From the Efficiency of Berlese Tullgren Funnel to the Spatiotemporal Variation of Two Uropodina Genera, Afrotachytes Kontschán, 2006 and Trachyuropoda Berlese, 1888 (Acari, Mesostigmata) in Côte d’Ivoire

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Abstract

Due to their interaction with many other small Arthropods, Uropodina mites can be considered as good indicators of soil fauna of forest litter. In order to better understand their distribution and phenology according to forest type four sites from primary forest to plantations were sampled in 2008 in Côte d’Ivoire: 1- the Lamto savannah (6°13’ N, 5°02’ W), 2- Oumé primary forest (6°31’ N, 5°30’ W), 3- Oumé teak plantation (6°31’ N, 5°30’ W) all situated in the Sudanese domain and finally, 4- the Tai primary forest (5°45’ N, 7°07’ W) located in the Guinean domain. After a preliminary study devoted to the efficiency of Berlese Tullgren funnel, the spatiotemporal variation of two Uropodina genera - Afrotachytes Kontschán, 2006 and Trachyuropoda Berlese, 1888 - was assessed. We hypothesized that the abundance of Uropodina would be higher in primary forest and lower in savannah and monospecific plantation. Whatever the season, we expected that the abundance of Uropodina would decrease with soil depth and would vary along transect. On each site, 15 sampling points were allocated over a 14-m transect with 1m intervals between two consecutive points. For each sampling point, 9 cores (litter, 0-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-35 and 35-40 cm) were taken with a steel corer (Ø 3.5 cm). Thus, a total of 1,080 soil cores were collected over two sampling periods from January to March 2008 (dry season) and August to October 2008 (rainy season). Soil physico-chemical parameters were also characterized. Mites were extracted using the Berlese-Tullgren funnels for one week after testing the extraction duration in a preliminary study. The bulbs lighting as soon as the soil cores were placed in Berlese Tullgren gave better results regarding the abundance of extracted mites. The results showed that the abundance of Afrotachytes sp and Trachyuropoda sp was higher in rainy season, and varied significantly through the sites, whatever the season. The highest abundances of Afrotachytes sp were observed in Oumé primary forest whereas those of Trachyuropoda sp were recorded in Oumé primary forest, and in Lamto savannah, whatever the season. Apart from the distribution of Trachyuropoda sp in dry season, the abundance of Afrotachytes sp and Trachyuropoda sp was greater in the topsoil (litter and 0-5 cm) and decreased with soil depth. The abundances of Afrotachytes sp and Trachyuropoda sp did not follow a normal distribution along the transects. The season-soil depth interaction affected significantly the abundance of Trachyuropoda sp whereas the bulk density (dry season and rainy season), soil depth (dry season), carbon / nitrogen ratio (dry season) impacted significantly the abundance of Afrotachytes sp. This first study highlighted the spatiotemporal variation of Uropodina in Côte d’Ivoire. However, taking into account of the different dispersal agents in future studies would help us to better understand their abundance and distribution along different habitats, as well as their role as biological control agents.

Keywords: Uropodina, Abundance, Distribution, Abiotic Factors, Primary Forest, Savannah, Teak Plantation

Academic Discipline And Sub-Disciplines: Soil Ecology, Ecosystem, Biodiversity, Uropodina

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Introduction

The Uropodina mites occur in forest soil and leaf litter (Kazemi and Abolghasemi, 2016). Forest soil and litter covering up the mineral soil are known to be an important source of biological diversity, and harbor a diversity of animals of varying sizes (Duyar and Makineci, 2016). The Uropodina mites (Mesostigmata) play a crucial role in soil food webs and are important as biological control agents (Wissuwa et al., 2012). As a consequence of their position in the trophic structure of the ecosystem, the Mesostigmata are linked to the vegetation community type and the overall productivity of ecosystems only indirectly (Madej et al., 2011; Kaczmarek et al., 2012). Forest ecosystems are characterized by a high diversity of microhabitats, which can be used as habitats by the mites (Madej et al., 2011). The free living Mesostigmata inhabit nests, soil, soil litter, decaying wood, compost, and other detrital substrates (Marchenko and Bogomolova, 2015). They are often phoretic of bark beetles or other animals which act as agents of their dispersal in many types of forest ecosystems worldwide (Gwiazdowicz et al., 2011; Čejka and Holuša, 2014; Marchenko and Bogomolova, 2015; Zach et al., 2016). The Mesostigmata play an important role in ecosystem interactions, such as the regulation of populations of other small soil invertebrates, and indirectly participate in the decomposition of the organic substrates and nitrogen cycle (Marchenko and Bogomolova, 2015). They can thus be considered as bioindicators and their abundance and diversity may reflect past disturbances of ecosystems. These small Arthropods communities also reflect the state of ecosystems functioning (Duyar and Makineci, 2016). The mite communities of forest ecosystems are characterized by a specific structural and functional composition, depending on forest type, its structure, and complexity (Madej et al., 2011). In fact, seasonal changes in the plant community can directly or indirectly influence the soil invertebrate communities (Wu et al., 2014). Mites abundance and distribution between habitats depended on vegetation cover of the vascular plants, while moss cover and soil pH had no significant influence (Salmane and Spunģis, 2015). Abundance of Mesostigmatid mites is much higher on open site than on the closed one (Pérez-Velázquez et al., 2011).

The Uropodina is one of the most diverse groups of the Mesostigmatid mites, superorder Parasitiformes (Kontschán et al., 2013). They are small or medium sized (300-1200 μm), and mostly strongly sclerotised (Kontschán et al., 2013). The classification of Uropodina, particularly at higher level is not yet stable (Kazemi and Abolghasemi, 2016). Indeed, the group was divided into four to five superfamilies depending on authors.

The Uropodina genus *Trachyuropoda* Berlese, 1888 is composed of several species (Kontschán, 2007), mainly, *Trachyuropoda festiva* Berlese, 1888, *Trachyuropoda bostocki* Michael, 1894 from the Netherlands, United Kingdom, Luxemburg, Austria, and Hungary; *Trachyuropoda myrmecophila* Wiśniewski and Hirschmann, 1992 from Poland, Slovakia, and Hungary; *Trachyuropoda hirschnanni* Pecina, 1980 from Europe; *Trachyuropoda troguloides* Canestrini and Fanzago, 1877 from West and Central Europe; and *Trachyuropoda wasmanniana* Berlese, 1903 from Europe. During the investigation of the unsorted soil samples of the Hungarian Natural History Museum, five new Trachyuropoda species were found from different regions of the Neotropics: from Costa Rica *Trachyuropoda costaricana* n. sp.; from Ecuador *Trachyuropoda ecuatoriana* n. sp. and *Trachyuropoda chimboensis* n. sp.; and from Saint Lucia *Trachyuropoda saintluciana* n. sp. and *Trachyuropoda pesici* n. sp. (Kontschán, 2011). The species *Trachyuropoda arcuata* collected in the Galapagos Islands and both *Trachyuropoda bali* sp. nov. and *Trachyuropoda extremica* sp. nov. recorded in Colombia were described by Kontschán and Starý (2013).

The Uropodina genus *Afrotachytes* was established by Kontschán (2006a) on the basis of a newly described species, *Afrotachytes seticaudatus* Kontschán, 2006 collected in Angola. In the same year, Kontschán (2006b) described a further new species of this genus, *Afrotachytes longicaudatus* Kontschán, 2006 from Tanzania. Since 2009, the endemic status of *Afrotachytes* in Africa is reconsidered because the description of two new species, *Afrotachytes berziki* sp. nov. and *Afrotachytes mirabilis* sp. nov. was realized, respectively in South American, Ecuador and West African, Cameroon (Kontschán, 2009a).

In Côte d’Ivoire, except for the description of the Uropodina *Rotundabaloghia browni* spec. nov (Kontschán, 2009b), no Uropodina was described at the species level. However, this group abounds in the different local collections. Thus, before the description at the species level, the study aims to assess the spatiotemporal variation of two Uropodina genera, *Afrotachytes* Kontschán, 2006 and *Trachyuropoda* Berlese, 1888. Specifically, the study will focus on three points (i) test the efficiency of Berlese Tullgren funnel, (ii) evaluate the
abundance of two Uropodina genera following the season, soil depth and transect, and (iii) establish the relationship between the two Uropodina genera and abiotic factors. We hypothesized that the abundance of Uropodina would be higher in primary forest and lower in savannah and monospecific plantation. Whatever the season, we expected that the abundance of Uropodina would decrease with soil depth and would vary along the transects.

Materials and Methods

Site description
This study was conducted in Côte d’Ivoire, where four sites, all located in arboreal areas, were sampled in 2008. The Lamto savannah (6°13’ N, 5°02’ W), Oumé primary forest (6°31’ N, 5°30’ W), and Oumé teak plantation (6°31’ N, 5°30’ W) are situated in the Sudanese domain whereas Tai primary forest (5°45’ N, 7°07’ W) is located in the Guinean domain. The climate of Lamto savannah (LTO) is intertropical humid (Le Roux, 2006). The annual rainfall is 1,211 mm and the average monthly temperature is 27°C. The vegetation of Lamto is a forest-savannah mosaic (Menaut and César, 1979) with five facies: (i) the gallery forests, (ii) herbaceous savannah dominated by Loudetia simplex, (iii) shrub savannahs dominated by Hyparrhenia diplanda and Andropogon sp., (iv) wooded savannah, and (v) shrub savannahs protected from fire. All facies were dominated by tall palm trees (Borassus aethiopum), pretty regularly distributed (Barot, 1999). The sampling site (shrub savannahs protected from fire) is now completely covered by the invasive Asteraceae Chromolaena odorata. Soils were ferralsols (FAO classification) with a very low organic matter and nitrogen content. The climate of Oumé primary forest (OPF) is subequatorial (Monnier, 1983). The annual rainfall is around 1,275 mm and the average monthly temperature is 26°C. The forest is a semi-deciduous type (Monnier, 1983). The vegetation is very dense and even luxuriant. The undergrowth is also dense with lianas and dead wood. Some tree species, such as Griffonia simplicifolia (Caesalpiniaceae), Marantochloa leucantha (Marantaceae), Anthiaris toxicaria (Moraceae) are observed in OPF. Man-made activities are very weak and limited to some tracks. Soils were ferralsols (Assié et al., 2008). The Oumé teak plantation (OTK) is also located in Oumé, near the previous forest and is composed of even-aged teaks (Tectona grandis) planted in 1994. The climate of Tai primary forest (TPF) is subequatorial type, humid all the year round (Kouadio, 2006). The annual rainfall during the field works was 1,853 mm and the average monthly temperature was about 25°C. The Tai primary forest is the largest remaining forest in West Africa and the last largest island of the original Upper Guinean forest that once reached from Ghana to Guinea-Bissau. The vegetation was dominated by Eremospatha macrocarpa and Diospyros mannii. Highly desaturated ferrallitic soils and hydromorphic soils cover almost all areas (Avenard et al., 1971; Moreau, 1983).

Determination of the extraction conditions
In order to determine the bulbs lighting period of the Berlese Tullgren and the number of days required for the extraction of soil mites, a preliminary study was conducted in 2007 with soil cores from Oumé primary forest (OPF). In practice 18 soil cores were taken at the extreme layers (0-5 cm and 35-40 cm) during both dry and rainy season. The soil cores were replicated three times and were taken along a 17-m transect with 1m intervals between two consecutive points. A total of 108 soil cores were collected during each season and brought to the laboratory in plastic packets for mite extraction. Both, extractions with and without light, create different conditions within the soil cores (Barberena-Arias et al., 2012). Following the soil cores heating and desiccation, a temperature and humidity gradient is created between the upper and lower surfaces of the soil cores (Barberena-Arias et al., 2012). Bulbs lighting 24 hours or 48 hours after the soil cores were placed in Berlese Tullgren favors taking into account the environment of origin (André et al., 2002). As this gradient moves downwards, mites are forced down into the collecting liquid (Coleman et al., 2004). Thus, three treatments are considered for the extraction of soil mites:

Treatment 1: bulbs lighting 24 hours after the soil cores were placed in Berlese Tullgren.
Treatment 2: bulbs lighting 48 hours after the soil cores were placed in Berlese Tullgren.
Treatment 3: bulbs lighting as soon as the soil cores were placed in Berlese Tullgren.

Every day (24 hours), the number of mites extracted is determined after the withdrawal and sorting of the collection tubes. For the soil water content estimation, the soil cores are weighed before and after their passage to Berlese. The temperature in the Berlese was 39°C. The experiment lasted 10 days.

Consequence of site localization and vegetation cover on Uropodina

Soil sampling and mite identification
After the preliminary sampling, the design of mean study consisted of four sites: the Lamto savannah (LTO), Oumé primary forest (OPF), Oumé teak plantation (OTK), and the Tai primary forest (TPF). On each site, 15 sampling points were allocated over a 14-m transect with 1m intervals between two consecutive points. For each profile or sampling point, 9 cores (litter, 0-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-35 and 35-40 cm) were taken with a steel corer (Ø 3.5 cm). Thus, a total of 1,080 soil cores were collected over two sampling periods from January to March 2008 (dry season) and August to October 2008 (rainy season). Mites were extracted using the Berlese-Tullgren funnels for one week after testing the extraction duration in a preliminary study. Soil mites were sorted in Petri dishes using a dissecting microscope and mounted in lactic acid medium under a light microscope with phase contrast. A particular interest was devoted to two Uropodina genera, Afrotrachytes Kontschán, 2006 and Trachyuropoda Berlese, 1888 (Fig. 1) due to their abundance and their key role in the ecosystem functioning. The identification was made at genus levels by using keys and illustrations provided in Kontschán (2006a,b), Kontschán (2007), Kontschán (2009a), Kontschán (2011), Kontschán and Starý (2013).

Figure 1: Uropodina genre: Trachyuropoda Berlese, 1888 (A-dorsal aspect, C-ventral aspect, E-anterodorsal portion of propodosoma, G-detail of tritosternum); Afrotrachytes Kontschán, 2006 (B-dorsal aspect, D-ventral aspect, F-anterodorsal portion of propodosoma, H-epignyal shield)
Soil physico-chemical characteristics

Soil physico-chemical parameters were estimated from seven cores adjacent to the sampling point. Five cores were mixed together to measure the pH and other chemical analyses as recommended by Anderson and Ingram (1993). One core was reserved for the water content and the last one for the bulk density. At each sampling point, 8 layers (0-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-35 and 35-40 cm) were considered for the measurements of water content, bulk density and pH, whereas organic carbon, organic matter and total nitrogen were determined through the extreme depths (0-5 cm and 35-40 cm). The soil water content and bulk density of 960 cores sampled in both dry and rainy season were estimated after 48 h drying at 105°C (Baize, 1988; Duchaufour, 1991). The pH-H2O (Baize, 1988; Duchaufour, 1991) was estimated with a pH meter (HANNA) after calibration. On each site, five sampling points were taken into account for organic carbon and total nitrogen measurements, whether a total of 80 composites soil cores (4 sites x 5 sampling points x 2 layers x 2 seasons). To measure organic carbon, the carbon was oxidized to CO2 by heating the soil to at least 900°C in a flow of oxygen-containing gas according to ISO Standard 10 694. Total Nitrogen was determined by dry combustion, according to ISO Standard 13 878. Soil organic matter (SOM) was estimated through the formula, organic carbon x 1.7 as made by Noti et al., (2003).

Statistical analysis

Soil physico-chemical characteristics were compared across the sites and following soil depth by using a one-way ANOVA test. The abundance of soil mites was expressed as the number of individuals per square meter, but the abundance of Uropodina genus was expressed as the number of individuals from soil cores per site. As data did not follow a normal distribution, the impact of sites on the abundance of Afrotrachytes sp and Trachyuropoda sp was estimated by using a Kruskal-Wallis test. Within each site, the abundance of Afrotrachytes sp and Trachyuropoda sp was compared by using the Mann-Whitney test. The abundance of soil mites extracted during preliminary study was compared using a Kruskal-Wallis test whereas the data of water content was evaluated by a one-way ANOVA test. Rank Spearman correlation was performed to study the relationship between the abundance of Afrotrachytes sp and Trachyuropoda sp and soil physico-chemical parameters. These tests were conducted on both the dry and rainy season and along transect and soil depth. The factorial Anova with general linear mixed (GLM) model was used to explore the effects of season-sites-soil depth interaction on the abundance of Afrotrachytes sp and Trachyuropoda sp and soil physico-chemical parameters. All tests were conducted using the software Statistica 7.1 (StatSoft, Tulsa, USA). As explained by André et al. (2002), we estimated the soil depth in which 50 or 90% of Uropodina were living (respectively the Soil Depth50 and Soil Depth90).

Results

Extraction conditions

Water content in soil cores

Whatever the season and the layers, soil water content did not vary significantly across the three treatments (Table 1). The water content decreased with the soil depth. Whatever the season, soil cores from the extreme layers 0-5 cm and 35-40 cm, and submitted respectively to the treatment 3 and 1 revealed the lowest values of water content.

Table 1: Water content (%) measured in soil cores during the experiment. Treatment 1: bulbs lighting 24 hours after the soil cores were placed in Berlese, Treatment 2: bulbs lighting 48 hours after the soil cores were placed in Berlese, Treatment 3: bulbs lighting as soon as the soil cores were placed in Berlese. N = 54, one-way ANOVA test, p < 0.05.
Abundance of mites extracted

Whatever the season and the layers, the dynamic of soil mites extracted did not vary significantly (Kruskal-Wallis test, rainy season: 0-5 cm, \( P = 0.659 \), 35-40 cm, \( P = 0.621 \); dry season: 0-5 cm, \( P = 0.874 \), 35-40 cm, \( P = 0.548 \)) across the three treatments (Fig. 2). The amounts of mites extracted were higher during the first day of the experiment and decreased over the following days. Whatever the season and the layers, the treatment 3 (rainy season, 0-5 cm: 166 individuals, 35-40 cm: 50 individuals; dry season, 0-5 cm: 98 individuals, 35-40 cm: 24 individuals extracted) favored a higher extraction of the soil mites compared to treatment 1 (rainy season, 0-5 cm: 56 individuals, 35-40 cm: 21 individuals; dry season, 0-5 cm: 68 individuals, 35-40 cm: 16 individuals extracted) and 2 (rainy season, 0-5 cm: 110 individuals, 35-40 cm: 29 individuals; dry season, 0-5 cm: 71 individuals, 35-40 cm: 11 individuals extracted). After 5-6 days of experiment no individual was observed in the collection tubes.
**Figure 2:** Dynamics of soil mites extracted from Berlese Tullgren. T1-treatment 1: bulbs lighting 24 hours after the soil cores were placed in Berlese, T2-treatment 2: bulbs lighting 48 hours after the soil cores were placed in Berlese, T3-treatment 3: bulbs lighting as soon as the soil cores were placed in Berlese. A-B: rainy season, C-D: dry season, A-C: 0-5 cm, B-D: 35-40 cm. N = 30, Kruskal-Wallis test, \( p < 0.05 \).

**Consequence of site localization and vegetation cover on Uropodina**

**Total abundance**

The density of soil mites varied across the different study sites. In rainy season, the densities represented 22046 ind.m\(^{-2}\), 34386 ind.m\(^{-2}\), 9082 ind.m\(^{-2}\), 7141 ind.m\(^{-2}\), respectively in Lamto savannah (LTO), Oumé primary forest (OPF), Oumé teak plantation (OTK), and the Taï primary forest (TPF). The densities of soil mites recorded in the dry season were lower than those of the rainy season, and were about 8527 ind.m\(^{-2}\), 20451 ind.m\(^{-2}\), 5754 ind.m\(^{-2}\), 5269 ind.m\(^{-2}\), respectively in Lamto savannah (LTO), Oumé primary forest (OPF), Oumé teak plantation (OTK), and the Taï primary forest (TPF).

**Abundance of Afrotrachytes sp and Trachyuropoda sp**

The abundance of *Afrotrachytes* sp (Kruskal-Wallis test, rainy season: \( p = 0.0001 \); dry season: \( p = 0.0001 \)) and *Trachyuropoda* sp (Kruskal-Wallis test, rainy season: \( p = 0.0001 \); dry season: \( p = 0.0001 \)) changed significantly through the sites (Fig. 3). Except for the Tai primary forest (Mann-Whitney test, rainy season: \( p = 0.834 \); dry season: \( p = 0.916 \)), Lamto savannah (Mann-Whitney test, rainy season: \( p = 0.989 \); dry season: \( p = 0.995 \)), and Oumé teak plantation (Mann-Whitney test, rainy season: \( p = 0.525 \); dry season: \( p = 0.139 \)), the abundances of *Afrotrachytes* sp were significantly different compared to those of *Trachyuropoda* sp in Oumé primary forest (Mann-Whitney test, rainy season: \( p = 0.001 \); dry season: \( p = 0.0002 \)). Whatever the season, the highest abundances of *Afrotrachytes* sp were observed in Oumé primary forest (rainy season: 148 ± 1.10 individuals; dry season: 76 ± 0.12 individuals) whereas those of *Trachyuropoda* sp were recorded in Oumé primary forest (rainy season: 31 ± 0.24 individuals; dry season: 16 ± 0.06 individuals), and in Lamto savannah (rainy season: 31 ± 0.24 individuals).

**Vertical distribution**

If soil depths are considered, the abundance of *Afrotrachytes* sp (Kruskal-Wallis test, rainy season: \( p = 0.033 \); dry season: \( p = 0.0001 \)) and *Trachyuropoda* sp (Kruskal-Wallis test, dry season: \( p = 0.0001 \)) varied significantly across the sites, except for the abundance of *Trachyuropoda* sp (Kruskal-Wallis test, \( p = 0.155 \)) in rainy season. Apart from the distribution of *Trachyuropoda* sp in dry season, the abundance of *Afrotrachytes* sp and *Trachyuropoda* sp decreased with soil depth (Fig. 4). The highest abundances of both Uropodina were recorded in the topsoil (litter and 0-5 cm). In the rainy season, the Soil Depth\(_{50}\) and Soil Depth\(_{90}\) represented respectively for the *Afrotrachytes* sp (OPF: 8.41 vs.18.41 cm, TPF: 1.75 vs. 6 cm, LTO: 8.36 vs. 13.36 cm, and OTK: 1.915 vs. 16.33 cm) and *Trachyuropoda* sp (OPF: 8.41 vs. 13.41 cm, TPF: 1.75 vs. 6 cm, LTO: 8.36 vs. 18.36 cm, and OTK: 6.33 vs. 6.33 cm). In the dry season, they represented respectively for the *Afrotrachytes* sp (OPF: 11.8 vs. 41.8 cm, TPF: 3.165 vs. 38.83 cm, LTO: 3.26 vs. 14.02 cm, and OTK: 10.23 vs. 30.23 cm) and *Trachyuropoda* sp (OPF: 21.8 vs. 36.8 cm, TPF: 8.83 vs. 8.83 cm, LTO: 9.02 vs. 9.02 cm, and OTK: 10.23 vs. 10.23 cm). The abundance of *Trachyuropoda* sp varied significantly with the season-soil depth interaction (Table 2).
Figure 3: Abundance of *Afrotrachytes* sp and *Trachyuropoda* sp across the four sites. OPF-Oumé primary forest, TPF-Taï primary forest, LTO-Lamto savannah, OTK-Oumé teak plantation. A: rainy season, B: dry season. Entire biological profile (0-40 cm, including litter thickness) was considered. N = 540, Kruskal-Wallis test, $p < 0.05$. 
Figure 4: Abundance (number of individuals) of *Afrotrachytes* sp and *Trachyuropoda* sp following the soil depth. OPF-Oumé primary forest, TPF-Taï primary forest, LTO-Lamto savannah, OTK-Oumé teak plantation. A-C: rainy season, B-D: dry season. N = 36, Kruskal-Wallis test, *p* < 0.05.

Table 2: Anova table of general linear mixed (GLM) effect models on the abundance of *Afrotrachytes* sp and *Trachyuropoda* sp across the season, sites, and soil depth. F-values and the corresponding *p*-values are displayed.

|                | df | Afrotrachytes sp | | Trachyuropoda sp | |                   |  |
|----------------|----|------------------|---|------------------|---|------------------|---|
|                |    | F                | *p*|                  |   | F                | *p*|
| Season         | 1  | 1.33             | 0.2564 | 4.26             | 0.0470 * |                  |   |
| Sites          | 3  | 3.73             | 0.0208 * | 3.85             | 0.0183 * |                  |   |
| Depth          | 3  | 6.94             | 0.0009 *** | 9.16             | 0.0001 *** |                  |   |
| Season × Sites | 3  | 1.29             | 0.2914 | 1.34             | 0.2773 |                  |   |
| Season × Depth | 3  | 2.17             | 0.1106 | 5.83             | 0.0026 ** |                  |   |
| Sites × Depth  | 9  | 1.42             | 0.22   | 1.35             | 0.2488 |                  |   |
| Season × Sites × Depth | 9 | 1.25             | 0.2964 | 1.38             | 0.2356 |                  |   |

*P* < 0.05, **P* < 0.01, ***P* < 0.001
Repartition along the transect

The abundance of *Afrotrachytes* sp (Kruskal-Wallis test, rainy season: $P = 0.00001$; dry season: $P = 0.0003$) and *Trachyuropoda* sp (Kruskal-Wallis test, rainy season: $P = 0.0005$; dry season: $P = 0.001$) varied significantly through the sites, if we considered the sampling transect. Except for Taï primary forest (Mann-Whitney test, rainy season: $P = 0.933$; dry season: $P = 0.755$), Lamto savannah (Mann-Whitney test, rainy season: $P = 0.648$; dry season: $P = 0.868$) and Oumé teak plantation (Mann-Whitney test, rainy season: $P = 0.164$), the abundances of *Afrotrachytes* sp were significantly different compared to those of *Trachyuropoda* sp respectively in Oumé primary forest (Mann-Whitney test, rainy season: $P = 0.0001$; dry season: $P = 0.0042$), and in Oumé teak plantation (Mann-Whitney test, dry season: $P = 0.021$). The abundances of *Afrotrachytes* sp and *Trachyuropoda* sp did not follow a normal distribution along the transect (Fig. 5). However, some abundance maximum could be observed, mainly in both Oumé primary forest (*Afrotrachytes* sp: 17 individuals; *Trachyuropoda* sp: 3 individuals) and Oumé teak plantation (*Afrotrachytes* sp: 12 individuals) during the dry season, and in Lamto savannah (*Afrotrachytes* sp: 53 individuals; *Trachyuropoda* sp: 10 individuals) during the rainy season.

Figure 5: Abundance (number of individuals) of *Afrotrachytes* sp and *Trachyuropoda* sp following the sampling transect. OPF-Oumé primary forest, TPF-Taï primary forest, LTO-Lamto savannah, OTK-Oumé teak plantation. A-C: rainy season, B-D: dry season. N = 60, Kruskal-Wallis test, $p < 0.05$.

**Soil physico-chemical characteristics**

Whatever the site and the season, the bulk density increased significantly ($N = 120$, $P < 0.05$) from the 0-5 to 35-40 cm layers. Contrary to bulk density, the water content decreased significantly with soil depth in the two seasons ($N = 120$, $P < 0.05$), except in Lamto savannah (LTO) in the dry season ($P = 0.928$). Taï primary forest (TPF) soils were acidic and the pH values differed significantly from those (alkaline pH) observed in other sites ($N = 120$, $P < 0.05$). The deeper the layer, the greeter’s the pH in Taï primary forest (TPF). If we consider the entire profile (0-40 cm), the soil pH-H$_2$O (dry season and rainy season) and the water content (dry season) varied significantly across the study sites (Table 3). In rainy season, the highest values of bulk density (1.12 ±
0.03 g.cm⁻³), water content (18.21 ± 0.78%) and pH-H₂O (7.49 ± 0.04) were recorded, respectively, in Taï primary forest (TPF), Oumé teak plantation (OTK), and Oumé primary forest (OPF). In dry season, the maximum values of bulk density (1.22 ± 0.05 g.cm⁻³), water content (19.48 ± 1.40%) and pH-H₂O (7.32 ± 0.03) were observed, respectively, in Oumé primary forest (OPF), Taï primary forest (TPF), and Oumé teak plantation (OTK). Whatever the season and the extreme layers, soil organic carbon, total nitrogen, C/N ratio and the soil organic matter differed significantly across the four sites. Except for C/N ratio, the other chemical parameters were higher in the topsoil (0-5 cm) and lower in the bottom (35-40 cm). The greater amounts of organic carbon and total nitrogen from 0-5 cm layer were observed in Oumé primary forest (OPF) whereas those from 35-40 cm layer were recorded in Taï primary forest (TPF). The environmental factors such as season, sites, and soil depth impact the soil physico-chemical parameters as presented in Table 4.

Table 3: Mean and SE values of soil physico-chemical characteristics measured along the four sites. LTO-Lamto savannah, OPF-Oumé primary forest, OTK-Oumé teak plantation, TPF-Taï primary forest. SOC-Soil organic carbon, TN-Total nitrogen, C/N-Carbon nitrogen ratio, SOM-Soil organic matter, BD-Bulk density, WC-Water content, pH-H₂O-Potential of Hydrogen-Water. Extreme layers 0-5 cm and 35-40 cm N = 20, Entire profile 0-40 cm N = 60, one-way ANOVA test, p < 0.05. More details are given in N’Dri and André (2011).

|                    | LTO       | OPF       | OTK       | TPF       | p value   |
|--------------------|-----------|-----------|-----------|-----------|-----------|
| **Rainy season**   |           |           |           |           |           |
| 0-5 cm             |           |           |           |           |           |
| SOC (g.kg⁻¹)       | 11.80 ± 1.59 | 36.80 ± 6.30 | 16.60 ± 0.87 | 17.80 ± 1.39 | 0.0004*** |
| TN (%)             | 0.11 ± 0.02 | 0.37 ± 0.06 | 0.18 ± 0.01 | 0.14 ± 0.01 | 0.0001*** |
| C/N                | 10.99 ± 0.11 | 9.92 ± 0.33 | 9.50 ± 0.28 | 12.49 ± 0.40 | 0.0001*** |
| SOM (g.kg⁻¹)       | 20.06 ± 2.71 | 62.56 ± 10.70 | 28.22 ± 1.48 | 30.26 ± 2.37 | 0.0004*** |
| **35-40 cm**       |           |           |           |           |           |
| SOC (g.kg⁻¹)       | 5.30 ± 0.00 | 5.30 ± 0.00 | 5.44 ± 0.14 | 6.00 ± 0.00 | 0.0001*** |
| TN (%)             | 0.03 ± 0.00 | 0.04 ± 0.00 | 0.04 ± 0.01 | 0.05 ± 0.00 | 0.0010*** |
| C/N                | 17.67 ± 0.00 | 13.60 ± 1.14 | 12.95 ± 1.35 | 12.00 ± 0.00 | 0.0010*** |
| SOM (g.kg⁻¹)       | 9.01 ± 0.00 | 9.01 ± 0.00 | 9.25 ± 0.24 | 10.20 ± 0.00 | 0.0010*** |
| **Entire profile 0-40 cm** |           |           |           |           |           |
| BD (g.cm⁻³)        | 0.90 ± 0.03 | 1.04 ± 0.04 | 1.05 ± 0.04 | 1.12 ± 0.03 | 0.2918    |
| WC (%)             | 14.63 ± 0.47 | 15.29 ± 0.59 | 18.21 ± 0.78 | 14.81 ± 0.83 | 0.4517    |
| pH-H₂O             | 6.48 ± 0.04 | 7.49 ± 0.04 | 7.34 ± 0.06 | 5.88 ± 0.03 | 0.0010*** |
| **Dry season**     |           |           |           |           |           |
| 0-5 cm             |           |           |           |           |           |
| SOC (g.kg⁻¹)       | 9.60 ± 0.68 | 26.60 ± 2.69 | 16.80 ± 1.39 | 23.60 ± 2.77 | 0.0001*** |
| TN (%)             | 0.09 ± 0.01 | 0.27 ± 0.03 | 0.18 ± 0.02 | 0.19 ± 0.02 | 0.0001*** |
| C/N                | 10.64 ± 0.26 | 9.69 ± 0.23 | 9.35 ± 0.05 | 12.49 ± 0.51 | 0.0001*** |
| SOM (g.kg⁻¹)       | 16.32 ± 1.15 | 45.22 ± 4.58 | 28.56 ± 2.37 | 40.12 ± 4.71 | 0.0001*** |
| **35-40 cm**       |           |           |           |           |           |
| SOC (g.kg⁻¹)       | 5.30 ± 0.00 | 6.18 ± 0.72 | 5.44 ± 0.14 | 7.20 ± 0.97 | 0.1460    |
| TN (%)             | 0.03 ± 0.00 | 0.06 ± 0.01 | 0.05 ± 0.01 | 0.07 ± 0.01 | 0.0580    |
| C/N                | 15.90 ± 1.08 | 10.93 ± 1.00 | 12.31 ± 0.94 | 10.85 ± 0.68 | 0.0040**  |

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SOM (g.kg\(^{-1}\))  & 9.01 ± 0.00 & 10.51 ± 1.22 & 9.25 ± 0.24 & 12.24 ± 1.65 & 0.1460 \\

\hline
Entire profile 0-40 cm & & & & & \\
BD (g.cm\(^{-3}\)) & 1.04 ± 0.05 & 1.22 ± 0.05 & 1.03 ± 0.05 & 1.06 ± 0.04 & 0.3472 \\
WC (%) & 8.08 ± 1.36 & 7.03 ± 0.75 & 12.51 ± 0.99 & 19.48 ± 1.40 & 0.0001*** \\
pH-H\(_2\)O & 6.52 ± 0.06 & 7.20 ± 0.05 & 7.32 ± 0.03 & 6.01 ± 0.04 & 0.0001*** \\

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"P < 0.01, ***P < 0.001
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Table 4: Anova table of general linear mixed (GLM) effect models on soil physico-chemical characteristics across the season, sites, and soil depth. F-values and the corresponding p-values are displayed. SOC-Soil organic carbon, TN-Total nitrogen, SOM-Soil organic matter, BD-Bulk density, WC-Water content, pH-H\(_2\)O-Potential of Hydrogen-Water.

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\*P < 0.05, **P < 0.01, ***P < 0.001
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Relationship between the abundance of \textit{Afrotrachytes} sp and \textit{Trachyuropoda} sp and soil characteristics.

At the landscape scale, the abundance of \textit{Afrotrachytes} sp was correlated significantly to the bulk density (rainy season: \( R = -0.70, P = 0.0005 \); dry season: \( R = -0.55, P = 0.0102 \)), soil depth (dry season: \( R = 0.44, P = 0.0498 \)) and C/N ratio (dry season: \( R = -0.51, P = 0.0215 \)) in the topsoil (Table 5).
Table 5: Rank Spearman correlation performed at the landscape scale and between the abundances of *Afrotrachytes* sp and *Trachyuropoda* sp and soil physico-chemical characteristics. SOC—Soil organic carbon, TN—Total nitrogen, C/N—Carbon nitrogen ratio, SD—Soil depth, BD—Bulk density, WC—Water content, pH—H₂O—Potential of Hydrogen-Water.

|                  | Rainy season |                  | Dry season |                  |
|------------------|--------------|------------------|------------|------------------|
|                  | Afrotrachytes sp. |                  | Trachyuropoda sp. |                  |
|                  | *N* | *R*  | *P*   | *N* | *R*  | *P*   |
| BD (g.cm⁻³)      | 20 -0.70      | 0.0005 ***       | 20 -0.39   | 0.0867         |
| WC (%)           | 20 0.38       | 0.0954           | 20 -0.23   | 0.3100         |
| pH-H₂O           | 20 0.30       | 0.1869           | 20 -0.07   | 0.7501         |
| SD               | 20 0.31       | 0.1738           | 20 0.34    | 0.1364         |
| SOC (g.kg⁻¹)     | 20 0.42       | 0.0596           | 20 -0.02   | 0.9143         |
| TN (g.kg⁻¹)      | 20 0.40       | 0.0749           | 20 -0.02   | 0.9141         |
| C/N              | 20 -0.20      | 0.3878           | 20 -0.14   | 0.5513         |

* *p < 0.05, ***p < 0.001

Discussion

The Mesostigmata are a diverse and widespread group of invertebrates which include around 11000 described species (Marchenko and Bogomolova, 2015). More than 2000 species make up the group of Uropodina (Kontschán et al., 2013). Beyond their great diversity, the study highlighted that abundance of the soil mites and both Uropodina genera was higher in the rainy season. The abundance of soil mites depends on soil moisture and season (Huhta and Hänninen, 2001; Salmane and Spuņģis, 2015). Indeed, there was a significant seasonal effect on the abundance of *Trachyuropoda* sp at the scale of the four study sites. If we consider each study site, the seasonal effect is significantly marked with *Afrotrachytes* sp in Oumé primary forest (Litter: *p = 0.001; 0-5 cm: *p = 0.024), and with *Trachyuropoda* sp in Lamto savannah (Litter: *p = 0.012; 0-5 cm: *p = 0.029). Seasonal changes in the plant community can directly or indirectly influence the soil invertebrate communities (Wu et al., 2014). Whatever the season, the abundance of *Afrotrachytes* sp and *Trachyuropoda* sp significantly varied through the different sites, indicating that the Uropodina structuring was strongly impacted by abiotic factors, which was more pronounced in the Oumé primary forest. The great vegetation cover and the diversity of plant species favor the emergence of microhabitats in Oumé primary forest (Madej et al., 2011). The structural features of microhabitats can influence the life cycle of arthropods (Duyar and Makineci, 2016). This heterogeneity provides a high potential for niche partitioning and habitat specialization, thereby facilitating species coexistence and promoting biodiversity (Wu et al., 2014). The investigation made by Napierała and
Bloszyk (2013) pointed out that Uropodina communities inhabiting merocenoses are often predominated by one or two species, which constitute more than 50% of the entire community. The numerous occurrence of *Afrotrachytes* sp and *Trachyuropoda* sp in the soil of Oumé primary forest and *Trachyuropoda* sp in Lamto savannah can be a good indicator not of the type of habitat, but the processes that habitat undergoes. In Lamto, all facies were dominated by tall palm trees (*Borassus aethiopum*), and sampling was conducted in an unburned area dominated by *Chromolaena odorata* (Asteraceae). The abundance of mites in fallow systems (dominated by the invasive shrub *Chromolaena odorata*) might be due to population growth, characterized by spatial heterogeneity and vegetation regrowth where factors such as the quality and quantity of litter and the age of fallow crops play a key role (Koné et al., 2012).

In contrast to our expectation, the lowest abundance of Uropodina was observed in Taï primary forest. Probably, the soil cores were taken away from the stumps. The coarse woody debris (CWD) is an important component of forest ecosystems (Kamczyc et al., 2017). It is characterized by higher abundance and diversity of mesostigmatid mites than (nearby) soil/litter (Kamczyc et al., 2014). In fact, with increasing distance to CWD (stumps), the total number of mite species in the soil/litter matrix decreases (Kamczyc et al., 2014). The lack of a clear relationship between Taï primary forest and Uropodina is probably related to their activity and ability to migrate (Kaczmarek et al., 2012). Another reason is that the abundance and diversity of soil mites are not necessarily linked to the diversity of plant species, because individual plants have also been shown to have large effects on soil biological communities in strongly nutrient limited situations (Bardgett, 2005). The work of De Deyn et al. (2004) in experimental condition indicated that plant traits that affect the resource quality were more important than plant diversity. These assertions might explain the higher abundance of *Afrotrachytes* sp in Oumé teak plantation compared to Taï primary forest.

The highest abundance of both Uropodina was recorded in the topsoil, as presented with the Soil Depth_{50}. Indeed, on the four sites, 50% of *Afrotrachytes* sp and *Trachyuropoda* sp was observed in 1.75-8.41 cm soil depth during the rainy season. In the dry season, a water stress period, the Uropodina sink further into the soil to escape desiccation, which results into a deeper Soil Depth_{50} for *Afrotrachytes* sp (3.16-11.8 cm) and *Trachyuropoda* sp (8.83-21.8 cm) compared to those estimated in the rainy season. The study also reveals that the Uropodina present a random distribution along the transects.

The abundance of the two Uropodina genera, *Afrotrachytes* Kontschán, 2006 and *Trachyuropoda* Berlese, 1888 could be impacted by the extraction method. The absolute efficiency of the Berlese-Tullgren funnels would vary, depending on the authors, from 26% (Forsslund, 1948) to 7% (André et al., 2002) and the Berlese-Tullgren funnels are also selective with respect to their efficiency for certain taxa. Particularly, the ratio of immature mites is especially low (less than 2%) and the rate of Actinedida varies from 2 to 6% (N'Dri and André, 2011). Certainly, the Berlese Tullgren has a low yield compared to flotation methods (André and Noti, 1993); however it would be suitable for tropical soils and less dangerous to use. The preliminary study revealed that bulbs lighting as soon as the soil cores were placed in Berlese Tullgren gave better results regarding the abundance of extracted mites. Unlike immature mites and Actinedida, the Uropodina are mostly strongly sclerotised (Kontschán et al. 2013) and therefore able to resist to the desiccation of soil cores in the Berlese. Despite their very low mobility (Berthet, 1964), the gradual decrease of moisture in the soil cores following an increase in heat due to a rise in temperature in the Berlese will promote the downhill of sclerotised mites, because generally characterized by a positive geotropism (Nef, 1960,1971).

This first study on the spatiotemporal variation of Uropodina from Côte d’Ivoire shows that abiotic factors such as season, soil depth, bulk density, C/N ratio, and habitat type influence the abundance and the distribution of Uropodina. However, taking into account of the different dispersal agents in future studies would help us to better understand their abundance and distribution along different habitats, as well as their role as biological control agents.
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References

[1] Anderson J.M. and Ingram J.S.I. 1993. Tropical soil biology and fertility: a handbook of methods, 2nd edn. CABI, Wallingford

[2] André H.M. and Noti M-I. 1993. Extracting sand microarthropods: a carbon tetrachloride flotation method. Eur. J. Soil Biol., 29: 91–96.

[3] André H.M., Ducarme X. and Lebrun Ph. 2002. Soil biodiversity: myth, reality or conning? Oikos, 96: 3–24.

[4] Assié K.H., Angui P. and Tamia A.J. 2008. Effets de la mise en culture et des contraintes naturelles sur quelques propriétés physiques d’un sol ferrallitique au Centre Ouest de la Côte d’Ivoire: Conséquences sur la dégradation des sols. Eur. J. Sci. Res., 23: 149–166.

[5] Avenard J-M. 1971. Aspect de la géomorphologie. In: Le milieu naturel de la Côte-d’Ivoire, Mémoires ORSTOM, 50: 70–72.

[6] Baize D. 1988. Guide des analyses courantes en pédologie. INRA Éditions, Paris, France.

[7] Barberena-Arias M.F., Gonzales G. and Cuevas E. 2012. Quantifying variation of soil arthropods using different sampling protocols: is diversity affected? In: Tropical Forests. Sudarshana P. (ed), pp. 51–70. InTech, Rijeka, Croatia

[8] Bardgett R.D. 2005. The biology of soil. A community and ecosystem approach. Oxford University Press, Oxford, UK

[9] Barot S. 1999. Interactions entre répartition spatiale, hétérogénéité environnementale et démographie : cas du palmier Rônier dans une savane humide de Côte d’Ivoire. Ecologie. PhD Dissertation. Université de Paris 6, France

[10] Čejka M. and Holuša J. 2014. Phoretic mites in uni- and bivoltine populations of Ips typographus: a 1-year case study. Turk. J. Zool., 38: 569–574.

[11] Coleman D.C., Crossley D.A.Jr. and Hendrix P.F. 2004. Fundamentals of soil ecology, 2nd (ed). Elsevier Academic Press, Burlington, New York

[12] De Deyn G.B., Raaijmakers C.E., Van Ruijven J., Berendse F. and Van der Putten W.H. 2004. Plant species identity and diversity effects on different trophic levels of nematodes in the soil food web. Oikos, 106: 576–586.

[13] Duchaufour P. 1991. Abrégés de pédologie. Sol, végétation, environnement (3ème éd.). Masson, Paris, France.

[14] Duyar A. and Makineci E. 2016. Seasonal and altitudinal variations of soil arthropods in Abies nordmanniana subsp. bornmulleriana forests. Bosque, 37(2): 335–345.

[15] Forsslund K-H. 1948. Något om insamlingsmetodiken vid markfaunaundersökningar. Medd. Statens Skogsforskningsinst, 37(7): 1–22.
[16] Gwiazdowicz D.J., Kamczyc J. and Błoszyk J. 2011. The diversity of phoretic Mesostigmata on *Ips typographus* (Coleoptera: Scolytinae) caught in the Karkonosze forest. Eur. J. Entomol., 108: 489–491.

[17] Huhta V. and Hänninen S-M. 2001. Effects of temperature and moisture fluctuations on an experimental soil microarthropod community. Pedobiologia, 45: 279–286.

[18] Kaczmarek S., Marquardt T., Faleńczyk-Koziróg K. and Marcysiak K. 2012. Diversity of soil mite communities (Acari) within habitats seasonally flooded by the Vistula River (Ostromecko, Poland). Biological Lett, 49(2): 97–105.

[19] Kamczyc J., Gwiazdowicz D.J., Teodorowicz E. and Strzymińska K. 2014. Mites (Acari, Mesostigmata) in boreal Scots pine forest floors: effect of distance to stumps. Exp. Appl. Acarol., 64: 61–71.

[20] Kamczyc J., Pers-Kamczyc E., Watral P., Sokolowski J. and Bułaj B. 2017. To what extent do pine and oak clear-cut stumps support mite (Acari: Mesostigmata) communities in temperate forests? Turk. J. Zool., doi:10.3906/zoo-1606-35.

[21] Kazemi S. and Abolghasemi S. 2016. New species and records of Uropodina mites from Iran (Acari, Mesostigmata). ZooKeys, 600: 25–34.

[22] Koné A.W., Edoukou E.F., Orendo-Smith R. and Tondoh J. E. 2012. Earthworms in *Chromolaena odorata* (L.) King and Robinson (Asteraceae) fallows along a chronosequence: Changes in community structure and identification of persistent and indicator species. Pedobiologia, 55: 193–201.

[23] Kontschán J. 2006a. Uropodina (Acari: Mesostigmata) species from Angola. Acta Zoologica Academiae Scientiarum Hungaricae, 52(1): 1–20.

[24] Kontschán J. 2006b. Uropodina mites of East Africa (Acari: Mesostigmata) I. Opuscula Zoologica Budapest, 35: 53–62.

[25] Kontschán J. 2007. Trachyuropodid mites of the Carpathian Basin (Acari Uropodina: Trachyuropodidae). Opusc. Zool. Budapest, 36: 43–56.

[26] Kontschán J. 2009a. Remarks on the genus *Afrotrachytes* Kontschán, 2006 (Acari: Uropodina), with description of two new species. Opusc. Zool. Budapest, 40(2): 41–46.

[27] Kontschán J. 2009b. *Rotundabaloghia browni* spec. nov., a new uropodine mite from Ivory Coast. Spixiana, 32(1): 35–38.

[28] Kontschán J. 2011. Six new species of the family Trachyuropodidae from the Neotropical region (Acari: Mesostigmata: Uropodina). Studies on Neotropical Fauna and Environment, 46(3): 211–223.

[29] Kontschán J. and Starý J. 2013. Three new *Trachyuropoda* (Acari: Uropodina: Trachyuropodidae) species from the Neotropical region. Turk. J. Zool., 37: 7–14.

[30] Kontschán J., Park S.J., Yoon T.J. and Choi W.Y. 2013. Uropodina mites from the Korean Peninsula (Acari: Mesostigmata). Zoological Collectings by the Hungarian Natural History Museum in Korea No. 204. Ad Librum Publishers, Budapest.

[31] Kouadio K.K.F. 2006. Analyse du système de biomonitoring du Parc National de Taï. Master Dissertation. École Supérieure d'Agronomie (ESA), Institut National Polytechnique Houphouet Boigny de Yamoussoukro, Côte d'Ivoire.
[32] Le Roux X. 2006. Climate. In: Lamto. Structure, Functioning, and Dynamics of a Savanna Ecosystem. Abbadie L, Gignoux J, Le Roux X, Lepage M. (Eds). Lamto. Structure, Functioning, and Dynamics of a Savanna Ecosystem, pp. 25-44. Springer Verlag, New York, USA.

[33] Madej G., Barczyk G. and Gawenda I. 2011. Importance of Microhabitats for Preservation of Species Diversity, on the Basis of Mesostigmatid Mites (Mesostigmata, Arachnida, Acari). Polish J. of Environ. Stud., 20(4): 961–968.

[34] Marchenko I.I. and Bogomolova I.N. 2015. Spatial–Typologic Organization of Populations of Soil Gamasid Mites (Acari, Mesostigmata) in Northern Altai Mountains. Contemporary Problems of Ecology, 8(2): 202–210.

[35] Menaut J.C. and César J. 1979. Structure and primary productivity of Lamto savannas, Ivory Coast. Ecology, 60(6): 1197–1210.

[36] Monnier Y. 1983. Végétation. In: Vennetier P. (Ed.), Atlas de la Côte d’Ivoire (2nd ed.), p. 17, Jeune Afrique, Paris, France

[37] Moreau R. 1983. Sur l’origine d’éléments d’aspects charbonneux observés dans les sols de la région de Taï. Office de la Recherche Scientifique et Technique d’Outre-Mer, Centre d’Adiopodoumé (Côte d’Ivoire), 6 pp

[38] N’Dri J.K. and Andre H.M. 2011. Soil mite densities from central Ivory Coast. Journal of Animal and Plant Sciences, 10: 1283–1299.

[39] Napierała A and Błoszyk J. 2013. Unstable microhabitats (merocenoses) as specific habitats of Uropodina mites (Acari: Mesostigmata). Exp. Appl. Acarol., 60: 163–180.

[40] Nef L. 1960. Comparaison de l’efficacité de différentes variantes de l’appareil de Berlese-Tullgren. Z. angew. Ent., 46: 178–199.

[41] Nef L. 1971. Influence de l’humidité sur le géotactisme des Oribates (Acarina) dans l’extracteur de Berlese-Tullgren. Pedobiologia, 11: 767–785.

[42] Noti M-I., André H.M., Ducarme X. and Lebrun P. 2003. Diversity of soil oribatid mites (Acari: Oribatida) from high Katanga (Democratic Republic of Congo): a multiscale and multifactor approach. Biodiversity and Conservation, 12: 767–785.

[43] Pérez-Velázquez D., Castaño-Meneses G., Callejas-Chavero A. and Palacios-Vargas J.G. 2011. Mesostigmatid mite (Acari: Mesostigmata) diversity and abundance in two sites in Pedregal de San Ángel Ecological Reserve, Distrito Federal, México. Zoosymposia, 6: 255–259.

[44] Salmane I. and Spuņģis V. 2015. Factors influencing mesostigmat mites (Acari, parasitiformes) in the alkaline fen habitats. Proceedings of the Latvian academy of sciences, 69: 50–56.

[45] Wissuwa J., Salamon J-A. and Frank T. 2012. Effects of habitat age and plant species on predatory mites (Acari, Mesostigmata) in grassy arable fallows in Eastern Austria. Soil Biology and Biochemistry, 50: 96–107.

[46] Wu P., Liu X., Liu S., Wang J. and Wang Y. 2014. Composition and spatio-temporal variation of soil microarthropods in the biodiversity hotspot of northern Hengduan Mountains, China. Eur. J. Soil Biol., 62: 30–38.

[47] Zach P., Kršiak B., Kufan J., Parák M. and Kontschán J. 2016. Mites Trichouropoda and Urobovella spp. (Uropodoidea) phoretic on bark beetles (Scolytinae): a comparison from a declining mountain spruce forest in Central Europe. International Journal of Acarology, doi: 10.1080/01647954.2016.1154107