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IMPACT OF REDUCED TILLAGE ON THE PRESERVATION OF SOIL FERTILITY AND MACROFAUNA IN SEMI-ARID CONDITIONS

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Abstract

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Cereals and pulses are an important part of agricultural production in Algeria, particularly in semi-arid regions that are affected and influenced by climatic, geographic, and agronomic factors. Maintaining a reliable and sustainable agricultural production system has become one of the primary concerns of arid and semi-arid producers. Conservation agriculture is recommended by researchers as an effective technique for limiting soil degradation, preserving soil fertility and biodiversity, and ensuring long-term agricultural production, while protecting natural resources and the environment. This study is part of a Technical Institute of Field Crops (ITGC) project in Sétif that aims to assess the effect of conventional tillage (CT) and no tillage (NT) on the chemical and biological quality of Sétif›s soils. The pH of these soils ranged from 7.34 to 7.83, indicating that they were moderately basic to alkaline. An analysis of variance revealed that tillage type had no effect on pH, whereas crop type and depth had a significant effect. According to the findings, NT improves organic matter levels compared to CT. The fauna inventory uncovered a total of 2089 individuals representing 14 different species. There were 1329 individuals in the NT subplot. This number is higher than the 760 individuals recorded in the conventionally seeded subplot. Shannon–Weaver had a high diversity index value. More efforts are required to promote conservation agriculture in these areas.

Key words: tillage mode, semi-arid, cereals, soil propriety.

Introduction

Cereals and pulses are critical in many countries, both economically and agronomically. Cereal production must be improved to ensure long-term food security (Kouadria et al., 2019). Sustainable agriculture primarily consists of long-term preservation of soil fertility and quality maintenance for future generations (Sinaj, Jeangros, 2019). Various factors, including improved seeds and equipment, land management practices, and better water management, all contribute to increasing productivity to varying degrees (Minten, Barrett, 2008). In Algeria, cereal production is influenced by technical (tillage, fertilization, and rotation) and climatic factors (Abdellaoui et al., 2011). Inadequate tillage can degrade the soil's physical, chemical, and biological properties, lowering its quality. The macrofauna is critical for assessing soil quality because it is the foundation of soil biological functioning (Rakotomanga et al., 2016). As a result, it reflects the soil condition and is considered a bioindicator (Yan et al., 2012). Savadogo et al. (2017) demonstrated that anthropogenic actions positively or negatively impact these living beings. Agricultural intensification threatens biodiversity by combining the effects of inputs, inappropriate tillage, and the absence of organic inputs and crop rotations (Lavelle et al., 2000).

Both organic matter content and water conservation are factors that limit agricultural productivity, but they are also important in determining soil quality. Organic matter is essential for soil degradation and structure. Environmental factors and agricultural practices determine the rate at which it decomposes. Soil degradation is occurring in the cereal-growing areas of northern Algeria, namely the high plains and plateaus, owing to overexploitation of the land, inappropriate farming practices that do not match the soil and climate conditions, and water scarcity. Conventional tillage (CT) has reached its limits in some areas, degrading the soil quality. Several studies have shown that minimal soil disturbance is effective (Abellaoui et al., 2011; Moussadek et al., 2011; Sheehy et al., 2015). The purpose of this study is to discuss the effects of different tillage techniques, NT and CT, on the evolution of some chemical and biological parameters of soils in which cereals and legumes are grown in an arid region of northern Algeria under cultivation in the Sétif region's high plateaus.

Material and methods

Experimental site

The experiment was carried out in 2017 at the Technical Institute of Field Crops (ITGC) agricultural experimental station in the

Table 1. Some characteristics of the soils studied.

Sites	Horizons (cm)	Actual density	Apparent density	Porosity (%)	OM (%)	total N (%)	pH	CE (mmoh/cm)	Total CaCO3 (%)	Active CaCO3 (%)	Pols (ppm)
ITGC	(0-28)	2.42	1.06	56.1	3.1	0.2	7.81	0.69	21.29	40	5.9

Sétif high plains of north-east Algeria. The area of the plot, which is 4 km southwest of Sétif (36°08´00.0″ N 5°20´ 00.0″ E; altitude: 958 m), is 1300 m^2. The region's climate is Mediterranean continental, with a semi-arid bioclimatic zone. The average annual temperature is 7.6 °C, with a maximum of 19.6 °C. The average annual rainfall is less than 440 mm. According to Chennafi et al. (2008), the soils in this region are shallow steppe soils with low organic matter content. ITGC soil characterization on the experimental plot revealed a clay-loam texture, 3.1% organic matter content, and a pH of 7.8 due to the high quantity of total and active limestone present (21.29 and 40%, respectively). The soil also has a low total nitrogen and assimilable phosphorus content, but is not saline (Table 1).

Plant material and experimental protocol

The research plot was divided into two subplots. In each subplot, ITGC in Sétif sowed the barley variety Fouara and the vetch variety Languedoc. Two tillage techniques were used: NT with a cereal–legume rotation and seeding with the Boudour tine seeder and the John Sheraer seeder. Row spacing for the Boudour drill was 18 cm and for the John Sheraer drill was 23 cm. The maximum working width was 2.5 m. Glyphosate (3 l/ha) was used as a weedkiller. To prepare the seedbed for CT, the soil was worked with a disc plow, cover crop, and harrow (0.20-0.25 cm) to bury previous crop residues. Seeding was done with a standard 3-m-wide drill with 18 cm spacing. Both tillage methods have been used with a cereal–legume rotation since 2008. The seeding rate for both barley and vetch was 110 kg/ha. A 100 kg Monoammonium Phosphate (MAP) base fertilizer and a 120 kg urea cover fertilizer were applied.

Soil and macrofauna sampling

Only macro-arthropods visible to the naked eye were considered in this study. They were collected on April 20, 2018 after the rainy season. Soil invertebrates were collected using the 25×25×10 cm quadrat method at three different depths: 0–10, 10–20, and 20–30 cm from the soil. They were collected at three different points (10 m distance) on each sub-plot to estimate their abundance and diversity. Soil macrofauna was hand-sorted in the field and preserved in 70° alcohol vials. In the laboratory, macrofauna enumeration and identification were performed using a binocular magnifying glass, determination keys, and reference works.

Soil analysis

Soil samples were air-dried after fauna extraction, sieved with a 2-mm sieve, and stored in labeled bags for chemical and biological analysis. Anne method was used to determine organic matter, and a pH meter was used to measure pH in a soil/water suspension (1/2.5).

Calculation of ecological indices

The data collected to rapidly assess stand biodiversity was used to calculate the indices listed below. The abundance per square meter for trophic groups and the soil invertebrate community was calculated by counting the number of individuals in each sample (25×25 cm^2) and multiplying by 16 to get the number of individuals per square meter. The species richness S represents the number of species counted at a given time. Ratnadass et al. (2013) have classified invertebrates into orders and functional groups. Relative abundance is the percentage of a species' individuals in relation to the total number of individuals counted in the same sample and is calculated using the following formula:

$$AR\,(\%) = ni \times 100/N \tag{1}$$

where *ni* is the number of individuals of species *i* and *N* is the total number of individuals.

The Shannon–Weaver H' index can be used to observe changes in the biodiversity of a given environment and quantify its heterogeneity over time. It is calculated according to the following formula:

$$H' = -\sum Pi\log 2Pi \textit{ où } Pi = \mathrm{ni/N} \tag{2}$$

where *ni* is the population size of species *i* and *N* is the total population size. $H_0 = 0$ when there is only one species and its value reaches the maximum. The equitability or equipartition index is calculated from the species richness value *S* and *H'*, according to the following formula:

$$E = H'/H'\max \textit{ où } H'\max = 2S \tag{3}$$

where H'max is the maximum value that the Shannon–Weaver index can reach for a given number of species and *S* is an equivalent proportion for each species. This index ranges from 0 to 1, with 0 indicating that a single species dominates the entire stand and 1 indicating that species have identical abundances. The change index V was calculated for abundant groups (Wardle, 1995) to compare the decrease or increase in organism density for the two tillage modalities:

$$V = (2M_{CT}/M_{CT} + M_{NT}) - 1 \tag{4}$$

where M_{CT} and M_{NT} are the densities of organisms in CT and NT, respectively. The V index ranges from -1 when organisms are only found in NT to +1 when organisms are only found in CT. 0 denotes equal densities. Wardle (1995) estimated the following:

- Extreme inhibition by tillage if V < 0.67,
- Moderate inhibition by tillage if 0.67 < V < 0.33,
- Slight inhibition by tillage if 0.33 < V < 0,
- Slight stimulation by tillage if 0 < V < 0.33,

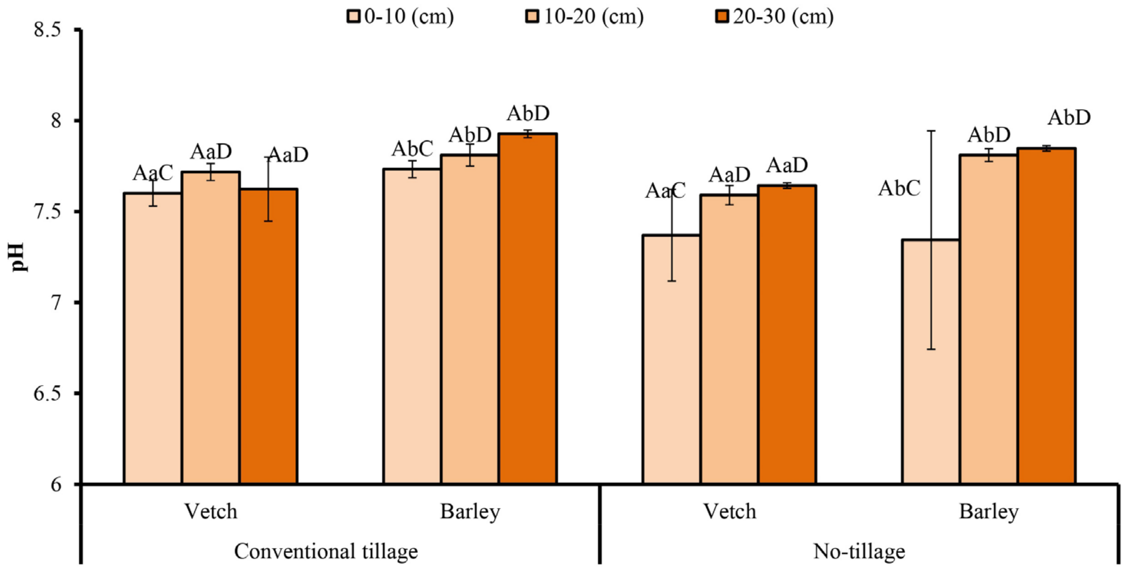

Fig. 1. Variations in soil pH as a function of tillage, crop and depth (A and B: tillage effect; a and b: crop effect; C and D: soil depth effect).

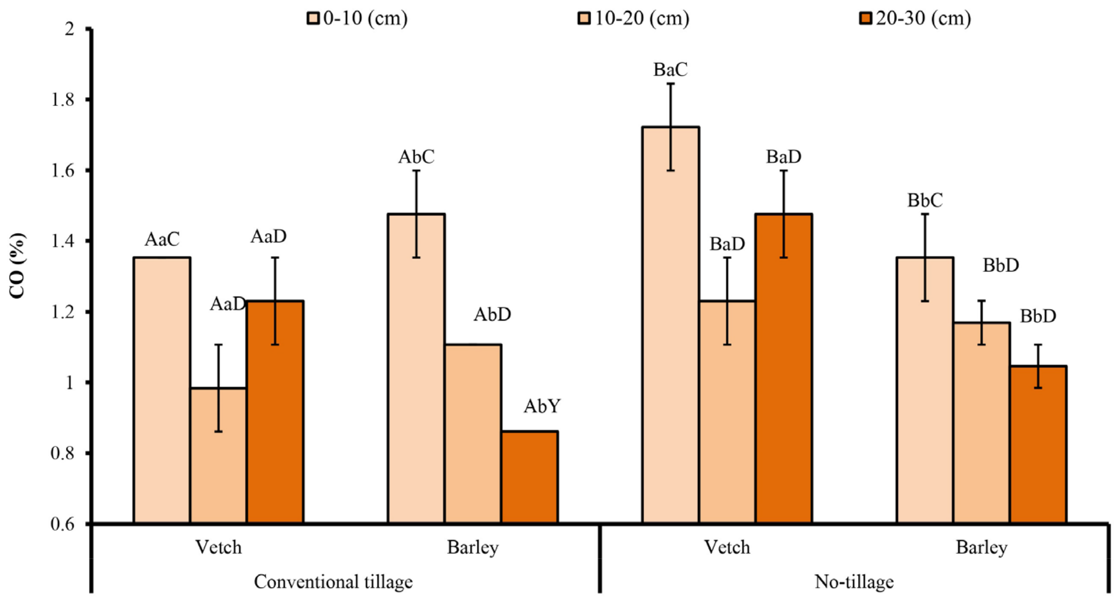

Fig. 2. Variation in organic carbon as a function of tillage, crop and depth (A and B: tillage effect; a and b: crop effect; C and D: soil depth effect).

- Moderate tillage stimulation if $0.33 < V < 0.67$,
- Extreme tillage stimulation if $V > 0.67$.

Statistical analysis

The data were subjected to a multifactorial analysis of variance (ANOVA) with a p-level of 0.05 to assess the effect of the tillage method on some soil chemical properties and invertebrate population density. Multivariate analyses confirmed the affinities between the tillage method, depth, and crop. R software was used for statistical analysis.

Results

Effect of tillage method

pH

Figure 1 depicts the effect of tillage type, crop, and soil depth on pH. The pH of the soils examined ranged from 7.3 to 7.9. These soils range from moderately basic to alkaline. The values were 7.7 and 7.6, respectively, for CT and NT soils. Depending on the crop, these values ranged from 7.8 to 7.6 and were significantly higher for barley than for vetch ($P = 0.03$). The pH increased significantly with depth (Fig. 1).

Organic carbon

Figure 2 depicts the effect of tillage type, crop, and depth on organic carbon (OC) variations. OC content varies significantly depending on tillage type, depth, and crop. OC increased in NT for crops and in all three depths, except for the 0–10 cm horizon of NT barley, where OC decreased slightly. Regarding the crop effect, NT vetch significantly increased OC content at all three depths, compared to 1.33% for vetch and 1.17% for barley. There was no clear trend in tilled soils. OC content decreased significantly with depth, reaching 0.86 and 1.72% for deep soils under barley in CT and surface soils under vetch in NT, respectively.

Wildlife surveys

Tillage methods can positively or negatively influence the number, composition, and distribution of micro-organisms and fauna in the soil.

Macrofauna density by taxonomic order and depth

Throughout the plot, 2089 individuals were collected and identified and divided into 14 species, 12 families, eight orders, and five classes (Table 2). With a ratio of 10/14, the arthropod phylum was the most numerous. With a ratio of 6/10, beetles were the most abundant insect order. There were 1329 individuals in the NT subplot. This number is higher than the 760 individuals recorded in the conventionally seeded subplot (Table 2). Individuals in reduced tillage systems are concentrated in the first soil horizons.

Multifactorial ANOVA, crop, depth, and tillage method (Table 3) revealed that soil depth significantly affected the number of invertebrates. The latter decreased significantly as soil depth increased. The effect of the tillage method and crop type on invertebrate numbers (Table 3) was not statistically significant.

Relative abundance

Determination of the relative abundance of invertebrates revealed 40.4% for *Tipula* sp. (843 individuals), followed by *Helix aspersa* Müller (AR = 20.1%, 419 individuals), *Messor barbarus*

Table 2. Abundance (density/m^2) of soil invertebrates as a function of tillage type, crop and soil depth.

					Conventional seeding						**Direct seeding**					
				Abb.	**Vetch**			**Barley**			**Vetch**			**Barley**		
Taxa	**Order**	**Family**	**Species**	**Abb.**	**N1**	**N2**	**N3**	**N1**	**N2**	**N3**	**N1**	**N2**	**N3**	**N1**	**N2**	**N3**
Arachnida	Phalangida	Phalangidae	*Opilion* sp.	Opisp	0	0	0	0	0	0	16	0	0	0	0	0
Annelida	Crassiclitellata	Lumbricidae	*Lumbricus terrestris*	Lte	16	0	0	64	0	0	16	0	0	0	0	0
Myriapoda	Chilopoda	Geophilidae	*Cryptops hortensis*	Chor	0	0	0	16	0	0	0	0	0	0	0	0
Gastropoda	Pulmonata	Helicidae	*Helix aspersa*	Hasp	24	40	24	107	32	0	64	16	24	56	16	16
Insecta	Homoptera	Cicadellidae	*Cicada atra*	Catr	0	0	0	16	0	0	16	0	0	0	0	0
	Coleoptera	Carabidae	*Harpalus fulvus*	Hrfu	0	0	0	0	16	16	0	0	0	0	0	0
			Chlaenius velutinus	Chve	16	0	0	0	0	16	16	0	0	0	0	0
			Carabidae sp.	Csp	16	16	0	32	0	16	0	0	0	0	0	0
		Scarabaeidae	*Scarabaeus* sp.	Scsp	32	0	16	37	0	16	16	32	0	27	0	16
		Hydraenidae	*Limnebius* sp.	Limsp	32	0	0	0	0	0	16	16	0	0	0	0
		Staphylinidae	*Ocypus olens*	Ocol	0	0	0	16	0	0	0	0	0	16	0	0
	Hymenoptera	Formicidae	*Messor barbarus*	Meba	0	0	0	16	0	16	0	32	64	75	0	0
	Diptera	Tipulidae	*Tipula* sp.	Tipsp	64	64	0	32	0	0	592	139	16	0	0	0
		Tachinidae	*Ceratitis capitata*	Ceca	0	0	0	0	0	0	0	0	16	0	0	0
Total individuals					168	88	40	336	48	80	752	235	120	174	16	32
Total species					7	3	2	9	2	5	8	5	4	4	1	2

Table 3. Multifactor analysis of variance results for macroinvertebrate density.

Factors	DF	Sum Sq	Mean Sq	F value	Pr (>F)
Crops	1	1.93	1.929	0.2111	0.64656
Type of tillage	1	1.52	1.524	0.1668	0.68355
Depths	2	64.01	32.006	3.5031	0.03249 *
Crops X type of tillage	1	12.6	12.595	1.3786	0.24213
Crops X depth	2	43.75	21.875	2.3943	0.09459
Depth X tillage	2	7.3	3.649	0.3994	0.67143
Crops X type of tillage X depth	2	3.23	1.613	0.17	0.83832

Note: *p<0.05 DF: degree of freedom.

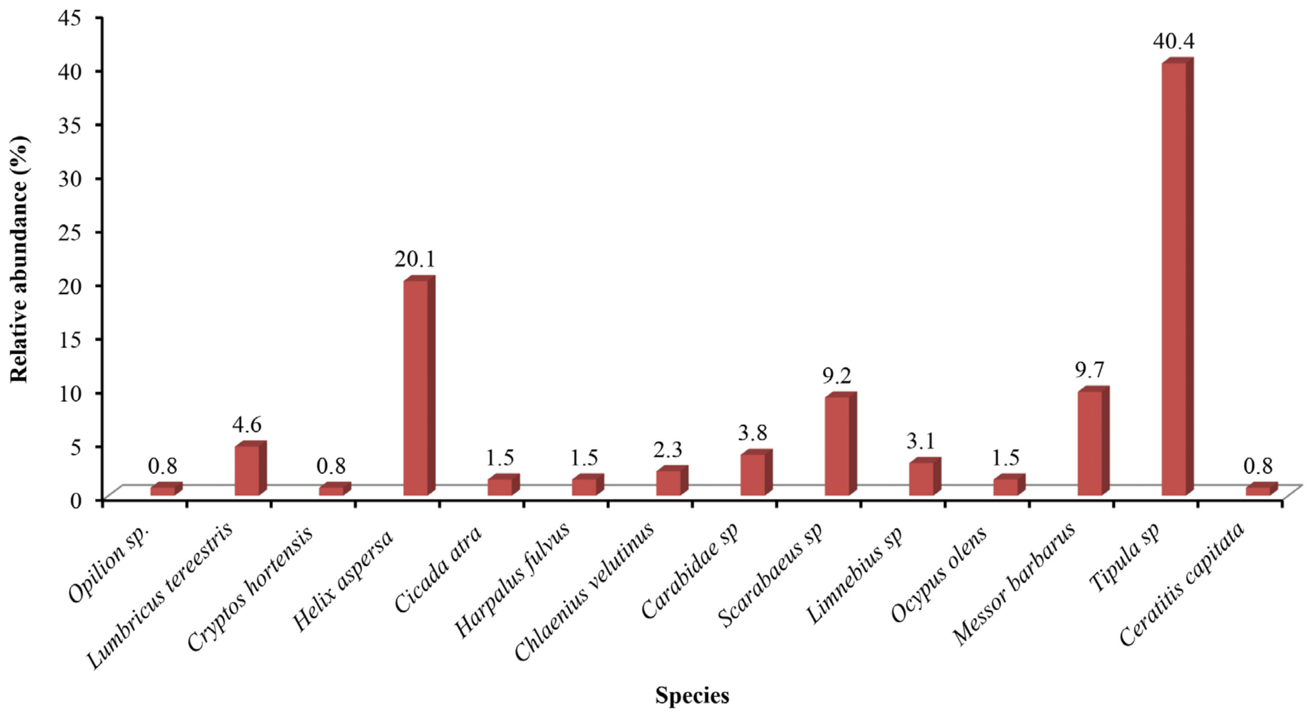

Fig. 3. Relative abundance of different species.

(AR = 9.7%, 203 individuals), *Scarabaeus* sp. (AR = 9.2%, 192 individuals), *Lumbricus terestris* (AR = 4.6%, 96 individuals) and *Carabidae* sp. (AR = 3.8%, 80 individuals). We report the existence of eight species with low abundance (Fig. 3).

Macrofauna density by functional group over 0–30 cm

The taxa collected can be used to identify various functional groups (Table 4, Fig. 4). Predators were the most abundant group on the entire plot (six species: 42.85% of total harvested), followed by phytophagous (four species: 28.57% of total harvested), coprophagous (two species: 14.28% of total harvested), detritivorous, and omnivorous (one species: 7.14%). NT yielded the greatest number of functional groups compared to conventional seeding. Regarding crop effect, vetch induced more functional group development than barley (Table 4, Fig. 4). In terms of density, phytophagous were the most discriminating against the crop system. Our inventory revealed a biodiversity of predatory species (six species: 42.85% of total harvested), phytophagous (four species: 28.57% of total harvested), coprophagous (two species: 14.28 of total harvested), detritivorous and omnivorous (one species: 7.14% of total harvested).

Macrofaunal diversity as a function of tillage method, crop, and depth

Table 5 displays specific richness, Shannon–Weaver index, and invertebrate equitability. It is worth noting that the specific richness, H'max, and H', and E of soil invertebrates were greater in CT vetch than in NT. Except for equitability, where statistical analysis revealed two homogeneous groups, this difference was not significant. Soil invertebrates had similar specific richness, H'max, and H' under NT and CT. However, in CT under vetch, equitability was significantly higher, with statistical analysis revealing two homogeneous groups, group A containing vetch and barley in CT and group B containing vetch in NT.

Table 4. Taxonomic groups identified during sampling.

	Order	Family	Species	Function group
Arachnida	Phalangida	Phalangidae	*Opilion* sp.	Predator
Annelida	Crassiciltellata	Lumbricidae	*Lumbricus terrestris*	Detritus feeders
Myriapoda	Chilopoda	Geophilidae	*Cryptos hortensis*	Predator
Gastropoda	Pulmonea	Helicidae	*Helix aspersa*	Phytophage
Insecta	Homoptera	Cicadellidae	*Cicada atra*	Phytophage
	Coleoptera	Carabidae	*Harpalus fulvus*	Predator
			Chlaenius velutinus	Predator
			Carabidae sp.	Predator
		Scarabeidae	*Scarabaeus* sp.	Coprophage
		Hydraenidae	*Limnebius* sp.	Coprophage
		Staphylinidae	*Ocypus olens*	Predator
	Hymenoptera	Formicidae	*Messorbarbarus*	Omnivores
	Diptera	Tipulidae	*Tipula* sp.	Phytophage
		Tephritidae	*Ceratitis capitata*	Phytophage

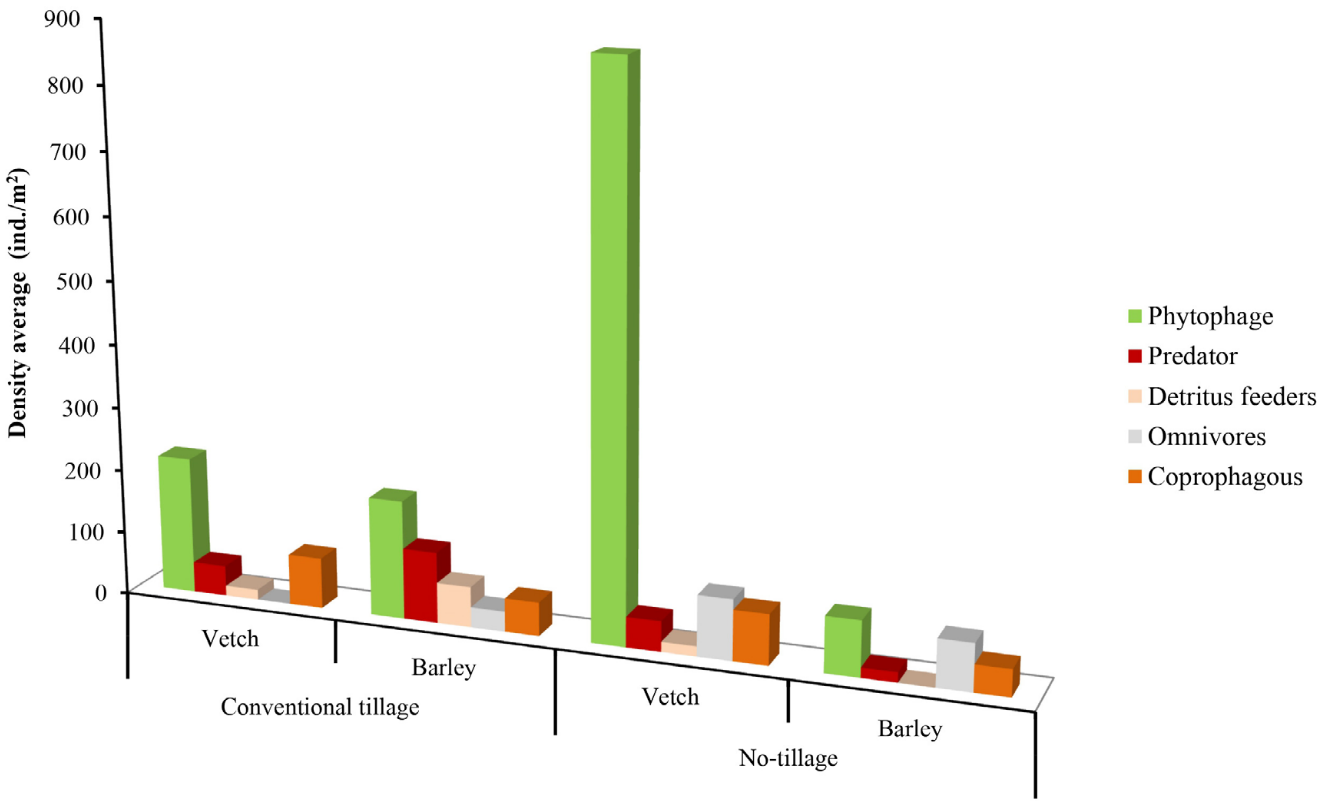

Fig. 4. Average soil macrofauna density (0-30 cm) for the different functional groups as a function of tillage method and crop planted.

Discussion

Variation in pH and organic status of the soils studied

Several authors have reported that NT reduces soil pH, particularly on the surface horizon. After 11 years of follow-up, Mrabet et al. (2001) discovered a difference of 0.2 pH units between NT and CT. In this study, tillage did not affect the pH levels. Statistical analysis revealed no significant difference in pH variations between NT and CT soils. However, despite a significant decrease in pH under vetch, the pH levels remained neutral, and this slight decrease may be due to vetch export.

Table 5. Variation in mean species richness, Shannon Weaver index and equitability of soil.

	Specific richness (S)		H´		H´max		Equitability (E)	
	CT	NT	CTa	NT	CT	NT	CT	NT
Vetch	4.67[a]	5.67[a]	1.89[a]	1.09[a]	2.13[a]	2.44[a]	0.88[aA]	0.40[bB]
Barley	5.33[a]	3.33[a]	1.98[a]	1.33[a]	2.25[a]	1.72[a]	0.87[aA]	0.76[bA]

Table 6. Variation in mean change index for different taxonomic groups**.**

Arachnida	-1	Extreme inhibition by tillage
Annelida	0.66	moderate stimulation by tillage if $0.33 < V < 0.67$
Myriapoda	1	extreme stimulation by tillage if $V > 0.67$
Gastropoda	0.08	mild stimulation by tillage if $0 < V < 0.33$
Insecta coleoptera	0.31	mild stimulation by tillage if $0 < V < 0.33$
Other insects	-0.64	extreme inhibition by tillage if V $-0.67 < V < -0.33$

According to Hinsinger et al. (2003), the crop's nature influences soil pH, but acidification is a particularly important phenomenon in legumes. The carbon content of these soils decreases significantly as depth increases. These findings are consistent with those of Jemai et al. (2013) and Moussadek et al. (2014). Similarly, Büchi et al. (2017) found that deep tillage without turning or plowing resulted in a decrease in OC. According to Dinel and Gregorich (1995), the different effects of crops on OC reflect the importance of the nature of residues and morphologic characteristics of different crops in enriching soil OC levels.

Büchi et al. (2018) demonstrated that reduced tillage could increase CO in the soil over time when intermediate crops are planted regularly. Sanginés de Cárcer et al. (2019) discovered that crop succession does not affect OC levels. After 50 years of testing, the C_{org} content of crop rotation plots is comparable to wheat monoculture plots. This is due to high C_{org} mineralization during the crop rotation (Sanginés de Cárcer et al., 2019). The duration of NT adoption has an effect on organic matter (OM) accumulation at the soil surface and in deeper layers, as demonstrated by Kibet et al. (2016), who found that the increase in OC levels under NT compared to CT is significant in the 0–10 and 10–20 cm horizons after a 33-year experiment. In a 9-year experiment, however, it did not occur. Cereals are grown in Algeria without organic fertilizer, with plowing and exporting all vegetative production, resulting in a decrease in soil organic matter levels.

Diversity and abundance of macrofauna in the soils studied

Biological soil quality indicators involved in ecosystem functions are of great interest because they are affected by agricultural practices and soil physicochemical conditions (Vincent et al., 2019). Taxa that respond to agricultural practices can be considered bioindicators (Cluzeau et al., 2012). The fauna count results are consistent with previous research on this topic: reduced soil tillage increases the abundance of soil fauna (Blanchart et al., 2006). The magnitude of the effects of NT on soil biocenosis, whether positive or negative, varies by organism (Van Capelle et al., 2012), with organisms living within the soil porosity being less impacted by tillage than those of larger size (Wardle, 1995; Reeleder et al., 2006).

Many factors influence the low diversity and reduced number of macrofauna in the soils studied. Rousseau et al. (2013) reported a decrease in cultivated soils, whereas Pelosi et al. (2014) reported a nearly complete change in its composition. According to Woodcock et al. (2005), vegetation type and age impact abundance and diversity. In moist soils, invertebrates are more abundant and diverse. Pesticides were applied to the soils studied, affecting soil organisms and macrofauna (Mazzia et al., 2015). Pesticides have been shown to negatively affect earthworms at the cellular and community levels by Pelosi et al. (2014) and Williams et al. (2021). Irrigation and fertilization also affect soil life (Williams et al., 2021).

The previous crop's residues were exported from the plot. Crop residues are a source of organic matter on the surface and provide a trophic reserve for certain earthworm species (Daniel, Galardon, 2008). That has been demonstrated that NT under plant cover increases soil organisms' density, diversity and activity (Blanchart et al., 2006, 2007). Sileshi and Mafongoya (2006) and Barros et al. (2003) found a link between the presence of litter and canopy permanently and the abundance and diversity of soil invertebrates. According to the findings, the presence of earthworms was low in our plot, with their numbers being nearly identical in conventional and direct seeding. This could be due to soil compaction following a period of direct seeding, as confirmed by the change index calculation results (Table 6). Blanchart et al. (2007) obtained the same result in Brazil, where the absence of plowing initially increased the density and biomass of ground glass, followed by a decrease after 8 years of NT.

The response of macrofauna to adapted tillage depends on the species present, according to Holland and Reynolds (2003), and they demonstrated that carabid beetles are more abundant and diverse in NT soils. However, Holland and Luff (2000) discovered that of the 47 carabid species studied, 21 were highly affected by tillage, 20 were abundant in plowed soils, and six were unaffected by the tillage intensity and type. The fauna of this plot is found in the surface horizons where the mineralization rate of organic matter is high, resulting in the presence of biological life in the case of reduced tillage or CT (Frey, 2015). These findings are consistent with those of Frey (2015), who found that organisms are abundant in the first 25 cm. CT and NT practice initially present different rates of carbon and nitrogen mineralization. However, their long-term effects often lead to similar rates of carbon and nitrogen mineralization in the two systems (Oorts et al., 2007).

Relative abundance and density of families

The relative abundance of taxonomic groups in this plot revealed that the Coleoptera, Hymenoptera, and Diptera families are the dominant macroinvertebrate taxa. They account for nearly 72% of the total macrofauna population. According to Hedde (2006), insects are the most numerous, accounting for 80% of soil fauna. These groups' abundance indicates a favorable environment for their development. They are the most abundant invertebrates in the soil macrofauna. Phytophages, which consume plant aerial organs and are responsible for the fragmentation and degradation of organic matter, are the functional group that discriminate the most between cropping systems in this study based on their densities. Soil cultivation always has a negative impact on soil organisms, resulting in a decrease in biodiversity (Lavelle et al., 2000), which has consequences for soil and vegetation. Soil communities are also influenced by root exudation and soil bioturbation (Berg, 2012).

Effects on the diversity of soil macrofauna

Unlike conventionally seeded soils, the index of change did not reach Daget's (1979) threshold of 0.80 in NT soils. Except for NT vetch (0.40), the equitabilities obtained tend toward 1, indicating a balance between the species in the environment. According to Baghem (2018), the species richness in this plot is low, which may be due, on the one hand, to the phenological stage of the plant, which influences species richness. Because of the favorable conditions, such as a high temperature that allows eggs to hatch and insects to develop, the appearance of species is very important at the heading stage. The absence of vegetation cover, on the other hand, can have negative ecological consequences, according to Perronne et al. (2019), increasing the amount of biomass exported (grazed or mown) reduces specific and functional richness. This results in a scarcity of resources, limiting the diversity and abundance of soil organisms (Cavigelli et al., 2012). The Shannon diversity indices in this study are low compared to the maximum index of 3.10, indicating an unbalanced structure and low diversity of the macrofauna population on the plot.

Shannon diversity index values greater than or equal to 3 indicate a balanced, stable structure and good diversity of a stand, while values less than 1 indicate pollution and degradation of habitat structure (Türkmen, Kazanci, 2010). These low values may result from soil poverty caused by overexploitation and a lack of organic matter inputs.

Conclusion

This study aimed to determine the effect of the tillage method, crop type, and sampling depth on pH, soil OC, soil macrofauna abundance and diversity, and ecological indices. According to the results, these parameters are influenced by tillage management in semi-arid Mediterranean conditions. NT favored soil macrofauna in terms of abundance, which could benefit agricultural ecosystems. Soil macrofauna diversity and abundance indices estimated at our study station were influenced by litter export, pesticide application, and the duration of NT application. However, it is recommended that the experiment be repeated in the long term with more cropping practices (cover cropping, organic fertilization) to confirm that the beneficial relationship between tillage management, soil invertebrate diversity, and beneficial agricultural products is real.

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