Research article

Physical-Chemical Properties of Earthworm Casts in Different Earthworm Species

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Abstract Earthworms play important role in the soil ecosystem influencing soil properties regulating underlying ecosystem functions such as soil organic matter (SOM) decomposition and soil erosion and quantifying their influence on SOM cycling in tropical ecosystems. The casts produced enhance microbial activities in soil that promote nutrient cycling and help in aggregate formation and stability in soil. The aims of this paper are to study focuses on the dynamic of physical and chemical properties of earthworm casts in different species of earthworm and aging of earthworm. The oven-dried weight of casts has been quantified in laboratory. The soil parameters pH, electrical conductivity (EC), bulk density, porosity, organic matter and exchange capacity were analyzed. The results found that pH values of casts ranged from 6.36 to 8.18. Fresh casts were characterized by higher EC, Mg^{2+}, Ca^{2+}, K^{+}, Na^{+} and organic matter than in old cast. The values were higher in earthworm casts of Khitarae (*Pheretima peguana*). The moisture contents were significantly higher in fresh casts (ranged 6.89% to 33.93%). The cast of Khikhu (*Pheretima* sp.) bulk density values was highest (1.19 g cm^3). Exchangeable K^{+}, Ca^{2+}, and Mg^{2+} in earthworm casts were higher than bulk soil. Porosity was highest (69.52%) in fresh casts of Khitarae (*P. peguana*). In conclusion, the physical-chemical properties of earthworm casts were different between the earthworm species. The distribution and biodiversity of earthworm may play and importance role in soil fertility.

Keywords earthworm casts, earthworm epecies, soil properties, aging

INTRODUCTION

Earthworm casts are known to contribute significantly to surface soil fertility in agroecosystems. Earthworm casts are mainly produced during the rainy season in tropical regions (Chaudhuri et al., 2009). Seasonal variations in cast production are attributed to fluctuations in factors including soil physico-chemical properties, land use patterns, feeding habits and availability of food resources. The cast of the earthworm, fortified with mucilaginous secretion, helps in aggregate formation and stability (Shipitalo and Protz, 1988; Marinissen and Dexter, 1990) which is the foundation for soil structure formation. Water stable biogenic structures i.e. organic matter in aggregates are found in the earthworm presence soil (Jouquet et. al., 2004; Bossuytet et al., 2005; Jouquet et. al., 2009). Three ecological categories of earthworms epigeics, anecics and endogeics. Each of these creates earthworm spheres with differing characteristics. The anecics and endogeics are known as soil ecosystem engineers and their impact on soils is great and may influence properties and processes

at the ecosystem level. The functional role of epigeics is primarily that of litter transformers, like other litter invertebrates (Lavelle, 1997).

Therefore, the present investigation was conducted to study physical-chemical properties of earthworm casts of different earthworm species. Earthworm casts properties were measured in order to explain the distribution of earthworm cast on soil ecosystem. This study focuses on the dynamic of physical and chemical properties of earthworm casts from different species of earthworm ranging from low to high casting activity.

MATERIALS AND METHODS

Sampling of Earthworm Casts

Cast samples were collected in three replicates of 50 g each, at the Research Developing and Learning Center on Earthworm for Agriculture and Environment, Khon Kean University, Thailand. Sampling was carried out during two weeks in December 2017. Earthworm casts were divided into two ages: (i.) Fresh cast (from earthworm surface casting activity on soil), and (ii.) Old cast (rounded shape macro-aggregates that were clearly identified not recent). Four species of earthworm were used in this study; (i.) Tiger worm (*Eisenia foetida*); (ii.) African Night Crawler (*Eudrilus eugeniae*); (iii.) Khitarae (*Pheretima peguana*) and ; (iv) Khikhu (*Pheretima* sp.).

Measurements

Cast samples were collected from the study sites by random sampling, particularly near the site of surface casting. Three random samples (25 cm × 25 cm × 30 cm) were collected (Anderson and Ingram,1993). Casts were taken to the laboratory, air-dried, ground with mortar and pestle, and passed through a fine (0.2 mm-mesh) sieve. The study monitored and compared the change of earthworm cast physical and chemical properties. Exchangeable cations and total exchange capacity were measured by the ammonium acetate method at pH 7.0 (Lavkulich, 1981). pH was determined in 1:2.5 (soil:water) suspensions. Organic matter was assessed by measuring total C content with an elemental analyzer by titrating $FeSO_4$ dropwise (Walkley and Black,1980). Soil core (100 cm^3) were collected from 2-7 cm depth. After drying in the oven at 105 ^{0}C during 24 h, gravimetric soil water content was calculated. The weight of soil core and the volume of particle density in soil were measured and used to determine the percent of moisture and porosity.

Statistical Analysis

Data collected were first subjected to classical statistical analysis to obtain descriptive statistics, including minimum, maximum, mean, standard deviation, skewness, and coefficient of variation. Spearman rank order correlation coefficients between cast abundance and all parameters were calculated with Statistical program software. Differences were considered significant, only when P values were lower than 0.05.

RESULTS AND DISCUSSION

The pH values of most casts ranged from 6.36 to 8.18. Fresh casts had higher pH and EC (mS/cm) contents than the old casts ($P < 0.05$) (Table 1). The higher pH of cast soil may be due to the ammonia secreted in the worm's gut, which may act as a neutralizing factor (Wallwork, 1983) and the production of calcium carbonate in calciferous glands and its release into the intestine (Lee, 1985).

Organic matter mostly ranged from 2.15 to 11.50%. Organic matter was significantly higher in earthworm cast type fresh casts (Table 1). It appeared that microbial activity was considerably influenced by organic matter availability in soil. The EC creates hot spots that promote high

microbial biomass as they contain higher moisture content and available organic carbon than surrounding soil (Edwards and Bohlen, 1996). Organic matter ranged from 4.99% in old casts to 8.29% in new casts (Table 2). The lower production of casts in the present study may be attributed partly to the lower abundance of surface casting species of earthworms (viz. *Drawida* sp. and *M. houlleti*) and to low organic matter production in the early stages of the agroforestry sites. Reduction in casting rates has been related both to the degree of plant biomass removal and re-establishment of cover crops (Hauser and Asawalam, 1998). Casts had higher exchangeable cations(mg/kg^{-1}) contents with significant ($P < 0.05$) correlation between worm fresh cast and old casts to the potassium ranging from 435.08 % and 178.85%, magnesium (283% and 216.69%), calcium (2296.2% and 1754.8%) and sodium (280.42% and 113.42%) (Table 2). In this case, particle size selection by earthworms did not occur and casts only had a higher pH and were enriched in carbon and exchangeable cations (here Ca^{2+}, Mg^{2+} and K^{+}). The amount of organic and mineral materials incorporated into casts varied considerably depending upon diet and whether earthworms were actively feeding or burrowing (Lee and Foster, 1991).

The moisture content was significantly higher in fresh casts and ranged from 6.89% to 33.93%. Bulk density values ranged from 0.61 to 1.19 g cm^3 and most of the old casts. Earthworm casts are usually found to have greater exchangeable K^{+}, Ca^{2+}, and Mg^{2+} than bulk soil (Edwards and Bohlen, 1996; Mariani et al., 2007). Particle density and porosity were significantly higher in fresh casts (Table 1).

Table 1 Physical and chemical properties of old casts and new casts in different species of earthworm

Parameter/Species	Khikhu		The Tiger worm		African Night Crawler		Khitarae		CV %
	Old	New	Old	New	Old	New	Old	New	
Chemical									
pH	7.37^{c}	7.05^{d}	6.36^{e}	7.39^{c}	7.13^{d}	7.42^{c}	7.81^{b}	8.18^{a}	1.54
EC (mS/cm)	0.09^{g}	0.24^{f}	1.94^{d}	2.64^{b}	0.97^{e}	2.39^{c}	0.09^{g}	3.16^{a}	3.29
K^{+} (mg kg^{-1})	56.67^{d}	70.33^{d}	400.63^{b}	434.43^{b}	178.43^{c}	430.93^{b}	79.67^{d}	804.63^{a}	9.36
Mg^{2+} (mg kg^{-1})	187.60^{e}	216.33^{d}	294.38^{b}	290.23^{bc}	280^{c}	310.80^{a}	104.33^{f}	317.60^{a}	2.91
Ca^{2+} (mg kg^{-1})	1330.3^{f}	1573^{e}	2186^{d}	2434.3^{bc}	2305.7^{cd}	2625.7^{a}	1197^{f}	2551.7^{a}	4.33
Na^{+} (mg kg^{-1})	62.67^{f}	117.67^{e}	168.00^{d}	384.00^{a}	160.00^{d}	252.00^{c}	63.00^{f}	368.00^{b}	3.00
Organic matter (%)	3.85^{e}	4.39^{e}	5.69^{d}	7.88^{c}	8.28^{c}	9.36^{b}	2.15^{f}	11.50^{a}	7.30
Physical									
Bulk density	1.19^{a}	1.03^{b}	0.83^{c}	0.69^{d}	0.96^{b}	0.61^{de}	0.61^{de}	0.54^{e}	7.65
Particle density	2.08^{bc}	2.23^{a}	2.08^{bc}	1.98^{cd}	1.92^{d}	2.17^{ab}	1.74^{e}	2.00^{cd}	3.26
Porosity	42.45^{F}	54.20^{de}	60.21^{cd}	65.06^{bc}	50.28^{e}	71.94^{a}	69.23^{ab}	69.80^{ab}	6.02
Moisture (%)	1.85^{f}	15.01^{d}	8.01^{e}	37.33^{b}	2.19^{f}	40.11^{b}	20.69^{c}	43.31^{a}	6.91

Similar letter within the same row indicates no significant difference at p = 0.05 between treatments

Properties Correlation between Species Earthworm Casts

The higher pH values of casts most of Khitarae (*Pheretima peguana*). Casts had higher electrical conductivity (mS/cm) contents than the old casts of the Tiger worm (2.29 mS/cm), African Night Crawler (1.68 mS/cm), Khitarae (1.62 mS/cm) and lower EC (mS/cm) of Khikhu (0.17 mS/cm). Earthworm species Khitarae had higher K^{+} in fresh casts ranging from 804.63 mg/kg^{-1} to 79.67 mg/kg^{-1} and lower in old casts (Table 1). Higher Ca^{2+}, $Mg^{2+}$and Na^{+} was found in the Tiger worm, African Night Crawler and Khitarae species in fresh casts. Lower chemical properties were found in the species Khikhu (*Pheretima* sp). Epigeic species live in, consume, comminute and partially digest surface litter, rarely ingesting soil particles.

The mode of litter processing by earthworms in natural systems results in greater nutrient leaching into the soil. Since epigeics feed purely on litter and generally have a short gut transit time they probably depend on a rapid response of gut microbes to aid in digestion. Epigeic earthworm guts preferentially stimulate some microorganisms, and reduce others leading to a relative

dominance of microorganisms different to that found in undigested soils (Lavelle, 1983). Physical properties of casts on earthworm species Khikhu higher bulk density and particle density mean 1.11 (g cm^{-3}) and 2.16 (g cm^{-3}). Such differences in porosity between the earthworm species Khitarae was higher 69.52%, The Tiger worm 62.62% , African Night Crawler 61.11% and lower porosity in Khikhu 48.33%. Moisture higher in Khitarae, The Tiger worm and African Night Crawler range from 37.33 to 43.31% in fresh casts and lower moisture in Khikhu (15.01%) content.

Table 2 Mean value of old casts and new casts and soil physical and chemical properties

Parameter	Old casts	New casts
Chemical		
pH	7.17^{A}	7.51^{B}
EC (mS/cm)	0.77^{B}	2.11^{A}
K^{+} (mg kg^{-1})	178.85^{B}	435.08^{A}
Mg^{2+} (mg kg^{-1})	216.69^{B}	283.74^{A}
Ca^{2+} (mg kg^{-1})	1754.8^{B}	2296.2^{A}
Na^{+} (mg kg^{-1})	113.42^{B}	280.42^{A}
Organic matter (%)	4.99^{B}	8.29^{A}
Physical		
Bulk density	0.87^{A}	0.73^{B}
Particle density	1.96^{B}	2.09^{A}
Porosity	55.55^{B}	65.25^{A}
Moisture (%)	6.89^{B}	33.94^{A}

Similar letter within the same row indicates no significant difference at p = 0.05 between treatments

CONCLUSION

Our study focuses on the dynamic of physical and chemical properties of earthworm casts in different species of earthworm and aging of earthworm. Our results show that different earthworm species are affected by those properties and the severity of these effects vary between casts for each kind of earthworm. These effects are linked to nutrient gradients in the soil. Earthworm casts are usually found to have greater exchangeable K^{+}, Ca^{2+}, Mg^{2+} and Na^{+} in fresh cast more than bulk soil. Porosity were significantly higher (69.52%) in fresh casts of Khitarae (*Pheretima peguana*). The lower production of casts in the present study may be attributed partly to the lower abundance of surface casting species of earthworms and reduction in casting rates has been related both to the degree of plant biomass removal and systems.

Although the four studied earthworm species belong to two different ecological groups, no generalization can be made on the respective impact of anecic, epigeic and endogeic species. Microbiological properties should also be measured to better understand the cast functioning under such interactions between soil types and earthworm species. Indeed, physico-chemical and microbiological properties are closely interlinked and contribute together to nutrient cycling in casts.

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