending on wastewater composition, soil characteristics and duration of application (Minhas *et al.*, 2022). Wastewater irrigation has also been associated with changes in salinity, sodicity and other soil physicochemical properties, indicating that irrigation-water quality can modify the soil environment over time (Bekir *et al.*, 2022; Lu *et al.*, 2022).

These concerns are particularly relevant as in Punjab, Pakistan, wastewater-irrigated agricultural soils and crops have been reported to contain measurable concentrations of several heavy metals, with some elements transferred from soil to edible plant tissues (Atta *et al.*, 2023). Changes in soil chemistry, moisture, nutrient availability, organic matter and salinity may alter habitat and resource conditions for soil organisms. Responses of soil arthropods are likely to vary among taxonomic groups because of differences in their ecological requirements and tolerance to environmental disturbance. Consequently, contrasting irrigation conditions may influence abundance, species richness, evenness, dominance and overall community composition.

Despite increasing attention to wastewater reuse and soil contamination, recent information on species-level soil macro-arthropod assemblages under contrasting irrigation regimes remains limited, particularly in tomato agroecosystems of Punjab, Pakistan. Soil macro-arthropods contribute to litter decomposition, nutrient cycling and the maintenance of soil structure, and changes in their abundance and diversity may reflect ecological stress associated with altered soil conditions or contaminant exposure. A decline in macro-arthropod diversity may consequently affect soil functioning and the long-term sustainability of agricultural ecosystems. Moreover, where wastewater irrigation introduces potentially harmful contaminants into agricultural soils, associated changes in soil biota may provide an early indication of environmental disturbance with possible implications for crop production and food-chain safety. Therefore, the present study was conducted to compare the abundance, taxonomic composition and diversity of soil macro-arthropods in tube-well-irrigated and wastewater-irrigated tomato fields in Okara, Punjab, Pakistan.

Materials and Methods

Study area and sampling

The study was conducted in tomato (*Solanum lycopersicum* L.) fields in Okara, Punjab, Pakistan, under two irrigation conditions: tube-well irrigated and wastewater irrigated. Sampling was carried out from February to May during the spring tomato crop, covering the pre-harvest to post-harvest stages. Samples were collected at fortnightly intervals, resulting in seven sampling events for each irrigation condition. Five quadrats were selected from each site during each sampling event for the collection of soil macro-arthropods.

Collection and taxonomic identification

Collected soil macro arthropods samples were transported to the General Laboratory, Department of Zoology, University of Okara. Macro-arthropods were separated by hand sorting, forceps and Berlese funnel extraction and preserved in labelled glass vials containing laboratory-grade alcohol with a few drops of glycerin. Identification was based on morphological characteristics observed with the naked eye, magnifying glass and microscope using standard taxonomic keys and reference literature (Holloway *et al.*, 1992; Pocock, 1900; Triplehorn *et al.*, 2005). Before analysis, species names were taxonomically reviewed and standardized, and records with uncertain species-level identification were excluded from the final dataset.

Data analysis

Abundance and relative abundance were determined for each taxon under both irrigation conditions. Community diversity was assessed using the Shannon diversity index (H'), Pielou evenness (J), Simpson dominance (D) and Margalef richness index (R), with natural logarithms used in the diversity calculations.

Results

A total of 1,031 soil macro-arthropod individuals were recorded from the two tomato-field irrigation conditions. The tube-well-irrigated field contained 351 individuals (34.04%), representing 63 species, 53 genera, 33 families and 10 orders. In comparison, the wastewater-irrigated field contained 680 individuals (65.96%), comprising 42 species, 33 genera, 24 families and 7 orders (Table 1). Thus, although a greater number of individuals was recorded in the wastewater-irrigated field, greater taxonomic richness was observed in the tube-well-irrigated field.

Field type	Sampling events	Individuals, N (%)	Orders	Families	Genera	Species
Tube-well irrigated	7	351 (34.04)	10	33	53	63
Wastewater irrigated	7	680 (65.96)	7	24	33	42
Total	14	1,031 (100.00)				

Table 1. Overall taxonomic composition and abundance of soil macro-arthropods recorded from tomato fields in Okara, Punjab, Pakistan

Order-level composition showed marked variation between the two irrigation conditions (Table 2; Fig. 1). In the tube-well-irrigated field, Isopoda was the most abundant

Table 2. Order-level abundance and relative abundance of soil macro-arthropods recorded from tube-well-irrigated and wastewater-irrigated tomato fields

Order	Tube-well irrigated, N (%)	Wastewater irrigated, N (%)
Hymenoptera	74 (21.08)	73 (10.74)
Araneae	58 (16.52)	27 (3.97)
Orthoptera	17 (4.84)	7 (1.03)
Coleoptera	51 (14.53)	8 (1.18)
Dermaptera	33 (9.40)	49 (7.21)
Isopoda	88 (25.07)	514 (75.59)
Hemiptera	15 (4.27)	0 (0.00)
Lepidoptera	8 (2.28)	2 (0.29)
Isoptera	1 (0.28)	0 (0.00)
Scolopendromorpha	6 (1.71)	0 (0.00)
Total	351 (100.00)	680 (100.00)

order with 88 individuals (25.07%), followed by Hymenoptera with 74 (21.08%), Araneae with 58 (16.52%), Coleoptera with 51 (14.53%) and Dermaptera with 33 (9.40%). Lower contributions were recorded for Orthoptera 17 (4.84%), Hemiptera 15 (4.27%), Lepidoptera 8 (2.28%), Scolopendromorpha 6 (1.71%) and Isoptera 1 (0.28%). In the wastewater-irrigated field, Isopoda was strongly predominant, accounting for 514 individuals (75.59%). This was followed by Hymenoptera with 73 (10.74%), Dermaptera with 49 (7.21%), Araneae with 27 (3.97%), Coleoptera with 8 (1.18%), Orthoptera with 7 (1.03%) and Lepidoptera with 2 (0.29%). Hemiptera, Isoptera and Scolopendromorpha were not recorded from the wastewater-irrigated field.

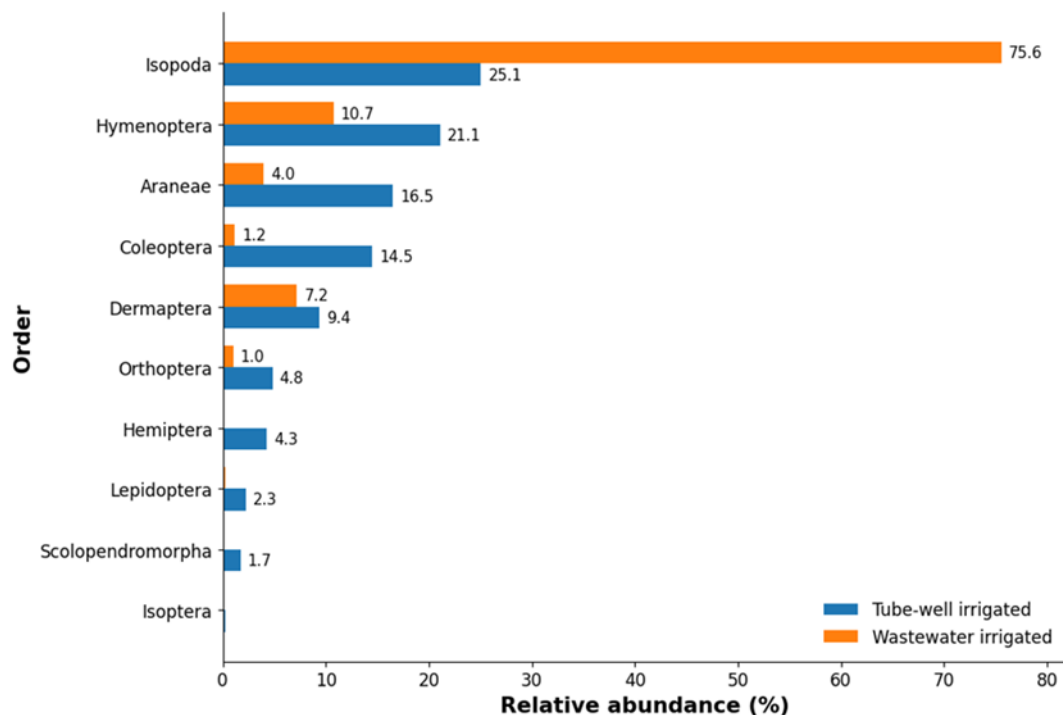


Figure 1. Relative abundance (%) of soil macro-arthropod orders in tube-well-irrigated and wastewater-irrigated tomato fields

At the species level, the dominant taxa also differed between irrigation conditions (Table 3). In the tube-well-irrigated field, *Trichoniscus pusillus* was the most abundant species with 36 individuals (10.26%), followed by *Solenopsis geminata* with 31 (8.83%) and *Messor instabilis* with 20 (5.70%). Other relatively abundant species included *Forficula auricularia* 16 (4.56%), *Trachelipus rathkei* 15 (4.27%), *Trichorhina tomentosa* 14 (3.99%), *Cimex lectularius* 14 (3.99%) and *Trochosa terricola* 11 (3.13%). *Camponotus oblongus* and *Pardosa lignosa* were each represented by 10 individuals (2.85%).

In the wastewater-irrigated field, *Porcellio scaber* was the most abundant species, with 361 individuals representing 53.09% of the total population. The next most abundant species was *Trachelipus rathkei* with 100 individuals (14.71%), followed by *Solenopsis geminata* with 45 (6.62%), *Chelisoche morio* with 43 (6.32%) and *Trichorhina tomentosa* with 28 (4.12%). *Camponotus compressus* accounted for 15 individuals (2.21%), while *Oniscus asellus*, *Monomorium indicum*, *Porcellionides pruinosus* and *Acheta domesticus* represented 1.91%, 1.03%, 0.88% and 0.59%, respectively.

Tube-well-irrigated species	N (%)	Wastewater-irrigated species	N (%)
<i>Trichoniscus pusillus</i>	36 (10.26)	<i>Porcellio scaber</i>	361 (53.09)
<i>Solenopsis geminata</i>	31 (8.83)	<i>Trachelipus rathkei</i>	100 (14.71)

Messor instabilis	20 (5.70)	Solenopsis geminata	45 (6.62)
Forficula auricularia	16 (4.56)	Chelisoches morio	43 (6.32)
Trachelipus rathkei	15 (4.27)	Trichorhina tomentosa	28 (4.12)
Trichorhina tomentosa	14 (3.99)	Camponotus compressus	15 (2.21)
Cimex lectularius	14 (3.99)	Oniscus asellus	13 (1.91)
Trochosa terricola	11 (3.13)	Monomorium indicum	7 (1.03)
Camponotus oblongus	10 (2.85)	Porcellionides pruinosus	6 (0.88)
Pardosa lignosa	10 (2.85)	Acheta domesticus	4 (0.59)

Table 3. Dominant soil macro-arthropod species recorded from tube-well-irrigated and wastewater-irrigated tomato fields

The diversity indices further reflected differences in community structure between the two irrigation conditions (Table 4). The Shannon diversity index was higher in the tube-well-irrigated field ($H' = 3.6514$) than in the wastewater-irrigated field ($H' = 1.8750$). Similarly, Pielou evenness was higher in the tube-well-irrigated field ($J = 0.8813$) compared with the wastewater-irrigated field ($J = 0.5016$). In contrast, Simpson dominance was lower in the tube-well-irrigated field ($D = 0.0383$) than in the wastewater-irrigated field ($D = 0.3149$). Margalef richness followed the same pattern as Shannon diversity and evenness, with a value of 10.5788 in the tube-well-irrigated field and 6.2863 in the wastewater-irrigated field.

Field type	Individuals (N)	Species (S)	Shannon diversity (H')	Pielou evenness (J)	Simpson dominance (D)	Margalef richness (R)
Tube-well irrigated	351	63	3.6514	0.8813	0.0383	10.5788
Wastewater irrigated	680	42	1.8750	0.5016	0.3149	6.2863

Table 4. Diversity indices of soil macro-arthropods in tube-well-irrigated and wastewater-irrigated tomato fields

Discussion

Soil macro-arthropod communities in agricultural fields are shaped by the combined influence of resource availability, soil conditions and management practices. Irrigation source can modify the soil environment and may consequently affect the abundance, distribution and diversity of different arthropod groups. In the present study, clear differences were observed between tube-well-irrigated and wastewater-irrigated tomato fields. The wastewater-irrigated field supported a greater total number of individuals, whereas the tube-well-irrigated field

contained greater species richness and showed higher Shannon diversity and Pielou evenness. In contrast, Simpson dominance was higher under wastewater irrigation, indicating that the community was concentrated among comparatively fewer taxa. Such a pattern may occur when increased moisture, organic inputs or nutrient availability favour the proliferation of certain tolerant groups, while other environmental changes associated with wastewater irrigation may limit more sensitive taxa (Bian *et al.*, 2025; Ghanem *et al.*, 2024). Thus, the higher abundance observed in the wastewater-irrigated field in the present study did not correspond to greater taxonomic diversity, indicating a more uneven community structure under wastewater irrigation.

A prominent feature of the wastewater-irrigated tomato field was the strong dominance of Isopoda, which represented 75.59% of the recorded macro-arthropods, with *Porcellio scaber* alone accounting for 53.09% of the total population. Terrestrial isopods are important detritivores whose abundance may respond to the availability and nutritional quality of organic resources. A recent long-term experiment demonstrated that nitrogen enrichment increased both the abundance and biomass of terrestrial isopods, with the response associated with improved food quality and greater nutrient availability for detritivores (Ni *et al.*,

2025). In addition, *P. scaber* has been shown to modify soil nutritional status and influence bacterial–fungal interactions in agricultural soil, highlighting its close association with detrital and microbially active soil environments (Heffner et al., 2023). These findings provide a plausible ecological explanation for the high isopod abundance observed in the wastewater-irrigated field and suggest that altered resource availability and microhabitat conditions may have favored the persistence and proliferation of *P. scaber* under this irrigation regime.

In addition to the dominance of Isopoda under wastewater irrigation, clear differences were observed among other major arthropod orders. Hymenoptera, Araneae and Coleoptera showed higher relative abundance in the tube-well-irrigated field than in the wastewater-irrigated field. These groups can respond to variation in soil conditions, habitat structure and environmental disturbance, although responses are often taxon-specific. Duval et al. (2026) showed that metal contamination, together with vegetation, soil texture and pH, contributed to changes in the taxonomic and functional structure of ground-dwelling spider communities. Similarly, Amprako et al. (2020) demonstrated that irrigation source can shape arthropod community composition and diversity in vegetable production systems. The comparatively higher representation of Hymenoptera, Araneae and Coleoptera in the tube-well-irrigated field therefore suggests a broader distribution of individuals among major arthropod groups, whereas the wastewater-irrigated community was more strongly concentrated in a few dominant taxa.

The diversity indices further supported the differences in community structure between the two irrigation conditions. The tube-well-irrigated field showed higher Shannon diversity, Pielou evenness and Margalef richness, whereas Simpson dominance was considerably higher in the wastewater-irrigated field. High total abundance does not necessarily indicate greater biodiversity when a large proportion of individuals belongs to only a few taxa. In agricultural systems, environmental disturbance and changes in resource availability can favour certain adaptable groups, resulting in greater numerical dominance but lower evenness and overall diversity (Bian et al., 2025; del-Val et al., 2021). In the present study, the strong numerical dominance of Isopoda, particularly *Porcellio scaber*, in the wastewater-irrigated field likely contributed to the lower Shannon diversity and evenness observed under this irrigation condition. In contrast, the more balanced distribution of individuals among several orders in the tube-well-irrigated field was reflected in its higher diversity and richness values. Overall, the contrasting irrigation regimes were associated with clear differences in soil macro-arthropod community structure in tomato fields. Wastewater irrigation supported a larger population but greater dominance by a few taxa, whereas the tube-well-irrigated field showed higher richness and a more even distribution of arthropod groups. These findings indicate that irrigation source can shape both the abundance and diversity patterns of soil macro-arthropod communities.

Conclusion

The present study revealed clear differences in the abundance, taxonomic composition and diversity of soil macro-arthropod communities between tube-well-irrigated and wastewater-irrigated tomato fields. Although the wastewater-irrigated field supported a higher total abundance of individuals, it exhibited lower species richness, Shannon diversity and evenness, together with greater community dominance. In contrast, the tube-well-irrigated field supported a richer and more evenly distributed macro-arthropod assemblage. The pronounced abundance of Isopoda, particularly *Porcellio scaber*, in the wastewater-irrigated field further indicated that contrasting irrigation conditions were associated with shifts in community composition and the relative abundance of particular taxa. Overall, the findings demonstrate that irrigation regime is associated with substantial variation in soil macro-arthropod abundance, composition and diversity in tomato agroecosystems. Such changes in soil-faunal communities may have implications for soil ecological processes and the long-term biological quality of agricultural soils. Continued monitoring of soil macro-arthropod diversity, together with sustainable irrigation management, may therefore contribute to maintaining the ecological integrity of agroecosystems.

References

- Amprako, L., Stenchly, K., Wiehle, M., Nyarko, G., & Buerkert, A. (2020). Arthropod Communities in Urban Agricultural Production Systems under Different Irrigation Sources in the Northern Region of Ghana. *Insects*, 11(8), 488. <https://doi.org/10.3390/insects11080488>
- Atta, M. I., Zehra, S. S., Dai, D.-Q., Ali, H., Naveed, K., Ali, I., Sarwar, M., Ali, B., Iqbal, R., Bawazeer, S., Abdel-Hameed, U. K., & Ali, I. (2023). Amassing of heavy metals in soils, vegetables and crop plants irrigated with wastewater: Health risk assessment of heavy metals in Dera Ghazi Khan, Punjab, Pakistan. *Frontiers in Plant Science*, 13, 1080635. <https://doi.org/10.3389/fpls.2022.1080635>
- Bekir, S., Zoghalmi, R. I., Boudabbous, K., Khelil, M. N., Moussa, M., Ghrib, R., Nahdi, O., Trabelsi, E., & Bousnina, H. (2022). Soil Physicochemical Changes as Modulated by Treated Wastewater after Medium-and Long-Term Irrigations: A Case Study from Tunisia. *Agriculture*, 12(12), 2139. <https://doi.org/10.3390/agriculture12122139>

- Bian, Z., Liu, L., Li, Y., Li, Y., & Ding, S. (2025). Effects of different fertilization treatments on ground-dwelling arthropods and their functional groups in agricultural landscapes. *Frontiers in Ecology and Evolution*, 13, 1437742. <https://doi.org/10.3389/fevo.2025.1437742>
- del-Val, E., Ramírez, E., & Astier, M. (2021). Comparison of arthropod communities between high and low input maize farms in Mexico. *CABI Agriculture and Bioscience*, 2(1), 40. <https://doi.org/10.1186/s43170-021-00060-9>
- Duval, A., Laderriere, V., Jans, M., Bouquerel, J., Usseglio-Polatera, P., Cebren, A., & Maunoury-Danger, F. (2026). Functional and Taxonomic Structuring of Ground-Dwelling Spider Communities Under the Combined Effects of the Environment and Metal Contamination. *Ecology and Evolution*, 16(8), e73958. <https://doi.org/10.1002/ece3.73958>
- Ghanem, M. F. S. A., Afzal, S., Nesar, H., Imran, Z., & Ahmad, W. (2024). Impact of metal polluted sewage water on soil nematode assemblages in agricultural settings of Aligarh, India. *Soil Ecology Letters*, 6(1), 230193. <https://doi.org/10.1007/s42832-023-0193-3>
- Heffner, T., Bami, S. A., Mendes, L. W., Kaupper, T., Hannula, E. S., Poehlein, A., Horn, M. A., & Ho, A. (2023). Interkingdom interaction: The soil isopod *Porcellio scaber* stimulates the methane-driven bacterial and fungal interaction. *ISME Communications*, 3(1), 62. <https://doi.org/10.1038/s43705-023-00271-3>
- Holloway, J. D., Bradley, J. D., & Carter, D. J. (1992). *Lepidoptera* (Reprint). Internat. Inst. of Entomology.
- Lu, J., Wang, H., & Hu, C. (2022). Changes in Physicochemical Properties of Typical Subtropical Soils under Different Treated Domestic Wastewater Irrigation Modes. *Sustainability*, 14(16), 10197. <https://doi.org/10.3390/su141610197>
- Mamabolo, E., Gaigher, R., & Pryke, J. S. (2024). Litter decomposition is positively related to soil fauna species richness especially in livestock-integrated agricultural fields. *Applied Soil Ecology*, 200, 105461. <https://doi.org/10.1016/j.apsoil.2024.105461>
- Minhas, P. S., Saha, J. K., Dotaniya, M. L., Sarkar, A., & Saha, M. (2022). Wastewater irrigation in India: Current status, impacts and response options. *Science of The Total Environment*, 808, 152001. <https://doi.org/10.1016/j.scitotenv.2021.152001>
- Muscarella, S. M., Alduina, R., Badalucco, L., Capri, F. C., Di Leto, Y., Gallo, G., Laudicina, V. A., Paliaga, S., & Mannina, G. (2024). Water reuse of treated domestic wastewater in agriculture: Effects on tomato plants, soil nutrient availability and microbial community structure. *Science of The Total Environment*, 928, 172259. <https://doi.org/10.1016/j.scitotenv.2024.172259>
- Ni, J., Liao, J., Zhang, C., Li, Y., Zou, X., Chen, H. Y. H., Ren, T., & Ruan, H. (2025). Nitrogen enrichment promotes isopods through reduced carbon and nitrogen stoichiometric mismatch with understorey plants. *Functional Ecology*, 39(11), 3225–3237. <https://doi.org/10.1111/1365-2435.70187>
- Pocock, R. I. (1900). *Arachnida*. Taylor and Francis; [etc., etc.]. <https://doi.org/10.5962/bhl.title.17227>
- Remelli, S., Gatti, F., Tarocco, P., Scotti, C., & Menta, C. (2025). Below-ground biodiversity in agricultural systems: The role of crop-specific management in shaping soil arthropod communities. *Agriculture, Ecosystems & Environment*, 393, 109850. <https://doi.org/10.1016/j.agee.2025.109850>
- Shahmoradi, B., Mohammadlou, S., Maleki, A., Shivaraju, H. P., Shabrandy, H., Jenkins, D. F., Reshadmanesh, N., Mohammadi, S., Rezaee, R., & Choi, H. J. (2025). Feasibility assessment of greywater irrigation for sustainable tomato planting. *South African Journal of Botany*, 182, 15–22. <https://doi.org/10.1016/j.sajb.2025.04.047>
- Shehzad, K., Tu, S., Majeed, M. Z., Lei, B., & Zhang, J. (2024). Arthropods in soil reclamation and bioremediation: Functional roles, mechanisms and future perspective. *Journal of Environmental Management*, 370, 122820. <https://doi.org/10.1016/j.jenvman.2024.122820>
- Triplehorn, C. A., Johnson, N. F., & Borror, D. J. (2005). *Borror and DeLong's introduction to the study of insects* (7th ed). Thomson, Brooks/Cole.



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