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Impact of a no-till with mulch soil management strategy on soil macrofauna communities in a cotton cropping system

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Abstract

Systematic exportation, burning of crop residues and decreases in fallow periods have led to a large-scale depletion of soil organic matter and degradation of soil fertility in the cotton (*Gossypium hirsutum* L.) cropping systems of Cameroon. The present study tested whether soil management systems based on a no-till with mulch approach intercropped with cereals, which has been shown to restore cotton production, could boost the biological activity of soil macrofauna. The impacts of no tillage with grass mulch (*Brachiaria ruziziensis* Germain and Eward) (NTG) and no tillage with legume mulch (*Crotalaria retusa* L. or *Mucuna pruriens* Bak.) (NTL) on the abundance, diversity and functional role of soil invertebrates were evaluated during the third year of implementation in northern Cameroon (Windé and Zouana), compared to conventional tillage (CT) and no tillage (NT) without mulch. Macrofauna were sampled from two 30 cm × 30 cm soil cubes (including litter) at the seeding stage of cotton, and 30 days later. The collected organisms were grouped into detritivores, herbivores and predators. Examination of the soil macrofauna patterns revealed that the abundance and diversity of soil arthropods were significantly higher in NTG and NTL than in CT plots (+103 and +79%, respectively), while that of NT plots was in-between the no tillage groups and CT (+37%). Regarding major ecological functions, herbivores and predators were significantly more abundant in NTG and NTL plots than in CT plots at Windé (+168 and +180%, respectively), while detritivores, predators and herbivores were significantly more abundant in the NTG plots than in CT plots at Zouana (+92, +517 and +116%, respectively). Formicidae (53.6%), Termitidae (24.7%) and Lumbricidae (9.4%) were the most abundant detritivores while Julidae (46.1%), Coleoptera larvae (22.1%) and Pyrrhocoridae or Reduviidae (11.8%) were the dominant herbivores. The major constituents of the predatory group were Araneae (33.8%), Carabidae (24.6%), Staphylinidae (15.7%) and Scolopendridae (10.3%). Direct seeding mulch-based systems, NTG and NTL, favoured the establishment of diverse macrofaunal communities in the studied cotton cropping system.

Keywords: Soil; Macrofauna; Conservation agriculture; No tillage; Cover crop; Cotton; Africa

1. Introduction

Sustainable crop productivity in agroecosystems relies on soil fauna abundance and biodiversity (Curry, 1994; Radford et al., 1995; Doube and Schmidt, 1997; Lavelle et al., 2006). Soil macrofauna communities encompass a wide range of organisms performing

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various functions that regulate soil physical properties and chemical processes (Stinner and House, 1990; Lavelle et al., 1997). Invertebrates play a major role in soil fertility by enhancing mixing, macroporosity, humidification and mineralization of organic matter (Francis and Fraser, 1998). These processes help to improve soil structure and texture, gaseous exchange, infiltration and soil water retention and soil chemical and nutritional properties, through increased root exploration (Lal, 1988; Kladivko, 2001; Ouedraogo et al., 2006). In addition, soil faunal abundance and biodiversity act to prevent pest outbreaks in agroecosystems by balancing the predator–herbivore ratio (Tillman et al., 2004).

In semi-arid tropical agroecosystems, abundance and biodiversity of soil organisms are frequently reduced through habitat structure disturbances of soil organism communities caused by extreme climatic conditions, overgrazing and trampling by cattle, burning of crop residues, ploughing and mechanized seedbed preparation, indiscriminate agrochemical use and monoculture (Lal, 1988; Loranger et al., 1999; Brown et al., 2001). Tropical soils devoid of meso- and macrofauna are particularly vulnerable to compaction and structural collapse which can impede water infiltration and root growth and contribute to erosion and rapid soil degradation (Lal, 1988).

Occupying more than 30% of the agricultural landscape and cultivated by 90% of farmers, cotton (*Gossypium hirsutum* L.) is the major crop in northern Cameroon (Mbetid-Bessane et al., 2006). Traditional soil management systems, including systematic exportation or burning of crop residues and decreases in fallow periods, have led to large-scale depletion of organic matter and degradation of soil fertility (Boli et al., 1991), resulting in bare and crusted soils characterised by very low water infiltration and nutrient imbalances (Ouedraogo et al., 2004). As a result, a regular decrease of seed cotton yields has been observed in the conventional cotton cropping systems for over a decade (SODECOTON, 2004). To increase sustainability of crop yields, national research and extension services have implemented soil restoration measures by conservation tillage (CT) and a no-till with mulch approach, through the ESA (Eau Sol Arbre) Project (Naudin et al., 2003). While the introduction of this soil management system has been shown to restore soil fertility (Erenstein, 2003; Ito et al., 2006), few detailed studies have focused on its impact on soil macrofauna communities or guilds, particularly in a semi-arid environment (Blanchart et al., 2006; Maria de Aquino et al., in press).

The objective of this study was to evaluate the impact of a no-till mulch-based system, intended to increase organic resources, on the abundance and diversity of taxonomic and functional groups of soil macrofauna in a cotton cropping system. As pointed out by Blanchart et al. (2006), soil macrofauna play an essential role in physical, chemical and biological functions, which condition the soil quality and plant productivity of the agroecosystems. Soil macrofauna were sampled from plots subjected to conventional tillage or no-till treatments, with and without mulch. The results of this project should provide elementary knowledge for designing new soil management systems to boost biological activity and favour productive and sustainable agriculture in semi-arid tropical regions.

2. Methods

2.1. Study site

This study was carried out during the 2004 growing season at the ESA Project experimental sites in the villages of Windé (4 ha, 8°29″N and 13°26″E) and Zouana (3.5 ha, 10°08″N and 14°29″E), both situated in the cotton-growing region of Cameroon (Fig. 1). Windé is characterised by a Sudanian climate with a single rainy season from mid-May to mid-October (1200 mm mean annual rainfall), whereas Zouana is characterised by a Sahelo-Sudanian climate with a rainy season from June to September (800 mm mean annual rainfall). The mean minimum and maximum temperatures in this region during the growing season were 23 and 32 °C, respectively. Both sites present ferruginous tropical and hydromorphic soils that are highly susceptible to erosion (pH 5.5–6.0). Soil analyses of samples from the region showed very low soil organic matter contents (SOM) for the 0–20 cm upper layer; the SOM contents of Zouana and Windé have been measured at 0.20–0.42 and 0.49–0.84%, respectively (Olina, unpublished data).

2.2. Experimental design and cropping systems

The soil management systems tested were conventional tillage (CT), no tillage (NT), no tillage with grass mulch (NTG) using *Brachiaria ruziziensis* Germain and Eward and no tillage with legume mulch (NTL) using *Crotalaria retusa* L. or *Mucuna pruriens* Bak. These four systems have been conducted in the same manner since 2002, across a traditional cotton–cereal rotation. In the case of CT, ploughing was carried out 5–7 days before sowing. In this study, CT refers to mouldboard ploughing (approximately 15–20 cm depth) in which moist soil is inverted prior to planting and produces a surface with little or no remaining plant residues. In NT agriculture, no soil manipulation is performed prior to planting. Both mulches were established at the end of the previous season and intercropped with maize (*Zea mais* L.) or sorghum (*Sorghum vulgare* Pers.) at Windé and Zouana, respectively. Maize and sorghum residues were removed from NT and CT plots, in accordance with local practices. Each individual plot had a surface area of 200 m^2 (three replications) or 60 m^2 (four replications), at the Windé or Zouana sites, respectively. The plots were planted in June using the cotton varieties, 'Irma A1239' and 'Irma BLT-PF' (IRAD, Cameroon) at Windé and Zouana, respectively.

2.3. Sampling

Soil macrofauna were sampled by extracting two 30 cm × 30 cm × 30 cm soil cubes in the central part of each plot (Anderson and Ingram, 1993). Samples were collected at the seeding stage and then again 30 days later (25 May and 26 June, or 5 June and 6 July, at Windé or Zouana, respectively). Sampling was carried out 1–2 days after a minimum of 15 mm rainfall, to facilitate the extraction of the soil cubes (Fig. 1). A parallel survey of soil-dwelling macrofauna using Pitfall traps showed that the distribution of the number of trapped organisms was not significantly influenced by climatic conditions (such as rainfall or temperature) or crop stage (Bikay, unpublished data). Litter was initially collected by scraping the top layer of the cubes. The litter layer was spread out over a plastic cover and living organisms were hand-sorted directly, or after having sieved the finest particles. Soil was immediately withdrawn with a shovel, spread out over a plastic cover, and sieved with a 4-mm mesh. Macrofauna organisms were carefully collected and preserved in 40 ml vials containing 70% ethanol for subsequent laboratory identification. As defined by Gobat et al. (1998), soil macrofauna refers to the community of organisms that spend an important part of their life cycle in the soil or on its immediate surface, including surface litter. Macrofauna included all animal organisms visible with the naked eye (measuring 4–80 mm). All of the individuals collected from the soil and litter were classified according to their typical ecological functions as predators, herbivores or detritivores (Delvare and Aberlenc, 1989; Brown et al., 2001; McGavin, 2005).

2.4. Data analysis

Results were collected in the form of individual number per family or groups of families (Biaggini et al., 2007) per cube, according to the study site and the soil management system employed. These data allowed the calculation of abundance (number of collected individuals per surface unit), diversity (Shannon–Weaver index, H') and evenness (Pielou index, E). The Shannon–Weaver index takes into account the number

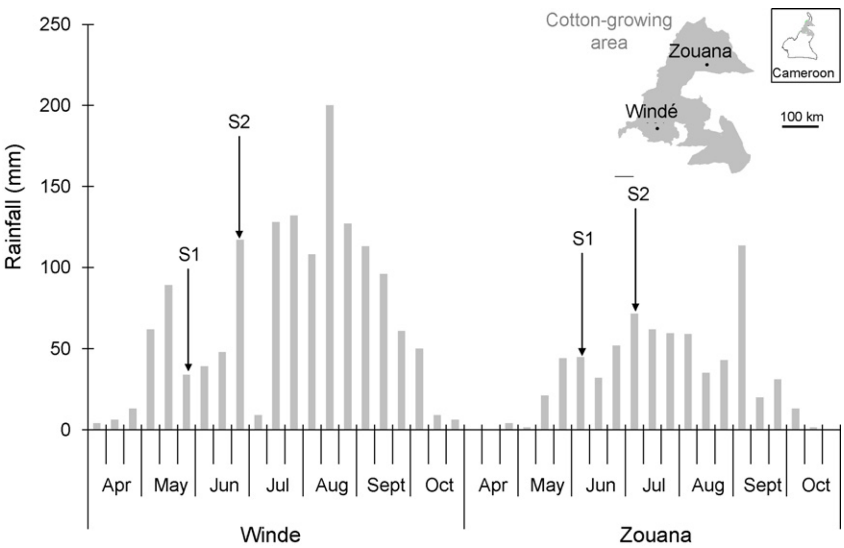

Fig. 1. Location of experimental sites and rainfall distribution during the 2004 growing season at the experimental sites of Windé and Zouana (northern Cameroon). Arrows indicate sampling times at the seeding stage and 30 days later (25 May and 26 June, or 5 June and 6 July, for Windé and Zouana sites, respectively). S: sampling date.

of families encountered. Its value is calculated by the following formula:

$$H' = -\sum p_i \log_2(p_i) \qquad (1)$$

with $i = 1$ to s, where p_i = probability of meeting a taxon i on a plot and s = total number of taxa encountered on the plot. $H' = 0$ when there is only one taxon and its value is at a maximum when all taxa are of equal abundance. The evenness index, also known as regularity measure, represents the distribution of taxa. This index is used to compare communities that present different number of taxa, with the objective of assessing the balance of populations. It is equal to the ratio between calculated diversity and theoretical maximum diversity as shown in the following formula:

$$E = \frac{H'}{\log_2(s)} \qquad (2)$$

E tends to 0 when one taxon largely dominates the community and is equal to 1 when all taxa are of equal abundance. In order to assess the soil management systems, the data were submitted to an analysis of variance (ANOVA) using the SAS GLM procedure (SAS Institute, 1989) followed by the Duncan test for comparisons of means.

3. Results

A total of 4128 individuals were recorded, belonging to 35 families, 22 orders, 8 classes and 3 phyla (Table 1). Phylum Arthropoda animals were the most abundant, accounting for >92.7% of the total individuals in both sites, followed by phylum Annelida (7.0%). Insecta was the most abundant class, accounting for 78.5% of the arthropod density. Significant densities of Diplopoda (9.6%, mainly Julida), Hexapoda (4.6%, diverse Thysanoura and Diplura) and Arachnida (4.5%, diverse Araneae, Pseudoscorpiones and Acari Trombidiidae) were also recorded. Additional arthropod classes such as Chilopoda (1.8%, mainly Scolopendrida) and Crustacea (1.0%, Isopoda) were observed. The class Insecta was essentially composed of Hymenoptera (52.5%, mostly ants), Isoptera (26.1%, termites), Coleoptera (16.6%, Carabidae, Staphylinidae, Chrysomelidae, Scarabaeidae, etc.) and Hemiptera (2.6%, Pyrrhocoridae and Reduviidae).

A substantial portion (34.9%) of the soil macrofauna was collected in the litter. Diverse Araneae, Carabidae and Pyrrhocoridae were mainly found in the litter, whereas Termitidae, Julidae, Lumbricidae, diverse larvae of Coleoptera, Japygidae, Scolopendridae and Scarabaeidae were mainly found under the soil surface (Fig. 2). Significantly more individuals were collected in the litter from NTG and NTL than from NT and CT (Fig. 3). Soil samples from NTG harboured significantly more arthropods than did the NT and CT plots, while soil samples from NTL harboured significantly more arthropods than did the CT plots.

Within most groups, the mean density of individuals in the soil cubes (including litter) varied significantly according to the soil management system (Table 2). At Windé, NTL harboured more individuals than did NT soil, particularly Lumbricidae, Julidae, Japigidae and Lepismatidae, Scolopendridae and diverse Araneae. In addition, NTL contained more Scolopendridae and Lumbricidae than NTG. Conversely, NTG harboured more Carabidae. At Zouana, macrofauna abundance

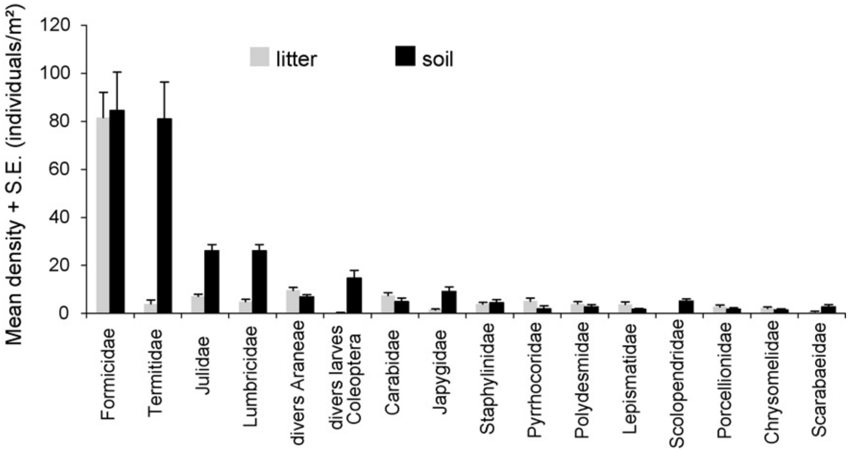

Fig. 2. Distribution of soil macrofauna between soil and litter layers for both Windé and Zouana experimental sites. Soil macrofauna were sampled by scraping the litter and by extracting two 30 cm-sided soil cubes from the central part of each plot at the seeding stage and 30 days later (112 samples) during the 2004 cotton-growing season. S.E.: standard error.

Table 1
Abundance of soil macrofauna taxa in the experimental sites of Zouana and Windé (northern Cameroon), during the 2004 cotton-growing season

Phylum	Class	Order	Family	Density (individuals/m^2)	
				Experimental site	
				Windé	Zouana
Arthropoda	Insecta	Hymenoptera	Formicidae	223	118
			diverse Hymenoptera	1	2
		Isoptera	Termitidae	53	109
		Coleoptera	Diverse Coleoptera larvae	30	2
			Carabidae	13	11
			Staphylinidae	4	12
			Chrysomelidae	2	5
			Scarabaeidae	4	2
			Thorictidae	6	0
			Elateridae	1	4
			Cydnidae	3	1
			Curculionidae	3	1
			Anthicidae	1	1
			Tenebrionidae	1	1
		Hemiptera	Pyrrhocoridae	6	8
			Reduviidae	1	2
		Diptera	Diverse Diptera larvae	2	2
		Orthoptera	Gryllidae	3	1
		Embioptera	Clothodidae	1	2
		Thysanoptera	Thripidae	3	0
		Lepidoptera	Noctuidae	2	1
	Diplopoda	Julida	Julidae	31	34
		Polydesma	Polydesmidae	10	4
	Hexapoda	Diplura	Japygidae	18	4
		Thysanura	Lepismatidae	1	9
			diverse Thysanura	2	4
	Arachnida	Araneae	Diverse Araneae	17	16
		Pseudoscorpiones	Diverse Pseudoscorpiones	0	2
		Acari	Trombidiidae	0	2
	Chilopoda	Scolopendrida	Scolopendridae	7	3
		Lithobiida	Lithobiidae	1	2
		Geophila	Geophilidae	1	1
	Crustacea	Isopoda	Porcellionidae	0	8
Annelida	Oligocheta	Haplotaxida	Lumbricidae	30	32
Mollusca	Gasteropoda	Stylommatophora	Diverse Stylommatophora	3	0
Total				484	406

Soil macrofauna were sampled by extracting two 30 cm-sided soil cubes (including the litter layer) in the central part of each plot, at the seeding stage and 30 days later (48 and 64 samples from Windé and Zouana, respectively).

was significantly higher under NTG than in CT, particularly with respect to Lumbricidae, Porcellionidae and Thysanura Lepismatidae, but also for diverse Araneae and some Coleoptera such as Staphylinidae and Carabidae. Macrofauna abundance under NTL (characterised by a lower biomass than under NTG) or in NT, was moderate. Higher taxonomic abundance was observed in the mulched plots of both sites. Abundance and diversity of soil arthropods were significantly higher in NTG and NTL than in CT plots (+103 and +79%, respectively), while NT plots were moderately higher (+37%) (Table 3).

The detritivore group consisted mainly of Formicidae (53.6%), Termitidae (24.7%) and Lumbricidae (9.4%) in both the layer and soil partitions. Meanwhile, the herbivore group was dominated by Julidae (46.1%), larvae of Coleoptera (22.1%) and Pyrrhocoridae or Reduviidae (11.8%). And the predator group consisted mainly of Araneae (33.8%), Carabidae (24.6%), Staphylinidae (15.7%) and Scolopendridae (10.3%).

Herbivores were significantly more abundant in mulched soil (NTG, NTL) than in non-mulched soil (NT, CT) at Windé, while they were more abundant in NTG than in CT at Zouana (Fig. 4). Predators were more

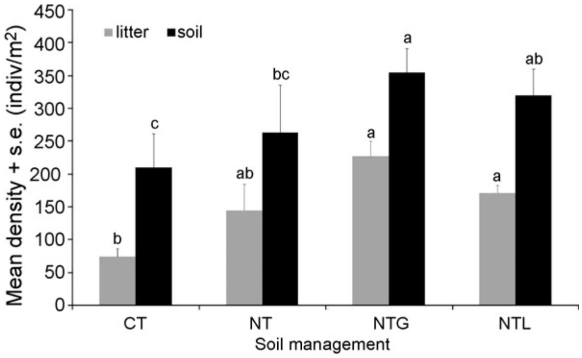

Fig. 3. Distribution of soil macrofauna between soil and litter layers as a function of the soil management system. Soil macrofauna were sampled by scraping the litter and by extracting two 30 cm-sided soil cubes from the central part of each plot at the seeding stage and 30 days later (28 samples per system) during the 2004 cotton-growing season. CT, conservation tillage; NT, no tillage; NTG, no tillage with grass mulch and NTL, no tillage with legume mulch. Bars of the same colour followed by different letters are significantly different (ANOVA SAS GLM, $P < 0.05$). S.E.: standard error.

abundant in NTG than in CT in both sites. At Zouana, predators were significantly more abundant in NTG than in NTL, NT and CT. At Windé, detritivores were significantly more abundant in NTL than in NT or CT, and no difference between soil management systems was observed. On the whole, detritivores, herbivores and predators were more abundant in no-tilled soils, particularly when covered with grass mulch (NTG).

4. Discussion

The abundance and biodiversity of soil macrofauna was significantly higher under the no-till with mulch system than under conventional tillage, 3 years after the implementation of these systems. The no-till system without mulch attained an intermediate level of abundance and biodiversity. Our findings are consistent with those of Radford et al. (1995), Andersen (1999), Wilson-Rummenie et al. (1999), Marasas et al. (2001) and Blanchart et al. (2006, 2007) in providing evidence of a positive contribution of mulch and no tillage to the biodiversity and abundance of soil fauna.

Soil cover improves environmental conditions for soil organisms by protecting the habitat against water and wind erosion, drastic variations in humidity and temperature, and by increasing organic matter as a food source, thus providing a more stable environment for soil and litter dwelling invertebrates (Stinner and House, 1990; Kladivko, 2001; Blanchart et al., 2006). Conversely, the mechanical impacts of conventional tillage reduce the population of beneficial arthropods (Robertson et al., 1994). Native arthropods may also emigrate from the fields (Thorbek and Bilde, 2004) because of habitat disruption and removal of essential reproduction sites or resources, thus increasing predation risk or reducing prey densities.

Similar to the findings of House and Stinner (1987), Robertson et al. (1994) and Marasas et al. (2001), our results showed that mulch had a significant effect on trophic levels. Consistent with the reports of House and Parmelee (1985), Brown et al. (2002) and Reeleder et al. (2006), more detritivores, particularly earthworms (Lumbricidae), were observed in no-tilled than in tilled soils. The detritivore functional group is particularly important as these animals act as catalysts in the process of organic matter transformation (Lavelle et al., 1997). Ants (Formicidae) and termites (Termitidae) were abundant, but their populations did not differ consistently between soil management systems, presumably due to their aggregative behaviour. In semi-arid regions,

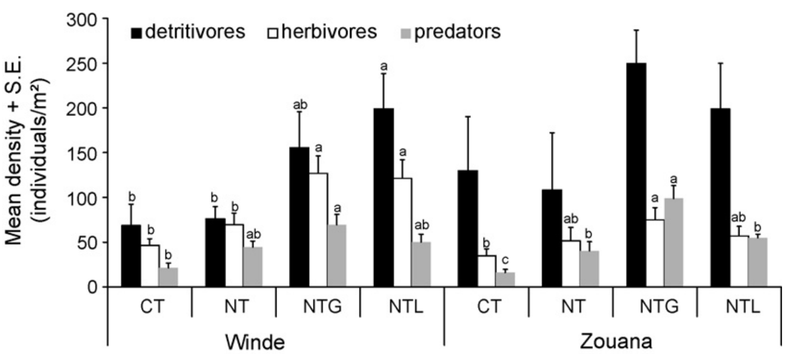

Fig. 4. Abundance of soil macrofauna communities as a function of the soil management system and experimental site. Soil macrofauna were sampled by extracting two 30 cm-sided soil cubes (including the litter layer) in the central part of each plot, at the seeding stage and 30 days later (16 and 12 samples per system, from Zouana and Windé sites, respectively) during the 2004 cotton-growing season. CT, conservation tillage; NT, no tillage; NTG, no tillage with grass mulch and NTL, no tillage with legume mulch. For each individual site, bars of the same colour followed by different letters are significantly different (ANOVA SAS GLM, $P < 0.05$). S.E.: standard error.

Table 2
Abundance of major soil macrofauna families as a function of the soil management system and experimental site

Class	Experimental site / Family	Mean density (individuals/m^2)							
		Windé				Zouana			
		CT	NT	NTG	NTL	CT	NT	NTG	NTL
Insecta	Formicidae	161(30)	273(104)	219(50)	238(25)	93(63)	124(70)	166(34)	92(13)
	Termitidae	36(19)	43(15)	69(43)	63(27)	105(61)	69(59)	122(35)	122(50)
	Larvae of Coleoptera	13(3) b	19(8) b	50(18) a	37(12) ab	3(3)	0(0)	3(2)	1(1)
	Carabidae	6(2) bc	24(7) a	21(9) ab	2(1) c	3(2) b	10(4) ab	21(8) a	9(3) ab
	Staphylinidae	0(0)	0(0)	6(4)	9(6)	6(2) b	7(3) b	22(8) a	10(3) ab
	Pyrrhocoridae	6(3)	2(1)	3(1)	12(6)	3(2)	6(4)	10(8)	11(6)
Diplopoda	Julidae	17(5) b	29(8) ab	34(6) a	46(11) a	23(6)	38(12)	47(10)	31(5)
	Polydesmidae	4(2)	10(4)	13(6)	12(6)	0(0)	4(4)	6(4)	5(3)
Hexapoda	Japygidae	10(4) bc	0(0) c	23(8) ab	37(10) a	4(2) ab	1(1) b	8(2) a	3(2) b
	Lepismatidae	0(0) b	0(0) b	1(1) ab	4(2) a	0(0) c	6(3) bc	19(5) a	10(5) ab
Arachnida	diverse Araneae	11(4) b	14(3) ab	25(4) a	17(3) a	5(2) c	14(4) bc	29(5) a	17(3) ab
Chilopoda	Scolopendridae	2(1) b	4(3) b	8(4) b	15(3) a	1(1)	1(1)	3(2)	5(2)
Crustacea	Porcellionidae	0(0)	0(0)	0(0)	1(1)	2(1) b	0(0) b	21(4) a	5(2) b
Oligocheta	Lumbricidae	11(5) c	19(5) bc	31(5) b	58(11) a	13(5) c	19(11) bc	61(8) a	29(5) b

Soil macrofauna were sampled by extracting two 30 cm-sided soil cubes (including the litter layer) from the central part of each plot, at the seeding stage and 30 days later (12 and 16 samples per system, from Windé and Zouana, respectively) during the 2004 cotton-growing season. CT, conservation tillage; NT, no tillage; NTG, no tillage with grass mulch and NTL, no tillage with legume mulch. For each individual site, values of the same row followed by different letters are significantly different (ANOVA SAS GLM, $P < 0.05$). (): standard error.

Table 3
Abundance, taxonomic richness, diversity and evenness of soil macrofauna as a function of the soil management system and experimental site

Site	Soil management system	Number of individuals/m^2	Number of families	Shannon–Weaver index	Evenness index	NF 95%
Windé	CT	302	16	2.5	0.63	11
	NT	466	17	2.3	0.57	9
	NTG	581	28	3.3	0.70	17
	NTL	623	28	3.2	0.67	14
Zouana	CT	276	18	2.5	0.59	10
	NT	328	20	2.9	0.68	13
	NTG	593	27	3.4	0.72	16
	NTL	410	29	3.4	0.70	18

Soil macrofauna were sampled by extracting two 30 cm-sided soil cubes (including the litter layer) in the central part of each plot, at the seeding stage and 30 days later (12 and 16 samples per system, from Windé and Zouana, respectively) during the 2004 cotton-growing season. NF 95%, minimum number of families to complete 95% of the total number of individuals. CT, conservation tillage; NT, no tillage; NTG, no tillage with grass mulch and NTL, no tillage with legume mulch.

termites and ants influence soil properties more than earthworms (Lal, 1988), but all are considered to be soil engineers as a consequence of their major roles in improving soil macroporosity, which improves root growth and subsequent availability of water (Knight et al., 1992; Lawton, 1994; Francis and Fraser, 1998; Lobry de Bruyn, 1999; Leonard and Rajot, 2001). The accumulation of organic matter in no-till with mulch systems, particularly leguminous residues, may provide a resource base for detritivores (Blanchart et al., 2006). Their soil mixing activities generate a more homogeneous distribution of organic matter. In Niger, termite activity improved water infiltration, trapped blowing sand, and encouraged re-growth of grass and other vegetation (Lal, 1988). In Burkina Faso, locally available organic matter applied on the soil surface of crusted soil triggered termite activity (Mando et al., 1996), thus stimulating the decomposition of organic matter (Ouedraogo et al., 2004).

Herbivore organisms were more abundant in mulched plots than in tilled plots. As reported by Stinner and House (1990), mulch provides a favourable habitat for soil arthropods, usually detritivores, but these may become pests when their food sources are depleted. For example, millipedes (Julidae) prefer to dwell in soil covered with mulch and may cause severe damage to cotton seedlings (Brévault, unpublished data). Similarly, black beetles (*Heteronychus* spp.) were reported to have caused significant damage to rice grown with mulch at the beginning of a growing season in Madagascar (Ratnadass et al., 2006). In contrast, Wilson-Rummenie et al. (1999) reported that reduced or zero-tillage did not increase the incidence of insect pests on emerging seedlings in Australia. When no-till systems were first introduced in the USA, it was originally thought that there would be more damage to crops than that which was observed, especially caused by soil-inhabiting insects, because ploughing and cultivation had been traditional methods of reducing populations of boll weevils and bollworms in cotton crops (Gaylor and Foster, 1987). The net effects of a tillage and mulch-based system on crop pests can be difficult to predict (in terms of time and location specificity) as ploughing and mulch can respectively kill or serve as refuge for pests and beneficial organisms (Ratnadass et al., 2006). In a meta-analysis of studies examining the influence of reduced tillage on invertebrate pests and their damage to crops, Stinner and House (1990) reported that 43% of the studied species and their damage decreased with decreasing tillage, 29% were not significantly influenced by tillage and 28% increased with decreasing tillage.

One of the most frequent and widespread observations regarding arthropods in conservation tillage is the increase in soil- and litter-inhabiting predatory arthropods, especially ground beetles (Carabidae) and spiders (diverse Aranae) (Stinner and House, 1990; Robertson et al., 1994; Pullaro et al., 2004). Our study confirmed that predators were encountered in greater abundance in no-tilled and covered soil than in tilled soil. Spiders, ground beetles, staphylinid beetles and centipedes constituted a major and ecologically important group of generalist arthropod predators in this study. They contribute to the regulation of biological activity of soil by acting at the top of the food chain and feeding on other organisms (Stinner and House, 1990). However, they also contribute to biological control of pests and create a link between soil and grazing food webs (Rypstra and Marshall, 2005). In cotton systems, removal of soil-dwelling predators from both conventional and conservation tillage systems significantly increased the emergence rate of adult *Heliothis* moths (Gaylor et al., 1984). Similarly, ants and *Geocoris punctipes* (Say) participated significantly more in the management of heliothines in CT with crimson clover and rye cotton cover crops than in control plots (Tillman et al., 2004). Soil and litter meso- or microfauna, particularly mites (Peachey et al., 2002) and nematodes, may also significantly control pests.

5. Conclusion and outlook

Increased diversity and activity of soil macrofauna under no-till with mulch systems are of great interest to those in the field of soil restoration. Compared to CT, direct seeding mulch-based systems favoured the establishment of detritivores (earthworms, termites, ants) and predators (spiders, carabids, staphylinids, centipedes). More detailed research will be necessary to identify organisms (down to genera or species), and to link this diversity to functional ecology and beneficial purposes to agriculture. Furthermore, it would be of great interest to identify groups or species that can be used to characterise the biological health of a soil and its sustained productivity and that may serve as indicators of environmental conditions or particular ecological processes in the soil.

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