Macrofauna pattern in conventional and direct seeding mulch-based cropping systems in North Cameroon

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Abstract
Within the framework of adopting direct seeding mulch-based cropping systems (DMC) in cotton farming systems in North Cameroon, we compared the macrofauna patterns from four soil management techniques: (1) non tilled soil covered with the graminousceae *Brachiaria ruzisiensis*, (2) non tilled soil covered with leguminous plants, *Crotalaria retusa* or *Mucuna pruriens*, (3) non tilled soil and (4) conventional tilled soil. In both study sites, micro-plots had been subjected to the same farming systems for the past 3 years. Sampling of organisms was carried out from soil cubes (30 cm) examination, including soil and litter.
The findings revealed that diversity, equitability as well as abundance of extracted macrofauna were found to be generally more important in mulch-based cropping plots: soil and surface litter transformers (earthworms, diplura, thysanura, etc.), but also predators (spiders, centipedes, carabids, etc.) and phytophagous arthropods such as millipedes. These preliminary results underline a significant impact of soil management techniques on macrofauna pattern and trophic communities, with key organisms serving as potential indicators of the biological activity of the soil.

Media summary
In North Cameroon, the analysis of macrofauna from cotton plots revealed a greater abundance and diversity of organisms for cover crop mulches compared to conventional cropping systems.

Key words
soil macrofauna, soil management, no tillage, mulch, cotton

Introduction
In cultivated ecosystems, soil organisms are principal components of soil fertility (Lavelle *et al.*, 1994). In tropical ecosystems, the diverse range of organisms and functions of macrofauna community performs in soil to produce diversity in biogenic soil structures that help regulate physical properties and chemical processes, activities endangered by poor agricultural practices (Lal, 1988; Stinner and House, 1990). In North Cameroon, traditional cultural practices characterized by systematic transportation of crop residues, repeated soil perturbation and decrease in the fallow period culminate in soil degradation (Harmand *et al.*, 2000; Boli *et al.*, 1991). As a result, a regular decrease of crop yields has been observed in cotton cropping systems for over a decade. The principal cause seems to be the reduction of soil fertility, particularly by depletion of organic matter.
Soil and crop management techniques that favour and enhance the activity of soil fauna include no-tillage, cover crop mulches, agro-forestry and other ecologically compatible farming systems. Incorporation of organic residues improves erosion protection, favours decomposition, and increases biological activity, all leading to increased soil fertility and structural stability (Henke, 1994). The objective of this study that was carried out in 2004, was to verify if direct seeding mulch-based cropping systems (DMC) is able to restore biodiversity of soil macrofauna. It was thus necessary to compare diversity and abundance of soil macrofauna in DMC vs. conventional cropping systems, after three years of implementation.

Methods
Soil management
In this study, the soil management techniques differ essentially by soil tillage and soil cover: (1) traditional seeding on tilled soil (TS), (2) seeding on non tilled soil (NS), (3) seeding on non tilled soil covered with the graminousceae *Brachiaria ruzisiensis* (GC) and (4) seeding on non tilled soil covered with leguminous plants, *Crotalaria retusa* or *Mucuna pruriens* (LC). Plots were planted of two cotton

varieties, Irma A1239 and Irma BLT-PF (*Gossypium hirsutum)* from IRAD. The preceding crop were maize or sorghum, respectively at Windé and Zouana.

Experimental design

This study was carried out at the ESA Project experimental sites, in the villages of Windé Pintchoumba (4 ha, 8°29'30''N and 13°26'51''E) and Zouana (3.5 ha, 4°45'01''N and 11°25'03''E), both in the cotton growing area of Cameroon. Micro-plots measured 200 m² (3 replications) and 60 m² (4 replications) at Windé and Zouana respectively. Windé is characterized by a sudan climate with one rainy season from mid-May up to mid-October (mean annual rainfall of 1200 mm), whereas Zouana is crossed by a sudano-sahel climate with a rainy season from June to September (mean annual rainfall of 800 mm). Both sites present ferruginous tropical and hydromorphous soils (pH=5.5 to 6, OM=1 to 2% for the 0 – 20 cm range) very sensitive to erosion. The surface presence of earthworm and termite mounts indicates an important soil bio-activity (Raunet, 2003).

Sampling

Gobat *et al.* (1998) defined soil macrofauna as the community of organisms that spend at least an important part of their cycle in the soil or on its immediate surface, including surface litter. Macrofauna includes organisms that measure 4 to 80 mm height, visible with the naked eyes. Soil macrofauna sampling was by extraction of 2 cubes of 30 cm (Anderson and Ingram, 1993), in the central part of each micro-plot, at the seeding stage and 30 days later. After soil sieving, organisms were carefully collected and kept in alcohol for subsequent identification.

Data analysis

The data obtained are presented in the form of sum of individuals per family, according to site and soil management techniques. These allow the calculation of : (1) abundance – density of collected individuals per unit surface and (ii) diversity evaluation by Shannon-Waever index (H') and equitability (E). Shannon-Weaver index takes into account the number of groups encountered. Its value is calculated by the following formula: $H' = -\sum p_i \times \log_2 (p_i)$ with i=1 to s, where pi = probability of meeting a taxon i on a field and s = total number of taxa encountered on the field. This index is equal to zero when there is only one taxon and its value is maximum when all taxons are of equal abundance. Equitability (E) also known as regularity measure, determines the distribution of taxons. This index is used to compare communities that present different number of taxa, with the objective of assessing the equilibrium of populations. It is equal to the ratio between calculated diversity and theoretical maximum diversity ($E = H' / \log_2(s)$). E tends to 0 when one taxon largely dominates the community and is equal to 1 when all taxons are of equal abundance.

In order to assess soil management practices, data were submitted to a variance analysis of the SAS GLM procedure (square root transformation). When the treatment effect was significant, Duncan test (0.05) was used to classify the means.

Results

The analysed sample resulted in identification of 4128 individuals, from 35 groups (common names), 22 orders, 8 classes and 3 phyla (Annexe 1). The Arthropoda phylum was most represented, with more than 92% of the total individuals in both sites, followed by Annelida (7%). The class Insecta was most abundant with 76.0 and 80.2% of arthropod density, in Zouana and Windé respectively. Equally important density of Diplopoda (9.6%, millipedes), Hexapoda (4.7%, thysanura and diplura) and Arachnida (4.6%, diverse spiders, pseudo-scorpions and trombidiids) were collected. Additional arthropod classes such as Chilopoda (1.9%, centipedes, lithobiids and geophilids) and Crustacea (1.1%, woodlices), particularly in Zouana, were encoutered. The class Insecta was essentially composed of Hymenoptera (52.5%, mostly ants), Isoptera (26.1%, termites), Coleoptera (16.6%, carabids, staphylinids, chrysomelids, scarabaeids, *etc.*) and Hemiptera (2.6%, pyrrhocorids and reduviids).

An important part of soil macrofauna was collected in litter (34.9%). Spiders, carabids, bugs, thysanura, polydesmids and woodlice were mostly found in litter, whereas termites, millipedes, earthworms, grubs, diplura, centipedes and scarabaeids were in subsoil (Fig. 1).

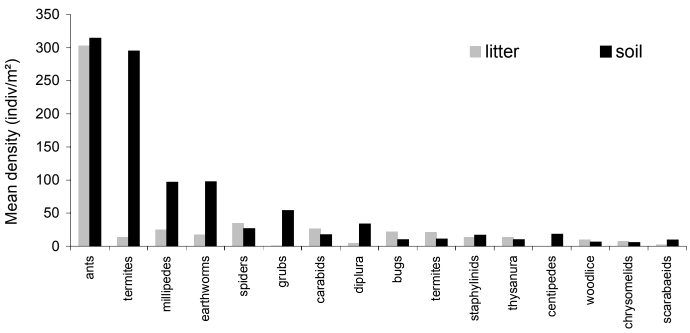

Figure 1. Macrofauna distribution in soil and litter (Windé and Zouana).

Whether in soil or litter, significant difference in the mean density of individuals was observed in the different soil management practices (Fig. 2). Furthermore, density of individuals was positively related to the biomass of litter.

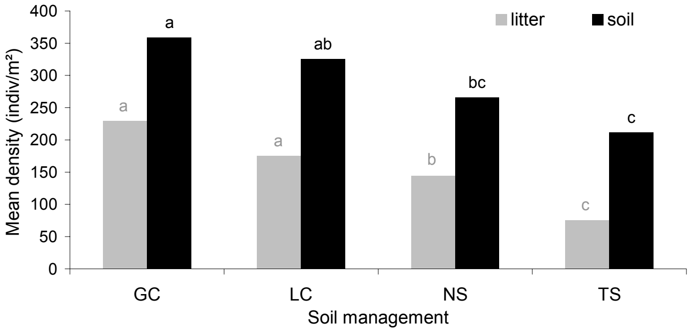

Figure 2. Macrofauna distribution in soil and litter, based on soil management practices (Windé and Zouana). Same colour columns followed by the same letter are not significantly different (0.05).

For certain groups of organisms, mean density varied significantly according to soil management practices (Tab. I).

Table I. Macrofauna distribution of groups based on soil management practices. For each site, same row data followed by the same letter (or nothing), are not significantly different (0.05).

Mean density (individuals/m²)		WINDE (n=12)								ZOUANA (n=16)							
	Soil management	GC		LC		NS		TS		GC		LC		NS		TS	
Insecta	Formicidae (ants)	219		238		273		161		166		92		124		93	
	Termitidae (termites)	69		63		43		36		122		122		69		105	
	Coleoptera (grubs)	50	*a*	37	*ab*	19	*b*	13	*b*	3		1		0		3	
	Carabidae (carabids)	21	*ab*	2	*c*	24	*a*	6	*bc*	21	*a*	9	*ab*	10	*ab*	3	*b*
	Staphylinidae (staphylinids)	6		9		0		0		22	*a*	10	*ab*	7	*b*	6	*b*
	Pyrrhocoridae (bugs)	3		12		2		6		10		11		6		3	
Diplopoda	Julidae (millipedes)	34	*a*	46	*a*	29	*ab*	17	*b*	47		31		38		23	
	Polydesmidae (polydesmids)	13		12		10		4		6		5		4		0	
Hexapoda	Japygidae (diplura)	23	*ab*	37	*a*	0	*c*	10	*bc*	8	*a*	3	*b*	1	*b*	4	*ab*
	Lepismatidae (thysanura)	1	*ab*	4	*a*	0	*b*	0	*b*	19	*a*	10	*ab*	6	*bc*	0	*c*
Arachnida	Araneae (spiders)	25	*a*	17	*a*	14	*ab*	11	*b*	29	*a*	17	*ab*	14	*bc*	5	*c*
Chilopoda	Scolopendridae (centipedes)	8	*b*	15	*a*	4	*b*	2	*b*	3		5		1		1	
Crustacea	Porcellionidae (woodlice)	0		1		0		0		21	*a*	5	*b*	0	*b*	2	*b*
Oligocheta	Lumbricidae (earthworms)	31	*b*	58	*a*	19	*bc*	11	*c*	61	*a*	29	*b*	19	*bc*	13	*c*

At Windé, leguminous soil cover harboured more individuals than tilled soil, particularly earthworms (Lumbricidae), millipedes (Julidae), hexapods (Japigidae and Lepismatidae), centipedes (Scolopendridae) and spiders. Graminasceous soil cover was surprisingly poorer in chilopods and earthworms. On the contrary, they harboured more carabids. Non tilled soil was intermediate. Therefore, cover mulch and tillage are factors that significantly influence macrofauna pattern.

At Zouana, *Brachiaria* soil cover was significantly richer than tilled soil, particularly earthworms, woodlices (Porcellionidae) and thysanura (Lepismatidae), but also spiders and some coleoptera (Staphylinidae and Carabidae). Leguminous soil cover, that presented low biomass, or non tilled soil were intermediate. If ants and termites were the major groups, differences were not significant because of the aggregative distribution of these social insects.

In both sites, a greater taxonomic abundance was observed in cover plots. Diversity and equitability index follow the trend below (Tab. II).

Table II. Macrofauna taxonomic richness, diversity and equitability, according to soil management practices. NG 95% : minimum number of groups that attain 95% of the total individuals.

Site	Soil management	Groups	Shannon-Weaver index	Equitability	NG 95%
WINDE	CL	28	3.2	0.67	14
	CG	28	3.3	0.70	17
	NT	17	2.3	0.57	9
	ST	16	2.5	0.63	11
ZOUANA	CL	29	3.4	0.70	18
	CG	27	3.4	0.72	16
	NT	20	2.9	0.68	13
	ST	18	2.5	0.59	10

The identified groups were classified based on their major ecological function (Fig. 2). At Windé, phytophagous and predatory organisms were significantly more represented in covered soil. No significant effect of soil management was observed because of the strong proportion of ants and termites in this trophic class. At Zouana, the density of detritivores was greater in *Brachiaria* covered soil. Similarly, more predatory and phytophagous organisms were counted, showing that tillage has a negative effect on these classes.

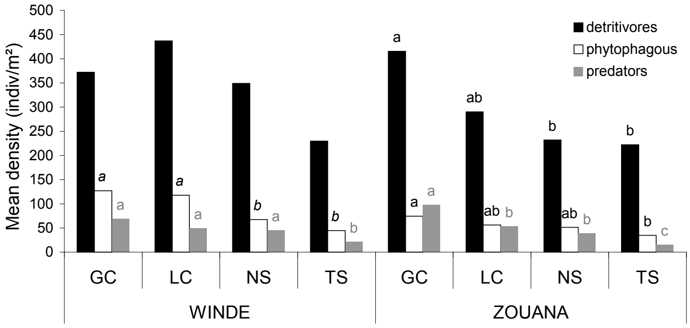

Figure 3. Distribution of ecological functions based on soil management practices. For each site, same colour columns followed by the same letter are not significantly different (0.05).

Detritivores were essentially composed of ants (53.6%), termites (24.7%) and earthworms (9.4%), the latter being significantly more represented in DMC. On the other hand, the phytophagous class was dominated by millipedes (46.1%), grubs (22.1%) and bugs (11.8%). Finally, predators were essentially composed of spiders (33.8%), carabids (24.6%), staphylinids (15.7%) and centipedes (10.3%), mostly represented in covered soils.

Conclusion

After three years of implementation, the graminasceous or leguminous soil cover has induced biodiversity improvement in soil macrofauna. These results are quite similar to those obtained by Wilson *et al.* (1999), Brown *et al.* (2001) or Andersen (2003) that put to evidence the positive contribution of soil cover and no tillage on biodiversity and abundance of soil fauna, with gradual increase with time. This contribution may be explained by favourable edaphic conditions provided by the cropping system. Soil cover would provide favourable environment for the fauna development by protecting the soil against water and wind erosion, drastic variations of humidity or temperature, and by increasing organic matter as food chain basics. On the contrary, tillage would destroy fauna by

accelerated degradation of organic matter and exposure of organisms to the destructive rays of the sun and predators.
Soil cover and tillage have a significant effect on the pattern of trophic classes, as shown by Robertson *et al.* (1994) and Marasas *et al.* (2001). Termites and earthworms, considered as soil engineers for their major role in the formation of galleries (macroporosity), contribute to water availability for crop, owing to improvement of soil structure and permeability (Henke, 1994; Francis and Fraser, 1998; Leonard and Rajot, 2001; Soutou *et al.*, in this congress, Naudin *et al.*, in this congress). Their activities permit a more or less homogeneous distribution of organic matter and mixing of mineral matter in the soil. Macrofauna thus serves as a catalyst in the process of transformation (Lavelle *et al.*, 1994). Detritivores millipedes may become phytophagous when their food sources are depleted. They are mostly numerous in soil cover mulches that provide favourable habitat; they may cause huge damages to cotton seedlings (Brévault and Naudin, in this congress). Correlatively, predators have been encountered in important proportions in covered soil. By acting at the top of the food chain and feeding on other organisms, they contribute in regulating the biological activity of the soil. Spiders, centipedes or carabids may also exercise some biological control against some soil or canopy pests.

All these processes *in fine* contribute to the improvement of soil fertility, with an increase in nutritive substances availability and acquisition efficacy of plants. These preliminary results highlight the importance of adequate decision-making in agricultural practices, in achieving a more balanced soil fauna community, thus enhancing potential benefits to soil fertility, crop production and sustainability. More detailed research will be necessary to identify organisms (down to genera or species, when possible), and attempting to link this diversity to functional communities.

Finally, soil macrofauna may serve as an indicator of environmental conditions or particular ecological processes in the soil (Doube *et al.*, 1997; Lobry, 1997). For example, Viaux and Rameil (2004) reported two spiders Linyphiidae, *Oedothorax apicatus* and *Erigone atra*, as indicators of favourable practices to biodiversity in soils in Essonne. From this study, a further attention should be given to earthworms (detritivores), millipedes (phytophagous), carabids, staphylinids or spiders (predators). It would be interesting to identify groups or species that can be used to characterise biological health of soil.

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Annexe 1. Macrofauna taxonomic composition in Zouana and Windé.

Phylum	Class	Order	Family	Group	Site		
					WINDE	ZOUANA	Total
Arthropoda	Insecta	Hymenoptera	Formicidae	ants	962	594	1556
			diverse Hymenoptera	wasps	5	10	15
		Isoptera	Termitidae	termites	228	551	779
		Coleoptera	diverse Coleoptera larvae	grubs	129	10	139
			Carabidae	carabids	57	55	112
			Staphylinidae	staphylinids	17	60	77
			Chrysomelidae	chrysomelids	10	23	33
			Scarabaeidae	scarabaeids	18	12	30
			Thorictidae	thorictids	25		25
			Elateridae	click beetles	5	18	23
			Cydnidae	cydnids	14	4	18
			Curculionidae	cuculionids	11	6	17
			Anthicidae	anthicids	4	7	11
			Tenebrionidae	tenebrionids	5	5	10
		Hemiptera	Pyrrhocoridae	true bugs	24	39	63
			Reduviidae	true bugs	3	11	14
		Diptera	diverse Diptera larvae	maggot	8	9	17
		Orthoptera	Gryllidae	crickets	11	5	16
		Embioptera	Clothodidae	clothodids	3	10	13
		Thysanoptera	Thripidae	thrips	11		11
		Lepidoptera	Noctuidae	caterpillars	8	3	11
	Diplopoda	Julida	Julidae	millipedes	136	172	308
		Polydesma	Polydesmidae	polydesmids	42	19	61
	Hexapoda	Diplura	Japygidae	diplura	76	22	98
		Thysanura	Lepismatidae	thysanura	5	46	51
			diverse Thysanura	thysanura	8	21	29
	Arachnida	Araneae	diverse Araneae	spiders	72	83	155
		Pseudoscorpiones	diverse Pseudoscorpiones	pseudoscorpions		10	10
		Acari	Trombidiidae	Trombidiids		10	10
	Chilopoda	Scolopendrida	Scolopendridae	centipedes	32	14	46
		Lithobiida	Lithobiidae	lithobiids	6	9	15
		Geophila	Geophilidae	geophilids	6	6	12
	Crustacea	Isopoda	Porcellionidae	woodlices	1	40	41
Annelida	Oligocheta	Haplotaxida	Lumbricidae	earthworms	128	162	290
Mollusca	Gasteropoda	Stylommatophora	diverse Stylommatophora	snails	12		12
Total					2082	2046	4128