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Soil Gamasina from savanna and ReviTec site of Ngaoundéré (Adamawa, Cameroon): abundance and species diversity

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Abstract

Soil Gamasina of Central African savanna are little known. In our study, Gamasina were assessed for a high Guinean savanna and for selected treatments of a ReviTec site for the rehabilitation of degraded soil, Ngaoundéré region (Adamawa, Cameroon). The experimental site was established in 2012. Four years later, in 2016, four sampling campaigns during the rainy season were undertaken (May, June, July, August). The investigated treatments were: (1) compost + mycorrhiza (cpmy), (2) compost + biochar (cpbc), (3) compost + biochar + bokashi (cpbcbo). The controls were: ReviTec control (ctrl1) and adjacent savanna (sav). Gamasina were extracted from 0 – 10 cm soil using a modified Berlese-Tullgren extractor and identified microscopically at the morphospecies level. Most of the thirty-four species belonging to fourteen genera and eight families seem to be new to science; they are treated as morphospecies with preliminary names. In comparison to savanna and control, the investigated ReviTec treatments increased total Gamasina abundance up to factor five and species number by factor two. Gamasina clearly preferred compost + biochar (cpbc) and compost + biochar + bokashi (cpbcbo) treatments compared to compost + mycorrhiza (cpmy). This confirmed our previous investigations in the same experiment. Expectations for low abundances and diversity of Gamasina in the savanna subjected to a four months' dry season have to be rejected. Expectations that the ReviTec application is initiating and accelerating the successional process are confirmed.

Keywords ReviTec | Gamasina | Cameroon | savanna | high Guinean savanna ecozone

1. Introduction

1.1 Gamasina as bioindicators for effective soil rehabilitation

Soil degradation is a global problem that is especially severe in the tropics and sub-tropics. It is characterized by the decline in quality or even loss of ecosystem goods and services (Lal 2015). Global population of 7.3 billion in 2015 is projected to increase to 9.5 billion by 2050, requiring to increase agricultural production by ~70 % between 2005 and 2050. Soil degradation, characterized by decline in quality and decrease in ecosystem goods and services, is a major constraint to achieving the required increase in agricultural production. Soil is a non-renewable resource on human time scales with its vulnerability to degradation depending on complex interactions between processes, factors and causes occurring at a range of spatial and temporal scales. Among the major soil degradation processes are accelerated erosion and depletion of the soil organic carbon (SOC). Unadapted land use practices are the main cause. In savanna ecosystems, deforestation and overgrazing are the predominant anthropogenic drivers (Osman 2014). Some 38 % of the agricultural area of the earth can be considered as degraded and the share of degraded territories in Africa is 65 % (Osman 2014). Bai

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et al. (2008) estimated the degrading area in Cameroon at 151,605 km^2 which represents 32 % of the territory, with a strong bias towards the dry and populated Northern part of the country (North and Far-North regions). More than 26 % of the population is affected. Soil degradation is continuously increasing due to population growth (firewood exploitation) and increasing meat demand (overgrazing).

ReviTec is an ecological rehabilitation approach developed by the Bremen-based partnership KeKo - Kesel, Koehler & partners, biologists, in co-operation with the Centre for Environmental Research and Technology (UFT) of the University of Bremen (Koehler et al. 2006). ReviTec is based on experience from long-term ecological research (Koehler & Müller 2003, Koehler & Melecis 2010). The modular design of ReviTec covers three levels of scale with various functions. The basic module is a bag of degradable fabric for initial erosion control, filled with substrate (30 L). The substrate is amended with abiotic and biotic elements (bioactivation) to initiate and accelerate ecological succession (Koehler 2005, Koehler et al. 2006, Kesel et al. 2006) and to rehabilitate essential ecosystem services of soil. In Cameroon, four demonstration, teaching and research sites have been established since 2012: one on the premises of University of Ngaoundéré (Adamawa region) and three near Maroua (Far North; East Sudanian savanna) (Kesel 2012, Koehler et al. 2013)). The preparation of the ReviTec site in Ngaoundéré in 2012 included experimental degradation (removal of vegetation and topsoil).

Soils capable to deliver the ecosystem services mentioned above are alive. Apart from above-ground vegetation, soil biota offer important information on the state of the soil. Soil biota are vital for life on earth which is based on the ecosystem services that result from their interactions with the abiotic environment, such as soil fertility, biogenic soil stabilization, water infiltration and storage, carbon sequestration. Pressure on the soil biota undermine the provisioning of ecosystem services (Gardi et al. 2013, Wagg et al. 2014).

In our study, we focus on predatory mites (Gamasina), which are considered to be valuable bioindicators (Karg & Freier 1995, Koehler 1997, Koehler 1999, Pérez-Velázquez et al. 2011). Gamasina occur in relatively modest abundances, but in high numbers of species (Petersen & Luxton 1982, Coja & Bruckner 2006). They are sensitive to anthropogenic and natural disturbances (Koehler 1999, Coja & Bruckner 2006, Bedano & Ruf 2007).

The overarching objective of this study is to contribute to the assessment of the efficiency of the ReviTec approach in a Central African context. The abundance, diversity and ecological roles of microarthropods in Sub Sahara African soil ecosystems are poorly known and understood. Until now there are only a few microarthropod studies of the Sahel and the savannas bordering South of it (e.g. Mosadoluwa & Buny 2000, Iloba & Ekrabene 2008, Gbarakoro et al. 2010, N'Dri & André 2011, Okiwelu et al. 2012, N'Dri et al. 2016). For Cameroonian savanna, the knowledge on soil microarthropods is limited to Oribatida species from the ReviTec site of Ngaoundéré, Adamawa region (Ermilov & Koehler 2017) and to two unpublished master's theses from the University of Ngaoundéré (Danra 2014, Djoussi 2015).

As parameters for this assessment, we use abundance, species diversity and community structure of Gamasina under three selected treatments and two controls. We provide baseline and reference data against which planned future savanna and woodland restoration can be measured.

We hypothesize that: (i) compared to the savanna (sav) Gamasina abundance and species composition would be lower in ReviTec control (ctrl1). The relatively low colonization of ctrl1 is expected to reflect the experimental degradation of the site. (ii) The compost amendments are expected to have a positive effect on Gamasina abundance and diversity, with a positive effect of the biochar amendments.

2. Material and methods

2.1 The ReviTec site Ngaoundéré

The study was carried out on the ReviTec site of the University of Ngaoundéré in Dang, Adamawa (7°25'21"N, 13°32'23"E) and the adjacent savanna. The Adamawa region is characterized by a rainy season from April to October and a dry season from November to March. Rainfall is practically nil from November to February (Fig. 1).

The ReviTec site of Ngaoundéré was installed in April 2012 on the premises of the University. The topsoil layer of a 50 × 50 m^2 area was removed, hand-tilled to 30 cm depth and then covered with 30 cm of loamy sand from local builder's merchant to mimic severe degradation. The entire site (50 × 50 m^2) was fenced to avoid disturbance from cattle and unauthorized persons.

Biodegradable coffee bags filled with substrates were arranged according to a Latin square design of twenty-five islands, assembled from 2 x 2 bags each, with 7 different treatments and 3 controls in 5 replications (Fig. 2, upper left). Three treatments and one control were selected for our study (Fig. 2). Additionally to the islands, half-

moons, bunds and tree-islands were constructed (ReviTec structures) which are not considered here.

The application of ReviTec initiated a rapid succession in the first rainy season 2012 (Fig. 3). By 2016, when we did our investigation, the ReviTec site was fully covered by the vegetative parts (branches) of *Brachiaria brizantha, Indigofera hirsuta, Indigofera nummularifolia* and *Stylosanthes guanensis*. The plants rooted in the bags of the ReviTec structures.

The samples are from:

- sav: the savanna adjacent to the ReviTec site is a grassy shrub and tree savanna, dominated by *Daniellia oliveri* and *Lophira lanceolata*. It is affected by grazing and bush-fire (see also: Mapongmetsem et al. 2016).
- ctrl1: sample plot on the ReviTec site without any treatment

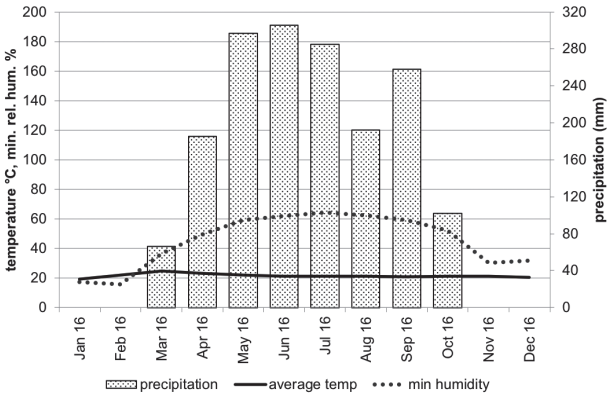

Figure 1. Weather data for the Ngaoundéré region, Jan. to Dec. 2016, provided by Ngaoundéré airport meteorological station; 1105 m ASL; precipitation = 1691 mm; temperature mean/min/max = 22/19/25°C; min rel. hum mean/min/max = 45/16/64 %.

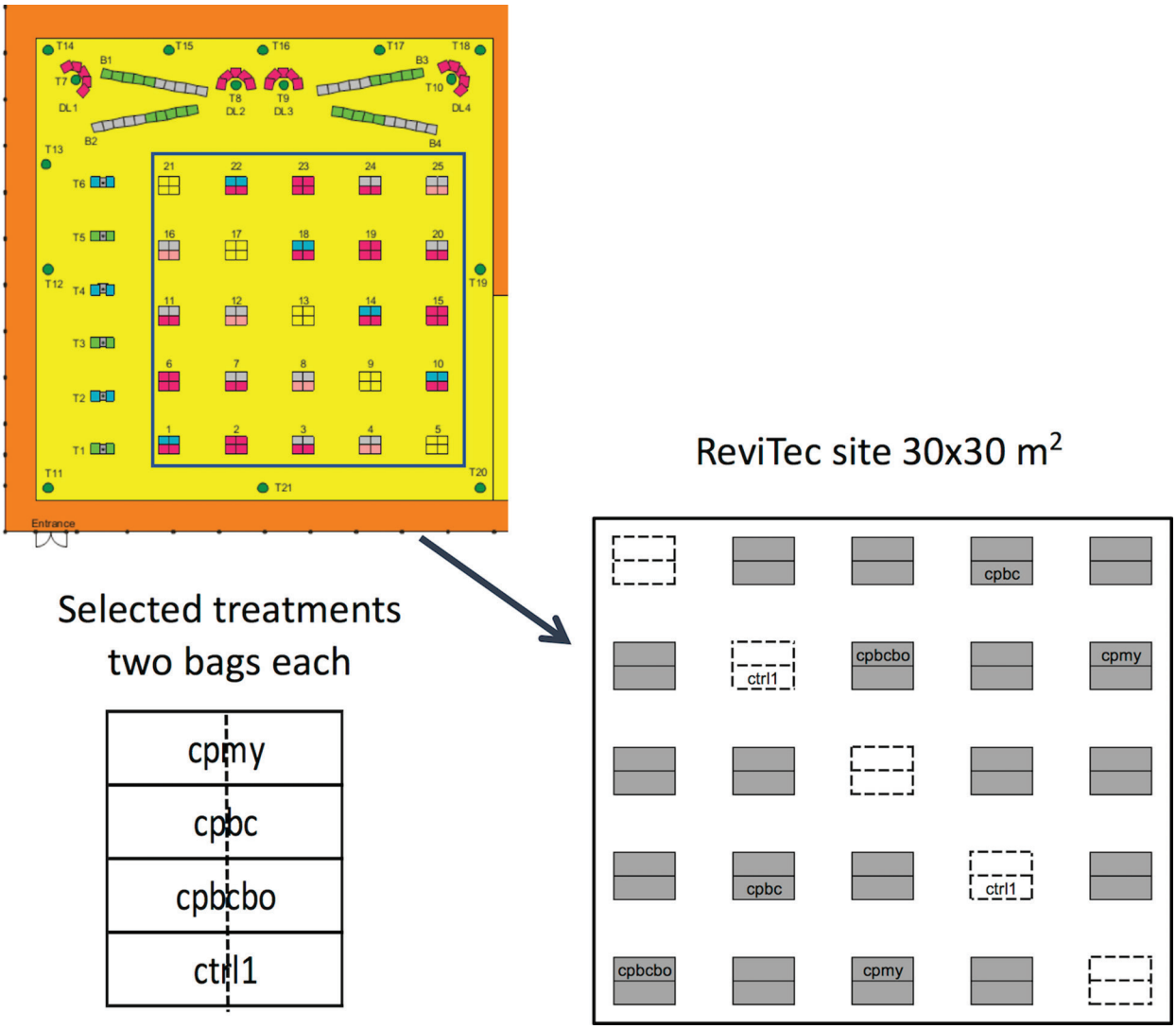

Figure 2. Sampling design of ReviTec site with the selected 3 x (2x2)-bag-islands and one control, sampled in 2016 (n = 2). Upper left: The ReviTec site, including structures and all treatments and controls.

- cpmy: compost with mycorrhizal fungi inoculate. The mycorrhiza is considered to be of no influence to the Gamasina.
- cpbc: compost with biochar amendment
- cpbcbo: compost and biochar-bokashi mixture.

The mixtures are summarized in Tab. 1.

2.2 Sampling

2.2.1 Sample tool, sample date, number of samples, sampling procedure

The soil samples (0–10 cm depth) were collected in May, June, July and August 2016 at 30-days-intervals using a steel corer of 10 cm diameter. Samples were always taken in the morning. The dry and hard soil in May was humified with water some hours before sampling.

Per sampling date, two soil cores were taken from savanna, control and the three selected treatments, resulting in a total of 40 soil cores (78.5 cm^2, 785 cm^3). For extraction, the soil cylinders were divided into 0–5 cm and 5–10 cm, resulting in 80 soil cores (392.5 cm^3). Details concerning the sampling and the samples are shown in Tab. 2.

The soil samples were placed in labelled plastic vessels made from water bottles and brought carefully to the laboratory avoiding any vibrations. Extraction of soil microarthropods was done with a Berlese-Tullgren extractor. The time required for complete extraction of the fauna was seven days. The animals were collected in 95% ethanol ensuring killing and preservation. Liquid detergent was added to the ethanol to ensure the sinking particularly of Collembola and ethanol was added if necessary to account for evaporation.

Figure 3. The ReviTec-Ngaoundéré site in August 2012, 4.5 months after installation. The seeded plants germinate from the bags, assembled in half moon, bund and island structures. In the background the buildings of Faculty of Science (Photo © Ngakou).

The mites were sorted and counted according to the following taxa: Gamasina, Uropodina, Astigmata, Oribatida, and Prostigmata. The rest of the Berlese-fauna was stored in alcohol in labelled storage flasks.

For light microscopical inspection and identification, Gamasina were cleared and mounted on cover slip slides in permanent mounts (polyvinyl-lactophenol). Images were taken with Sony DXC-9100P 3CCD camera mounted on an Olympus BX 60 microscope at the UFT, University of Bremen, Germany. Differential interference contrast (DIC) was used, mainly with objectives of 20x and 40x. The images were digitally

Table 1. The substrate composition (%) of the three selected ReviTec treatments.

		Substrate %					
Treatments	**code**	Loamy sand	Compost cp	Biochar bc	Bokashi bo	Mycorrhiza my	Replicated plots
Control 1 no bags, no substrate	ctrl1						2
Compost + mycorrhiza	cpmy	70	30			inoc	2
Compost + biochar	cpbc	70	20	10			2
Compost + (biochar-bokashi)	cpbcbo	70	10	10	10		2

Table 2. Sample tools, sample dates and number of samples.

date	**corer**	**soil cores**					**n per depth**	**n per treatment**					**n total**
year	diameter (cm)	area (cm^2) of soil cylinder	factor to calculate ind./m^2	depth1 (cm)	depth2 (cm)	volume (cm^3) per depth		sav	ctrl1	cpmy	cpmy	cpbcbo	per depth
2016	10	78,5	127	0–5	5–10	392.5	2	2	2	2	2	2	80

stored with frame grabber Optimas. For identification we used, among others, Hurlbutt (1973), Hurlbutt (1972), Karg (1993), Moraza (2005) and Castilho et al. (2012). However, most of the species were not listed in these sources. Therefore, we recur to morphospecies. Descriptions of new species are planned in the near future.

2.2.2 Data analysis

Abundance

The Gamasina extracted from each soil cylinder were recorded. For the calculation of abundance (ind./m^2) we used:

$abundance\ (ind./m^2) = n \times factor$

n is the numbers of individuals counted from a sample. The factor was used to obtain individual numbers per m^2.

We added records from depth1 and depth2 for each sample to obtain the 0–10 cm values. For details on sample dimensions and conversion factor see Tab. 2.

Community parameter

We exclude from our calculations the unidentified juveniles, which are 4% of all Gamasina individuals, and use the values obtained for the soil core of 0–10 cm (n = 2 per five plots per four dates, 40 in total).

Dominances were calculated using the formula:

$dominance\ of\ species\ i\ (d\%) = 100 \times ni/N,$

(ni = number of individuals of species i; N = total number of individuals of all species. Dominance classes were chosen according to the literature (Gwiazdowicz et al. 2011, Manu et al. 2013): eudominants > 10.0%; dominants 5.1–10.0%; sub-dominants 2.1–5.0%; recedents 1.1–2.0%, and sub-recedents < 1.1%.

Diversity indices

To describe the diversity of Gamasina, four indices were calculated: (1) the species richness (S), (2) the Simpson Diversity Index (D), (3) the Shannon-Wiener Diversity Index (H), (4) the Evenness Index (J'), (4) (Ballabio et al. 2001):

- Simpson Diversity Index:
  $D = \sum (p_i)^2$
  p_i is the relative abundance (dominance) of the i-th species, i = 1–34.
- Shannon Diversity Index:

  $$H' = -\sum_{i=1}^{s} p_i ln p_i$$

  p_i as above
- Evenness Index:
  $J' = H'/lnS$
  H' = Shannon – Wiener diversity Index;
  S = Total number of species

Similarity indices

To compare the treatments and sites in respect to their Gamasina communities, we calculated (1) species identity according Soerensen (SOE) and (2) dominants' identity Renkonen Index (REN).

- Soerensen index is calculated using the following equation (Schäfer 2012):

  $$SOE = \frac{2j}{a+b}$$

  SOE = Soerensen Index; j = Total number of species present in both substrates a and b; a = Number of species present in substrate a; b= Number of species present in substrate b.

- Renkonen index is calculated using the following equation (Schäfer 2012):

  $$REN = \sum_{i=1} min\,(p_{1i}, p_{2i})$$

  $\sum$ runs from i=1 to j, where j is the total species number.
  p_{1i} = the proportion of species i in sample 1 (=n_{1i}/N_1)
  p_{2i} = the proportion of species i in sample 2 (=n_{2i}/N_2)

3. Results

3.1 Gamasina abundances and species numbers

Abundances (ind. in tsd./m^2) and species numbers for each of the plots are calculated from the means over the four sampling dates (Tab. 3).

The abundances of Gamasina are high, reaching a maximum of 22 tsd. ind./m^2 on cpbcbo in August. Compared to sav, mean Gamasina abundances over the whole investigation period have highest abundances in the biochar amended plots cpbc and cpbcbo. Abundances on ctrl1 are lower than in sav soil.

The species numbers follow closely the trend of the abundances. The experimental degradation becomes already visible after four years of succession (ctrl1). The compost amendments and the biochar in particular are favourable for the development of Gamasina diversity.

3.2 Gamasina species

3.2.1 Community composition

Thirty-four Gamasina species belonging to fourteen genera and eight families were recorded over the sampling period (Tab. 3). The Gamasina community is dominated by small Rhodacaridae with eleven morphospecies and Ascidae with ten morphospecies. The family Hypoaspididae

Table 3. Gamasina dominances (%), 0-10 cm. sav = savanna, others as in Tab. 1.

morphospecles (work names)	code	sav	ctrl1	cpmy	cpbc	cpbcbo
Hypoaspis-Geolaelaps spec. 1	HYGEOA	**19.6**	**39.8**	**32.4**	**27.3**	**24.8**
Rhodacarus cf. *matatlanticae* Castilho & Moraes, 2010	RHOMAT	**33.1**	**28.0**	**27.7**	**18.4**	**17.2**
Afrodacarellus spec. 1	AFROVS	**12.2**	**1.1**	**4.3**	**6.3**	**5.6**
Hypoaspis cf. *sardoa* (Berlese, 1911)	HYSAR	0.7	5.4	0.8	0.6	0.6
Pachylaelaps cf. *latus* Berlese, 1905	PACLAT	4.7	1.1	0.4	0.6	
Afrogamasellus cf. *nyinabitabaensis* Loots, 1969	AFRNYI	8.1		**3.9**	**20.8**	**22.6**
Asca spec.1	ASSP1	6.8		0.4	0.8	1.6
Leioseius spec. 1	LEOSSP	1.4		0.4	1.3	1.4
Ololaelaps placentulus (Berlese, 1887)	OLOPLA	0.7		0.8	0.6	1.4
Macrocheles cf. *subbadius* Berlese, 1889	MACSP1	1.4		0.4	0.2	0.2
Asca spec. 2	ASSP2	2.0	1.1		0.2	1.2
Pseudoparasitus cf. *myrmophilus* (Michael, 1891)	PSMYR	0.7	3.2		0.2	0.2
Pachylaelaps spec.2	PACSP2	1.4	1.1		0.5	0.5
Afrodacarellus spec.2	AFROSH	3.4			1.0	0.9
Asca spec. 7	ASSP7	2.0			0.6	0.3
Asca spec. 4	ASSP4	0.7			0.3	0.6
Ameroseius spec. 1	AMESP1	1.4			0.3	
Multidentorhodacarus cf. *aegypticus* -a Abo-Shnaf, Castilho & Moraes, 2013	MUAEa		**10.8**	**9.8**	**7.8**	**6.4**
Asca spec. 3	ASSP3		2.2	1.2	1.6	2.3
Protogamasellus cf. *primitivus* Karg, 1962	PROPRI		1.1	1.2	0.8	0.8
Multidentorhodacarus cf. *aegypticus* -c Abo-Shnaf. Castilho & Moraes. 2013	MUAEc		3.2		0.2	0.2
Afrodacarellus cf. *lunguensis* (Ryke & Loots, 1966)	AFROLU		1.1	0.8		0.3
Multidentorhodacarus cf. *aegyptieus* -b Abo-Shnaf, Castilho & Moraes, 2013	MUAEb			0.4	0.2	0.3
Afrodacarellus spec.3	AFROVL			**5.9**	**2.7**	**2.2**
Gamasiphis spec. 1	GAMSP1			**3.1**	**2.4**	**2.5**
Afrodacarellus spec. 4	AFRLON			**3.5**	**1.1**	**1.7**
Asca spec.5	ASSP5			0.8	1.1	1.4
Amblyseius spec.1	AMBSP1			1.2	0.2	0.3
Asca spec. 8	ASSP8			0.4		0.5
Hypoaspis cf. *oophila* (Wasman, 1897)	HYOOP				1.0	1.2
Asca spec. 6	ASSP6				1.0	0.8
Protogamasellus cf. *minor* (Athias-Henriot, 1961)	PROMIN				0.2	0.2
Hypoaspis cf. *aculeifer* (Canestrini, 1883)	HYACU		1.1			
Pachylaelaps spec. 1	PACSP1			0.4		
Mean abundance 0–10cm. ind. in tsd./m^2		2.36	1.48	4.08	10.03	10.27
Species number		17	14	22	30	30
Simpson index		0.18	0.25	0.20	0.16	0.15
Shannon index		2.11	1.77	2.06	2.25	2.35
Evenness		0.75	0.67	0.67	0.66	0.69

Where: eudominants with % > 10.0; dominants with % of 5.1–10.0; sub-dominants with % of 2.1–5.0; recedents with % of 1.1–2.0, and sub-recedents with % < 1.1 (Gwiazdowicz 2011; Manu et al. 2017).

was represented by six morphospecies and the family of Pachylaelapidae by three morphospecies, while the family Ameroseiidae, Phytoseiidae, Gamasiphidae and Macrochelidae were represented by one morphospecies each (Tab. 3). Some individuals representing these families are shown in Fig. 4.

3.2.2 Gamasina species composition

The analysis of the community composition is based on means of abundances over the four sampling dates (0 – 10 cm). Eudominant species are *Hypoaspis-Geolaelaps* spec. 1 (HYGEOA), *Rhodacarus* cf. *matatlanticae* Castilho & Moraes, 2010 (RHOMAT), *Afrogamasellus* cf. *nyinabitabaensis* Loots, 1969 (AFRNYI); *Multidentorhodacarus* cf. *aegypticus* -a Abo-Shnaf, Castilho & Moraes, 2013 (MUAEa) and *Afrodacarellus* spec. 1 (AFROVS). These 5 species represent 76 % of all individuals. The rest of species occurred with less than 7 % dominance (Tab. 3).

Three species, HYGEOA, RHOMAT and AFROVS were found in all plots in high numbers. All 17 sav species were present on the ReviTec site, which is characterised by the respectable occurrence of MUAEa in all plots. AFRNYI was found particularly in the biochar amended compost plots.

Simpson index as well as evenness do not indicate high dominance concentrations. The relatively low Shannon index confirms the effect of experimental degradation on ctrl1. Apart from this, the plots are not clearly differentiated by the indices.

3.2.5 Similarity

The Sorenson and Renkonen indices reveal highest similarities of the Gamasina communities of the biochar treatments, followed by the similarities of the compost treatments. Dominant identities (Renkonen) are low between sav and the ReviTec plots, whereas species identities give a different result, with high similarities between sav and the biochar plots (Tab. 4).

3.2.6. Development of species abundances in time

The development of abundances (tsd ind./m^2) for the five eudominant species is shown in Figs 5 & 6. The species account for almost 80 % of the whole Gamasina community in the investigated soils. Four of the five species are rather small and slender Rhodacarids, which probably are able to survive in deeper soil during the dry season.

The Rhodacarid RHOMAT is present from the very beginning of the investigation, indicating its survival

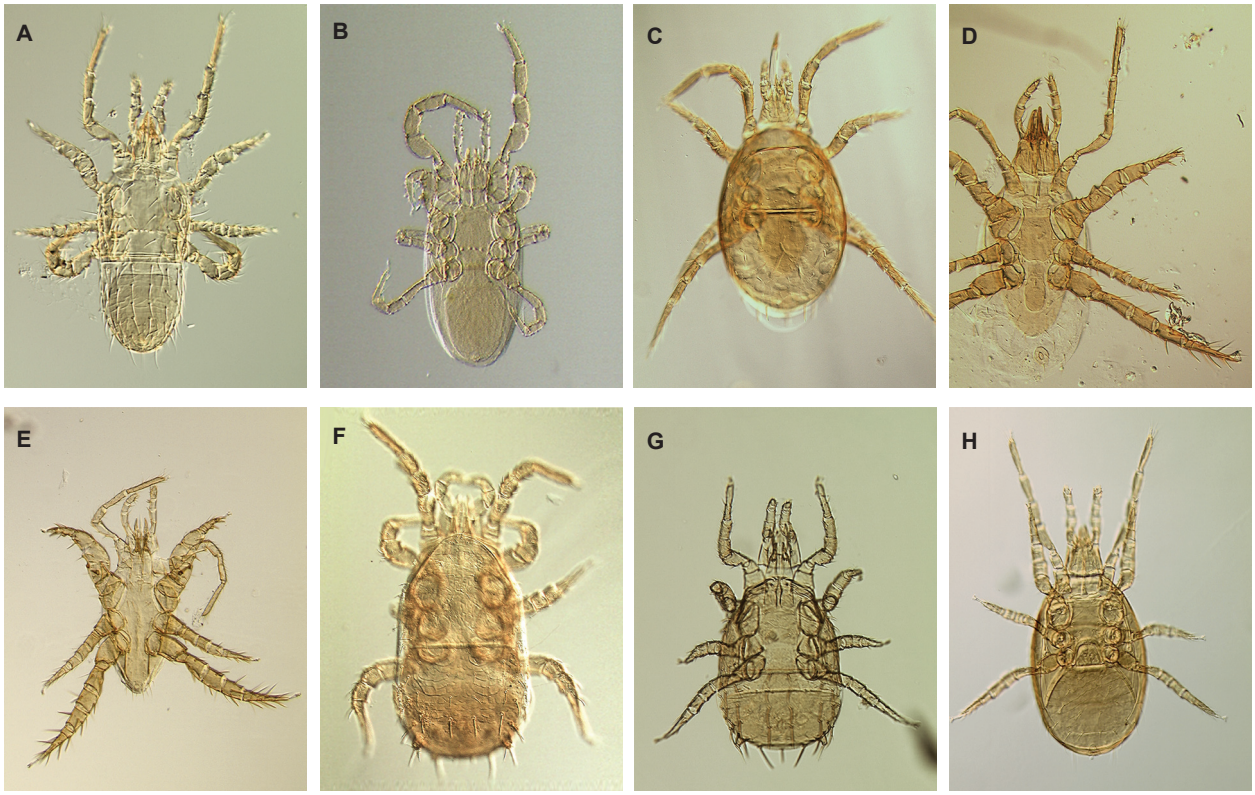

Figure 4. Gamasina from Ngaoundéré savanna and ReviTec site (idiosoma length IL in µ): (**A**) Rhodacaridae (AFROVL IL= 340), (**B**) Rhodacaridae (AFRNYI IL=320), (**C**) Hypoaspididae (HYOOP IL=490), (**D**) Hypoaspididae (HYGEOA IL= 570), (**E**) Hypoaspididae (HYGEOA, male IL= 430), (**F**) Ascidae (ASSP1, IL= 380), (**G**) Ascidae (ASSP8, IL= 270), (**H**) Gamasiphinae (GAMSP1, IL=350).

Table 4. Similarity indices of the different ReviTec treatments (cpmy, cpbc and cpbcbo) and controls (sav and ctrl1). sav = savanna area; ctrl1 = ReviTec control; cpmy = compost+mycorrhiza; cpbcbo = compost+biochar+bokashi.

	sav	**ctrl 1**	**cpmy**	**cpbc**	**cpbcbo**
sav	*	0.51	0.51	0.72	0.64
ctrl1	0.51	*	0.5	0.54	0.54
cpmy	0.54	**0.7**	*	**0.73**	**0.77**
cpbc	0.56	**0.6**	**0.7**	*	**0.93**
cpbcbo	0.53	0.52	**0.64**	**0.86**	*

Soerensen (SOE) shown above the diagonal and Renkonen (REN) shown below the diagonal.

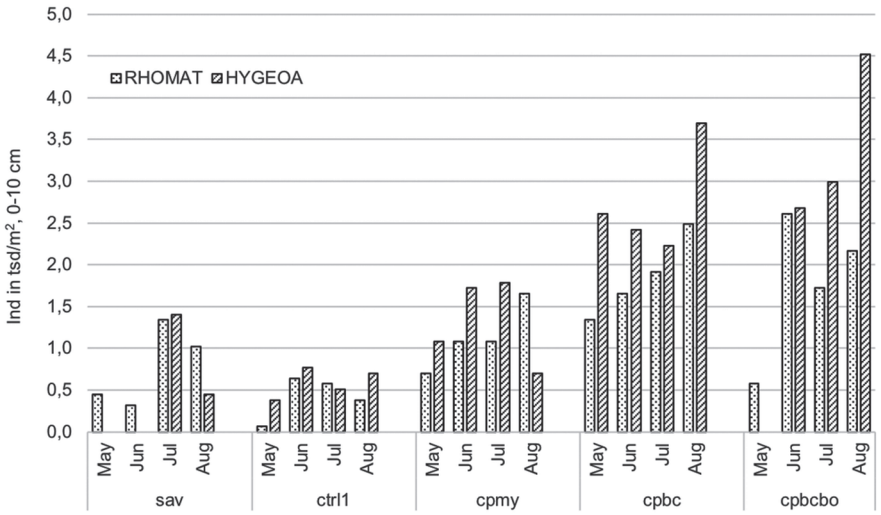

Figure 5. Mean abundances (ind. in tsd./m², 0–10 cm, n = 2) for the two most dominant Gamasina morphospecies (*Rhodacarus* cf. *matatlanticae*, *Hypoaspis*-*Geolaelaps* spec.1). sav = savanna, others as in Tab. 1.

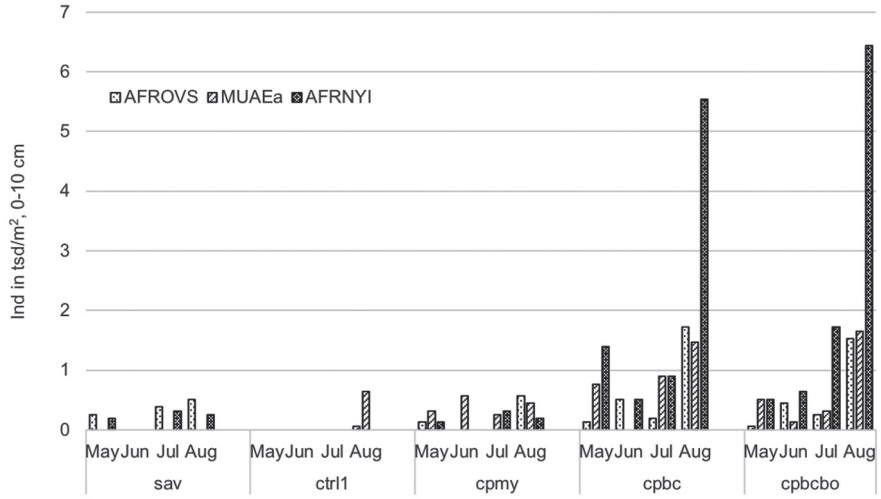

Figure 6. Mean abundances (ind. in tsd./m², 0–10 cm, n = 2) for the three eudominant Gamasina morphospecies (*Afrodacarellus* spec.1, *Multidentorhodacarus* cf. *aegypticus* -a, *Afrogamasellus* cf. *nyinabitabaensis*). sav = savanna, others as in Tab. 1.

in lower depth. *Hypoaspis* spec. HYGEOA appears in savanna late after two months of rainy season, whereas in the ReviTec site it is present from the very beginning (Fig. 5).

In contrast to the two species in Fig. 5, the Rhodacarids shown in Fig. 6 prefer the biochar amended treatments, particularly in August. The strongest population development is documented for *Afrogamasellus* cf. *nyinabitabaensis* (AFRNYI).

There was is a slight trend that more Gamasina or more eudominants live in 5 – 10 cm than in 0 – 5 cm, but there are no clear preferences.

4. Discussion

4.1 Method

One challenge in this investigation was to improve the methodology regarding soil sampling, extraction, counting, mounting the species individuals on the slides and their identification. As was confirmed in an extraction with the highly efficient Bremen Mac-Fadyen-type extractor, the efficiency of the Ngaoundéré apparatus is well comparable. We observed that some of individuals got lost during the mounting process. However, the identified group represented 75 % of those counted.

Sample size per plot is very limited. However, we decided to sample five plots for having a first idea on the species composition of ReviTec plots and savanna. The differentiation of depth into two 5 cm steps might be too fine to document vertical distribution.

4.2 Gamasina species composition

More than 50 % of the species documented belong to the Rhodacaridae (11 morphospecies) and Ascidae (mainly genus Asca, 10 morphospecies). They all are small in size. Being acquainted with the Gamasina fauna of temperate climates (Norther Germany), the absence of Parasitidae is striking.

The Gamasina community documented is indicative for the different plots. As control (ctrl1) mimics degradation, the absence of *Afrogamasellus* cf. *nyinabitabaensis* suggests that this species is sensitive to degradation.

The compost amendments seem to have facilitated the dominance of *Hypoaspis-Geolaelaps* spec. 1 (HYGEOA), *Rhodacarus* cf. *matatlanticae* (RHOMAT) and *Afrogamasellus* cf. *nyinabitabaensis* (AFRNYI), the latter particularly where biochar was added.

Hypoaspis-Geolaelaps spec. 1 (HYGEOA), *Rhodacarus* cf. *matatlanticae, 2010* (RHOMAT) and *Afrodacarellus* spec. 1 (AFROVS) were the omnipresent species as they were recorded in all the investigated plots. *Multidentorhodacarus* cf. *aegypticus* -a (MUAEa) is a species from the ReviTec site, which is characterized by being a successional site and by a high vegetation cover, even in ctrl1 by vegetative plant parts, providing an ameliorated microclimate.

Organic amendments with compost in the ReviTec site increased Gamasina abundance and species number considerably when compared to the control (ctrl1) and also to savanna. It is unlikely that Gamasina possibly imported with the substrate and its amendments survive the typical successional conditions. As was shown by a Bremen ReviTec site (Koehler & Warrelmann 2007), the initial (imported) compost fauna was replaced within half a year by typical successional species. Reactions of Gamasina to organic amendment were reported by Minor & Norton (2004) and Koehler (1997): ephemeral organic materials such as manure or dung initiate colonization by phoretic surface species, e.g. from the families Ascidae, Macrochelidae and Parasitidae.

We found five species in the savanna soil as well as in the compost amended soil, indicating that they prefer organic matter with its associated food source. The biochar amended treatments are colonized by seven exclusive species.

Gamasina clearly preferred the two treatments having biochar as additive: compost + biochar (cpbc) and compost + biochar + bokashi (cpbcbo). Biochar and bokashi could have induced better soil humidity and provided more food and diverse living space which in turn positively affected Gamasina community. Thies & Rillig (2009) reported that pore size variation observed across biochar particles from different feedstocks and pyrolysis conditions is such that the microflora could colonize and be protected from predators and grazers, being a reliable food source for the food web, topped by the predators. The higher porosity of biochar may also retain moisture. According to Bedano et al. (2007) more adequate living space and abundant prey could be another reason for the high species and individual number of Gamasina in these treatments. From a Bremen ReviTec experiment, Oben (2017) reported consistently higher species richness of Gamasina in biochar amended compost substrates. According to Ekebafe et al. (2015) substrate formula containing biochar bokashi supported the development of high soil biodiversity.

Temporal development reveals quite different patterns for the eudominant species, particularly for *Afrogamasellus* cf. *nyinabitabaensis* (AFRNYI), exhibiting a strong increase in August.

Calculations of similarities of the Gamasina communities of the investigated plots confirm the high similarities in the biochar amended treatments, as well as

in the compost treatments. The high species identity of the community of savanna with those of the two biochar plots is remarkable: this similarity might be due to the natural pyrogenic carbon in savanna soil from the regular grassland fires. Bedano & Ruf (2007) reported that the choice of similarity measure had a considerable effect on site discrimination. The dominance structure of the Gamasina community was not affected by the habitat differences, due to the prevailing eudominant species.

5. Conclusion

In this study species richness and individual number of Gamasina were widely applicable for the evaluation of the ReviTec treatments,

High abundance and Gamasina species diversity are documented in this investigation, supporting the use of these mites as bioindicators of rehabilitation processes in savanna-type ecosystems, specifically in Adamawa (Cameroon).

Our findings confirm that the ReviTec approach is reaching its objective of stimulating and accelerating the successional process, since the increase of abundance and diversity was obvious for the selected ReviTec treatments. The expectation that biodegradable bags filled with substrate accelerate the succession and promote the recolonization in the ReviTec approach for soil rehabilitation is confirmed. Compost amendments and particularly biochar amendment have a clear positive effect on the development of abundance and diversity of soil Gamasina.

Our study highlights the need for extensive taxonomic work for the largely undescribed Gamasina species. The findings confirm previous investigations with less efficient and standardized extractors from Ngaoundéré and Far North ReviTec sites (Salak, near Maroua; Danra 2014, Djoussi 2015) and for Ivory Coast and Kenya (Maribie et al. 2010, N'Dri & André 2011, N'Dri et al. 2016). The results may initiate a reconsideration of savanna ecology.

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