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Growth of the Earthworm *Millsonia omodeoi* and Its Capacity to Accumulate Five Heavy Metals (HM) in Soils along a Toll Highway in Côte d'Ivoire

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Abstract

The roads in correlation with the traffic linked to their existences are at the origin of the emission of numerous polluting substances likely to induce disturbances of the growth and the behavioral changes in the organisms living in their vicinities. The purpose of this study is to analyze the growth and capacity accumulation of a common earthworm species (*Millsonia omodeoi*) in Cu, Cr, Ni, Pb and Zn in soils along a main road called "Autoroute du Nord" in Côte d'Ivoire. Thus, the earthworms were harvested in soils from a distance of 0 m (just after the sidewalk) to a distance of 200 m from the toll highway and in a control soil sampled in Lamto reserve (Côte d'Ivoire). The study was carried out in the soil laboratory at the ecological station of Lamto reserve. The Ford-Walford technique was used to determine the model and parameters most appropriated for describing the growth of earthworms. A pairwise comparison of the growth parameters was carried out using the Kruskal-Wallis test with the STATISTICA 7.1 software. The heavy metals contained in the cultivated soils and earthworms were detected and quantified using a Scanning Electron Micro-scope (MEB FEG Supra 40 VP Zeiss) and an Atomic Absorption Spectrometer SPECTRA 110 (VARIAN). The capacity accumulation of heavy metals in earthworm was determined by the bioaccumulation factor (BAF) calculation. The results of this study showed that Gompertz is the most appropriated model to describe the growth of *M. omodeoi*. The life cycle of *M. omodeoi* shows that this earthworm adopts a K type demographic strategy. Cu is the most accumulated heavy metals in *M. omodeoi*, when Cr is the least accumulated. Concerning heavy metal content in the earthworms, it decreases while moving away from the pavement. These results highlight a possibility of choice of *M. omodeoi* as 1) indicators of heavy metals pollution and 2) target of biological organisms for environmental impact studies.

Keywords

M. omodeoi, Bioaccumulation, Heavy Metals, "Autoroute du Nord", Côte d'Ivoire

1. Introduction

Roads and highways borders are subjected to a chronic pollution which is strongly influenced by changes in the car fleet, fuels, road equipment and vehicles in circulation [1]. Pollutants such as heavy metals resulting from road wear, abrasion and corrosion of the constituent metals of vehicles (brakes, bodywork), wear of tires and catalytic converters, emission from exhaust gases and corrosion of safety barriers, are thus dumped onto the track and its surroundings [2]. Because of their non-biodegradability, heavy metals, after their accumulation in soil, alter natural biological processes and can enter the trophic chain via plants and constitute a threat to animal and human health [3] [4]. Many scientific published papers [5] [6] [7] have shown that the accumulation of these substances in the plants, animal organisms and humans leads to the inhibition of germination, growth or reproduction as well as serious ailments such as, neurological diseases, cancer, osteomalacia, hydrargyrism, tubular nephritis and growth disorders in children.

Otherwise, studies of polluted soils have revealed that density, survivability and reproduction of endogenous organisms, such as earthworms, are negatively affected by heavy metals [8] [9]. These organisms have been recognized as excellent potential partners for the management of ecosystems and ecosystem services [10]. Many ecosystem services are highly dependent on earthworms. According to Blouin *et al.* [10] and Lavelle *et al.* [11], earthworms act as catalysts on two support services essential for other services to be delivered: soil formation and nutrient recycling. They can also play a role in the repair of negative human impacts on the functioning of ecosystems due to their potential to be used for the restoration of degraded ecosystems [12], or specifically to absorb various types of pollution [13] [14]. Thus, the presence of earthworms in a given soil is synonymous of a good state of the health of this soil [15].

In the West African region, the "Autoroute du Nord" toll highway in Côte d'Ivoire is one of the busiest roads with a frequency of more than 8000 vehicles per day [16]. Indeed this toll highway links Abidjan (economic capital), to many other countries of West Africa such as Burkina Faso, Mali, Guinée, etc. However, in this region, like many other regions of Sub-Saharan Africa, road traffic is characterized by the use of imported second-hand cars, the lack of reliable vehicle technical controls, the increasing use of two-wheeled vehicles and poor quality fuels [17] [18]. The consequence of these short comings is the drastic increase in the concentrations of many pollutants such as heavy metals. It is therefore appropriated to study the effect of this traffic on the biological diversity of endogenous species, particularly that of earthworms known as excellent bioindicators, in order to anticipate the consequences of the heavy metals on the biocenosis that marks the borders of road and highway of this region. This study has been carried out in order to analyze the growth and the accumulation capacity of heavy metals by a common species of earthworm (*Millsonia omodeoi*) in soils collected at different distances from the "Autoroute du Nord" toll highway to the bush. The study is based on the assumptions that "the distribution of pollutants is likely to influence the growth capacity of *M. omodeoi* as they move away from the highways borders on the one hand and these earthworms would be excellent bioindicators because of their ability to accumulate the heavy metals contained in these soils on the other hand".

2. Materials and Methods

2.1. Soils Sampling Sites

Samples of cultivated soils were taken along the toll highway linking the district of Abidjan (south) and the city of Bouaké (center), in Côte d'Ivoire. This toll highway is subdivided into three sections, the first section linking the district of Abidjan and the town of Singrobo (140 km long), put into service in 1982, and the second section linking the town of Singrobo to the district of Yamoussoukro (80 km long), commissioned in December 2013 and the third section connecting the district of Yamoussoukro to the city of Bouaké (107.5 km long) commissioned in December 2022. The present study only concerned first section (Abidjan-Singrobo) which is the oldest. This section is located between latitudes 5˚18' and 6˚80' north and longitude 4˚00' and 5˚50' west. In addition to soils collected in the toll highway area, controls were collected from the grassy savannah of the Lamto reserve.

2.2. Sampling Device

Along the studied section of the toll highway (Abidjan-Singrobo), over a distance of 90 km, 10 linear transects, spaced 10 km apart, were delineated perpendicular to the roadway. On each of the transects, soils were collected at 05 points spaced 50 m apart corresponding to a total of 200 m exploited. Indeed the sampling points are: 0 m (just after the sidewalk), 50 m, 100 m, 150 m and 200 m (**Figure 1**).

2.3. Determination and Quantification of Heavy Metals in the Sampled Soils

The heavy metals were determined and quantified in the composite soil samples taken along the distance gradients and in the Lamto reserve. These substances have been identified by the Energy Diffusion Spectrometry (EDS) method, from

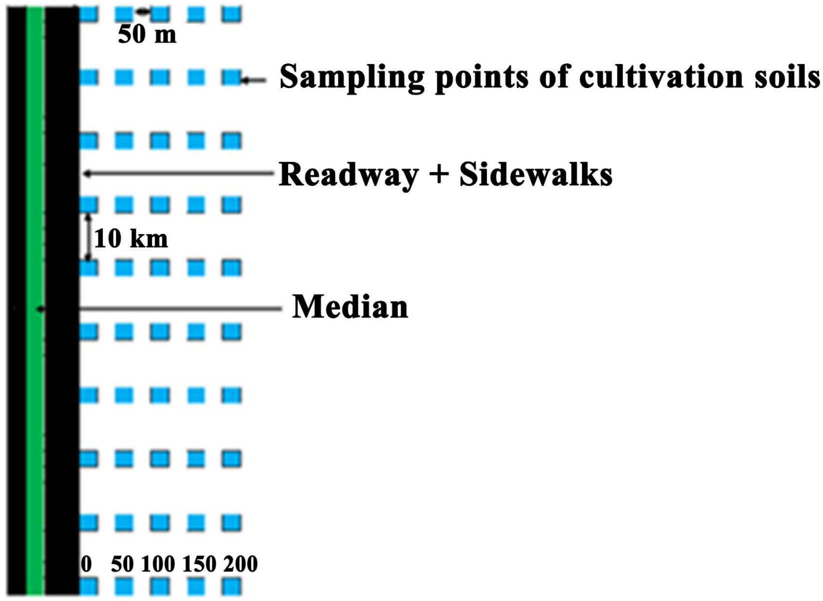


Figure 1. Cultivation soils sampling design.

a Scanning Electron Microscope (SEM FEG Supra 40 VP Zeiss) in the Laboratory of the Department of Analysis and Research of National Oil Company of Côte d'Ivoire (PETROCI). Thus, the soil sample was finely ground in a porcelain mortar and then sieved with a mesh screen of 250 µm. Ten (10) mg of the powder obtained after sieving were taken and plated on a primer with double-sided adhesive carbon. The apparatus performs a measurement of the transition energy of electrons at the level of the electron clouds of the K, L and M series of the atoms of the sample. This makes it possible to identify its chemical composition. The identified substances were quantified using an Atomic Absorption Spectrometer SPECTRA 110 (VARIAN). This operation is carried out after digestion of 0.5 g of each sample in 5 ml of 65% nitric acid (HNO_3), 2 ml of 98% sulfuric acid (H_2SO_4) and 1 ml of hydrogen peroxide (H_2O_2) to 30%.

2.4. Cultivation Conditions of the Earthworms

The species *Millsonnia omodeoi* was used in the frame of this study taking into account the fact that this species is common on the area of the toll highway and especially because of its very low mortality observed in cultivation [19].

In order to determine the capacity of accumulation of heavy metals by the earthworms, it was important to have juvenile individuals which are free of any heavy metals contamination. Therefore we first collected earthworms in the Lamto reserve, a area preserved from human activities and far from roads, and then we cultivated these earthworms in soils collected in the same reserve.,

The different soils sampled along the toll highway borders and in the Lamto reserve were first dried in the open air for one week and then sieved with a sieve mesh 2 mm, and mixed so as to obtain a single composite sample for the soils of the same distance. Finally, the resulting soils were placed in 1 liter plastic boxes on account of 2 kg of soil per box. For each soil type (0 m, 50 m, 100 m, 150 m, 200 m and control soil), 15 replications were performed; or a total of 90 boxes for cultivation.

Two juvenile earthworms were placed in each of the boxes. The boxes were then brought to a humidity of 18% and placed in a room at a temperature of 28˚C (room temperature).

The experiment lasted 5 months. Every two weeks, each box received 50 ml of water to maintain the moisture content. A sufficient quantity of ground grass (*Andropogon leucostachyus* and *Loudetia simplex*) was brought to the earthworms. Each month, the contents of each box were spilled into a tray. The earthworms were removed from the box and wiped with filter paper and then weighed on a weighing scale (Sartorius) with an accuracy of ±0.01 mg, in order to follow the evolution of their growth (mass). After the weighing, the earthworms and the non-renewed soils were put in the boxes for the continuation of the experimentation. At the end of the fifth month, the final concentrations of the heavy metals were determined both at the level of the different soils and in the earthworms. However, before the determination of pollutant concentrations in earthworms, they were first isolated from the soils and placed on filter paper, then left on an empty stomach for two weeks so that their intestinal contents were emptied of ingested soils. Then, they were sacrificed, dried in an oven for 24 hours and ground in a porcelain mortar so as to obtain a powder having been used to detect and quantify the heavy metals according to the processes previously described for the soils.

2.5. Data Statistical Analysis

2.5.1. Choice of the Growth Model and Determination of the Parameters

Three growth models are commonly used to describe the growth of earthworms. These are the Gompertz model, the logistic model and the Von Bertalanffy model [20] [21] [22]. It is therefore not appropriate to use a priori a growth mode. In order to remedy this problem, the choice of the most appropriate growth curve was determined using the [23] technique. According to this technique, in the Ford-Walford graph, for the Gompertz curve, the abscissa is a logarithmic axis while the ordinate must be a linear axis. For the logistic curve and the Bertalanffy curve, the abscissa and the ordinate are linear axes. The choice of the most appropriate growth model is based on the best alignment of the points in the Ford-Walford graph which is expressed by the determination coefficients (R2) closest to 1. Otherwise, the integrated form of the growth curve is derived by integrating a differential equation involving the specific rate of growth (G) (**Table 1**). In practice, this differential equation of mass (mass of earthworms) at time t (S) results from the regression of the specific rate of growth. The regression parameters can then be used directly in the writing of the integrated form. If G and S are correctly transformed, the ratio is linear.

An adjustment of the equation integrated to the measurements made (masses

Table 1. Differential and integrated equations of the curves corresponding to the growth models.

Growth model	Differential equation	Integrated equation
Gompertz	$G = -a\ln(S) + b$	$S = S_\infty \exp\left[-\exp - a(t + t_0)\right]$
		or $S = S_\infty \exp\left[-b\exp(-at)\right]$
Logistique	$G = -aS + b$	$S = S_\infty \left[1 + \exp - b(t + t_0)\right]^{-1}$
Von Bertalanffy	$G = a\frac{1}{S} - b$	$S = S_\infty \left[1 - \exp - b(t + t_0)\right]$

G = specific growth rate; S = mass at time t; a = slope (in the Ford-Walford graph) of growth rate slowdown; b = specific growth rate at time t = 0 (when the mass equals 1 mg); S_∞ = maximum mass predicted by the model; t_0 = integration constant.

of the earthworms) confirms the choice of the model and gives the appearance of the growth curve. For this study, this adjustment was made using the PASS 3.12 software. Pairwise comparisons of the growth parameters determined at the level of the different cultivation soils were carried out using the non parametric Kruskal-Wallis test using the STATISTICA 7.1 software.

2.5.2. Bioaccumulation Factors

The bioaccumulation factors (BAF) of pollutants by earthworms in different cultivation soils was determined by the method described by [24]. This factor assessed the ability of the worms to accumulate the different pollutants contained in farming environments.

The BAF was calculated by the following relation:

$$\text{BAF} = \frac{\text{C earthworms}}{\text{C soil}}$$

C earthworms: concentrations of pollutants in earthworms (tissues and gastrointestinal tract) in mg/g; C soil: concentrations of pollutants in soil in mg/g.

3. Results

3.1. Growth of Earthworms

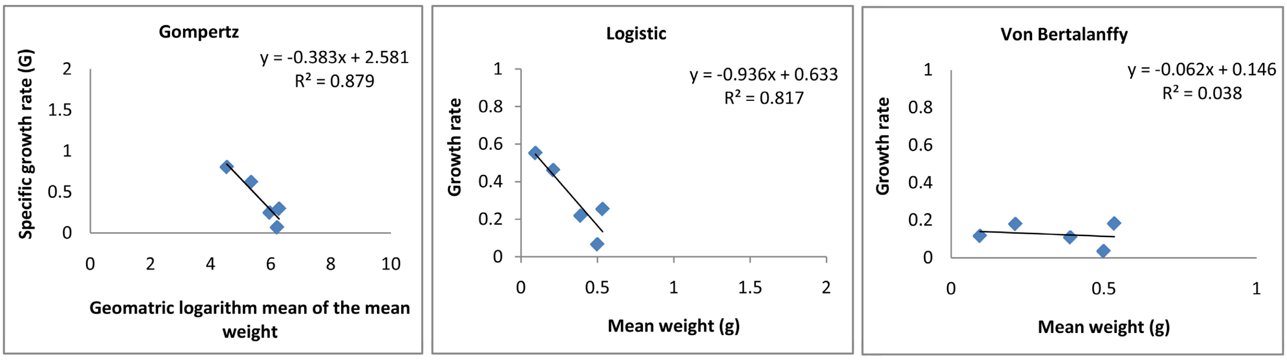
The Ford-walford chart was used to describe the growth of *M. omodeoi* in different livestock soils according to different growth models, including the Gompertz model, the logistic model and the Von Bertalanffy model (**Figures 2(a)-(f)**). The Gompertz model was chosen because it showed the highest determination coefficients (R^2) in all cultivation soils (**Table 2**). The growth parameters resulting from this model are shown in **Table 3**. Furthermore, the data (the masses measured every 2 weeks) of the different cultivation soils adjust relatively well to the Gompertz model (**Figure 3**).

The Gompertz equations corresponding to the growth of earthworms in the different cultivation soils are the following:

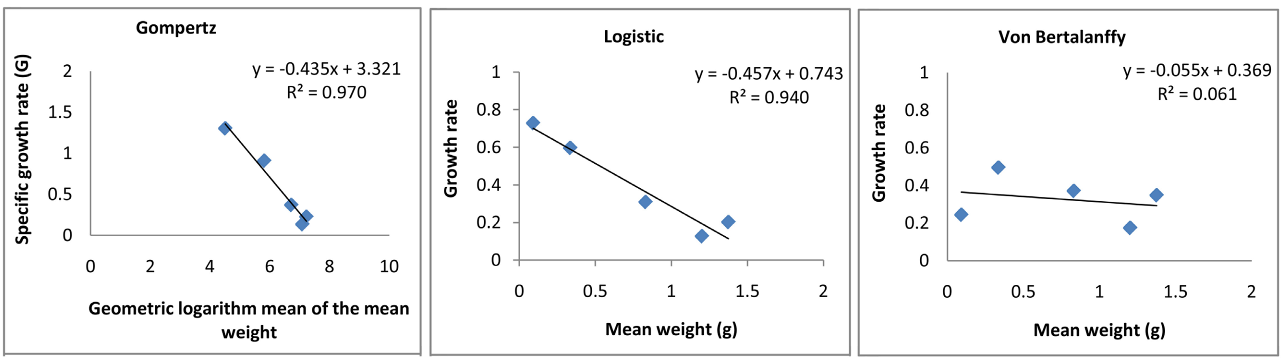
Table 2. Determination coefficients (R^2) of growth models (Gompertz, Logistique and Von Bertalanffy).

Cultivation soils	R^2 of the Gompertz model	R^2 of the Logistics Model	R^2 of the Von Bertalanffy model
Soil 0	**0.879**	0.817	0.038
Soil 50	**0.97**	0.94	0.061
Soil 100	**0.985**	0.879	0.266
Soil 150	**0.996**	0.911	0.258
Soil 200	**0.966**	0.81	0.47
Witness	**0.926**	0.675	0.914

Soil 0: Soil removed immediately after the sidewalk; **Soil 50:** Soil taken 50 meters from the sidewalk; **Soil 100:** Soil removed 100 meters from the sidewalk; **Soil 150:** Soil taken 150 meters from the sidewalk; **Soil 200:** Soil removed 200 meters from the sidewalk; **Witness:** Soil taken from the Lamto reserve.



(a)



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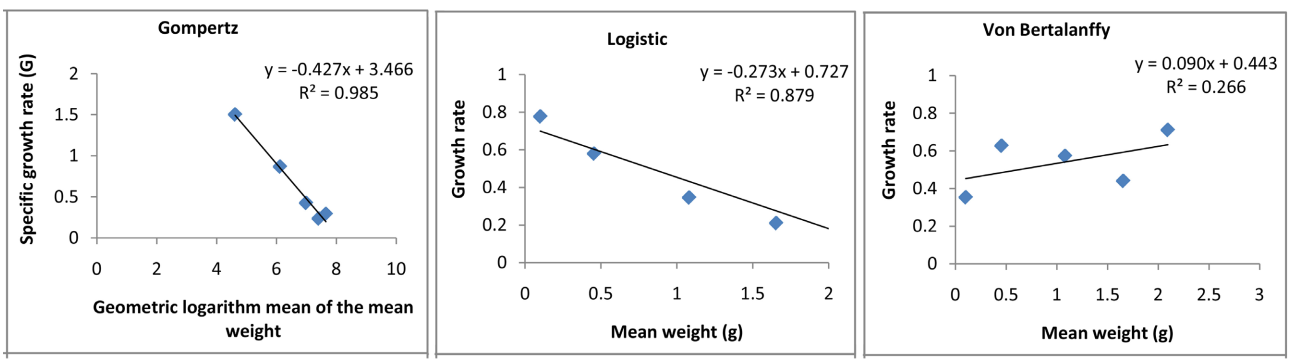

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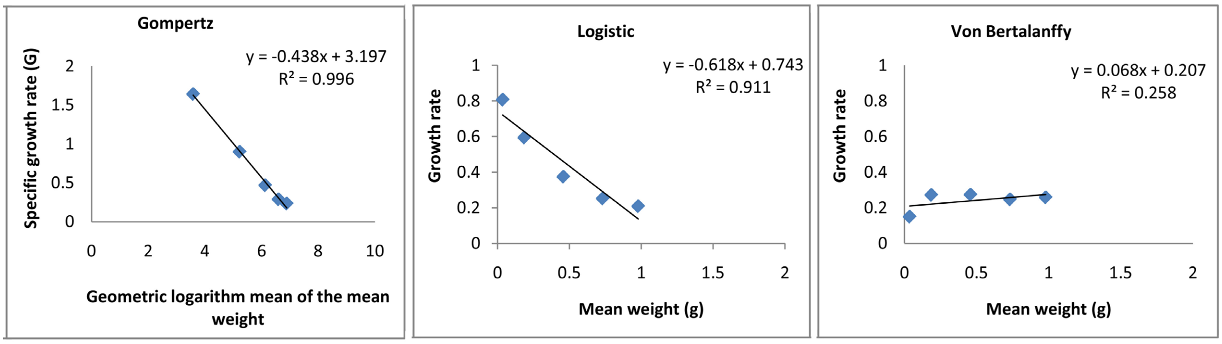
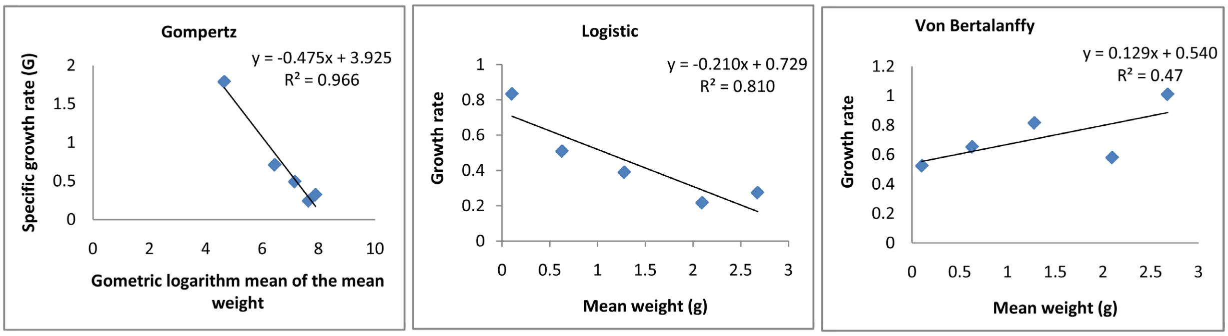


(d)



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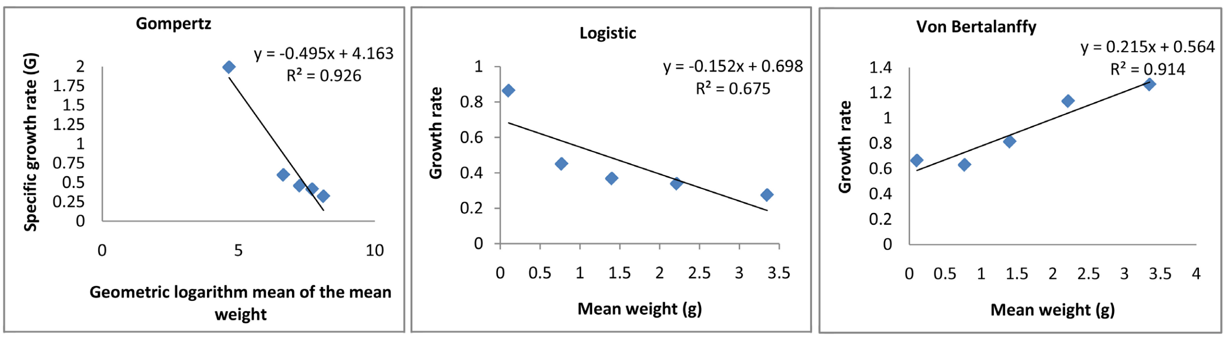
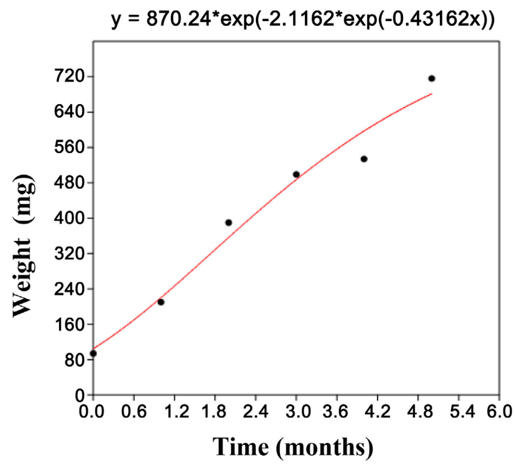


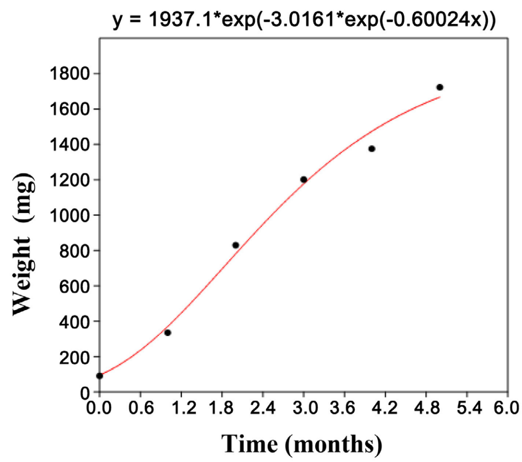
(f)

Figure 2. (a) Adequacy of growth points to different growth models in the FORD-WALFORD graph for soil 0 m; (b) Adequacy of growth points to different growth models in the FORD-WALFORD graph for soil 50 m; (c) Adequacy of growth points to different growth models in the FORD-WALFORD graph for soil 100 m; (d) Adequacy of growth points to different growth models in the FORD-WALFORD graph for soil 150 m; (e) Adequacy of growth points to different growth models in the FORD-WALFORD graph for soil 200 m; (f) Adequacy of growth points to different growth models in the FORD-WALFORD graph for witness.

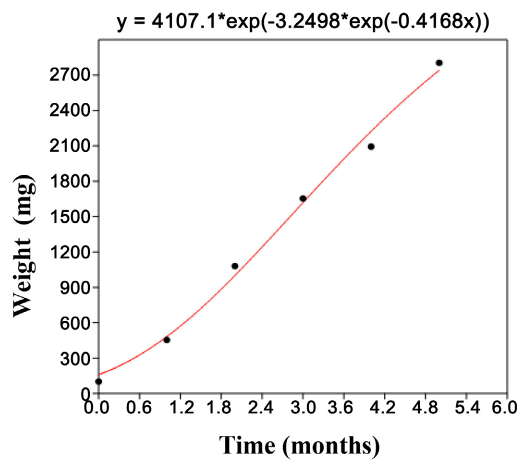
- $S = 870.24e^{\left(-2.116e^{(-0.432t)}\right)}$ For the soils of distance 0 m;
- $S = 1937.1e^{\left(-3.016e^{(-0.600t)}\right)}$ For the soils of distance 50 m;
- $S = 4107.24e^{\left(-3.25e^{(-0.417t)}\right)}$ For the soils of distance 100 m;
- $S = 1678.1e^{\left(-3.492e^{(-0.473t)}\right)}$ For the soils of distance 150 m;
- $S = 6223.4e^{\left(-3.353e^{(-0.364t)}\right)}$ For the soils of distance 200 m;
- $S = 1226.1e^{\left(-3.814e^{(-0.271t)}\right)}$ for witnesses.



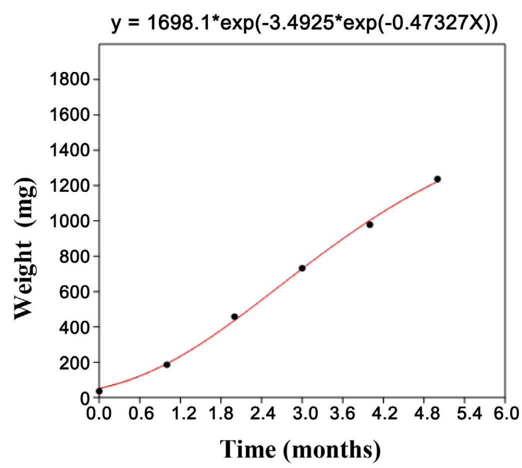
Growth pattern of the *Millsonia omodeoi* in soil at 0 m from toll highway



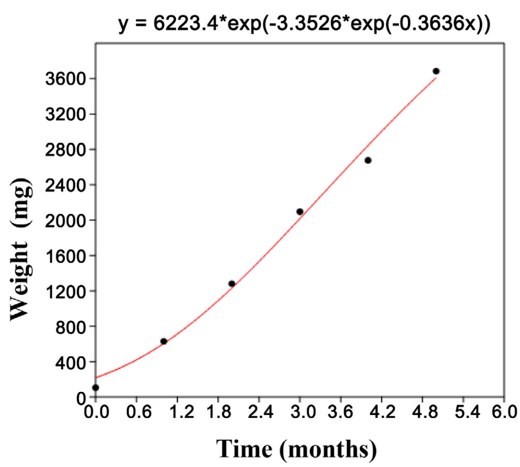
Growth pattern of the *Millsonia omodeoi* in soil at 50 m from toll highway



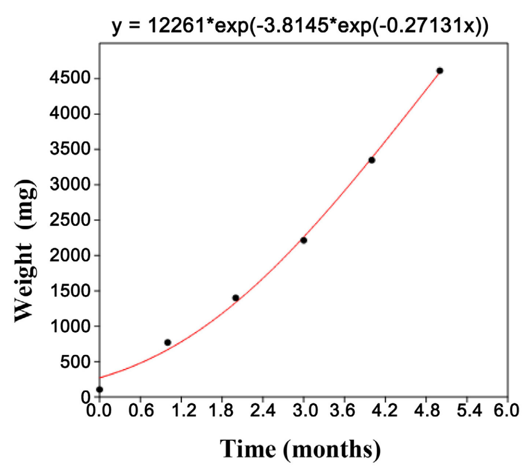
Growth pattern of the *Millsonia omodeoi* in soil at 100 m from toll highway



Growth pattern of the *Millsonia omodeoi* in soil at 150 m from toll highway



Growth pattern of the *Millsonia omodeoi* in soil at 200 m from toll highway



Growth pattern of the *Millsonia omodeoi* in the control soil (Soil of the Lamto reserve)

Figure 3. Adjustment of the growth of *Millsonia omodeoi* to the Gompertz model.

Table 3. Growth parameters of the Gompertz model.

Cultivation soils	*a*	*b*	S_∞	Number of times S_∞ is observed
Soil 0	−0.432[c]	2.116[c]	870.24[c]	0
Soil 50	−0.600[d]	3.016[c]	1937.1[c]	0
Soil 100	−0.417[c]	3.25[c]	4107.1[c]	0
Soil 150	−0.473[c]	3.492[c]	1698.1[d]	0
Soil 200	−0.363[c]	3.352[c]	6223.4[d]	0
Witness	−0.271[c]	3.814[d]	12261[d]	0

NB: Values followed by same letters in a column are not significantly different (P > 0.05). ***a*:** the slope of slowing the growth rate as a function of the average mass; ***b*:** the specific rate of growth at time $t = 0$; S_∞**:** maximum predicted average mass; **Soil 0:** Soil removed immediately after the sidewalk; **Soil 50:** Soil taken 50 meters from the sidewalk; **Soil 100:** Soil removed 100 meters from the sidewalk; **Soil 150:** Soil taken 150 meters from the sidewalk; **Soil 200:** Soil removed 200 meters from the sidewalk; **Witness:** Soil taken from the Lamto reserve.

The Kruskal-Wallis test carried out for the pairwise comparison of each of the growth parameters obtained (Table 3), shows that:

- For parameter a, only witness and soils of distance 50 meters differ significantly (p = 0.0028);
- For parameter b, only witness and soils of distance 50 meters differ significantly (p = 0.00006);
- For the S_∞ parameter, the differences between the soils are greater: the soils of the distance 150 meters differ from those of the distance 0 m (p = 0.0287); (p = 0.0003, p = 0.004, respectively) and witness differ from the distances 0, 50 and 100 (p = 0.00000001, p = 0.0000002, p = 0.0249, respectively).

Only the S_∞ parameter (the maximum mass reached at maturity) better describes the growth of *M. omodeoi* in the soils of the toll highway borders. However, this maximum mass was not reached on any of the soils during the 5 months of cultivation. Furthermore, no reproduction was observed between the earthworms during the 5 months of cultivation.

3.2. Variation in Heavy Metals Content in Soils and Earthworms during Cultivation

Five (05) heavy metals, including chromium (Cr), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn) were detected and quantified in the different soils before experimentation. Concentrations of these different heavy metals in soils ranged from 1.3 to 5.1 mg/kg for Cr; From 4.3 to 14.3 mg/kg for Cu; From 0.9 to 9.6 mg/kg for Ni; From 21.8 to 50.6 mg/kg for Pb; From 6.3 to 27.7 mg/kg for Zn. Otherwise for all these substances, the concentration is higher as the site of soil sampling is close to the toll highway.

At the beginning of the cultivation period, the average concentrations of the different heavy metals contained in the cultivation soils are higher than those of the earthworm tissues. On the other hand, at the end of cultivation (5th month), a decrease in the mean concentrations of these different polluting substances in the cultivation soils was observed, whereas those contained in the tissues of earthworms increased (**Figures 4(a)-(f)**).

3.3. Accumulation of Heavy Metals by *M. omodeoi*

Within the cultivation soils, the bioaccumulation factors of the identified heavy metals vary from 0.818 to 1.045 for Cr; from 2.901 to 3.763 for Cu; from 1.038 to 1.963 for Ni; from 0.906 to 1.288 for Pb; from 1141 to 2801 for Zn (**Table 4**). Except the bioaccumulation factors of the chromium at soil levels of 150 m (0.945) and 200 m (0.818), the lead at soil levels 200 m (0.906), in the cultivation soils, bioaccumulation factors of the different heavy metals are generally, greater than 1. In general, BAF of all heavy metals are higher in soil at 0 m, and gradually decrease from soils 0 m to soils 200 m. For witnesses, only the bioaccumulation factor of copper (3.763) was determined, the other heavy metals not being detected in this soil at the end of the cultivation.

4. Discussion

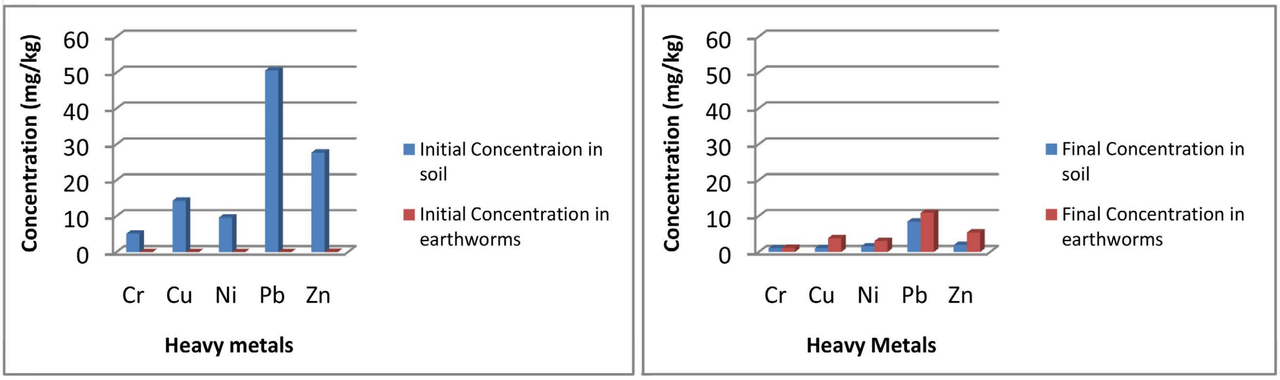
4.1. *M. omodeoi* Growth

The Ford-Walford technique that was used to measure growth parameters calls for three observations. First, this technique discriminates between different models describing growth and chooses the most appropriate. Second, the parameters determined can be compared statistically between the different groups of individuals. Thirdly, since the age of earthworms is difficult to determine in natural populations, this technique takes the mass as an independent variable

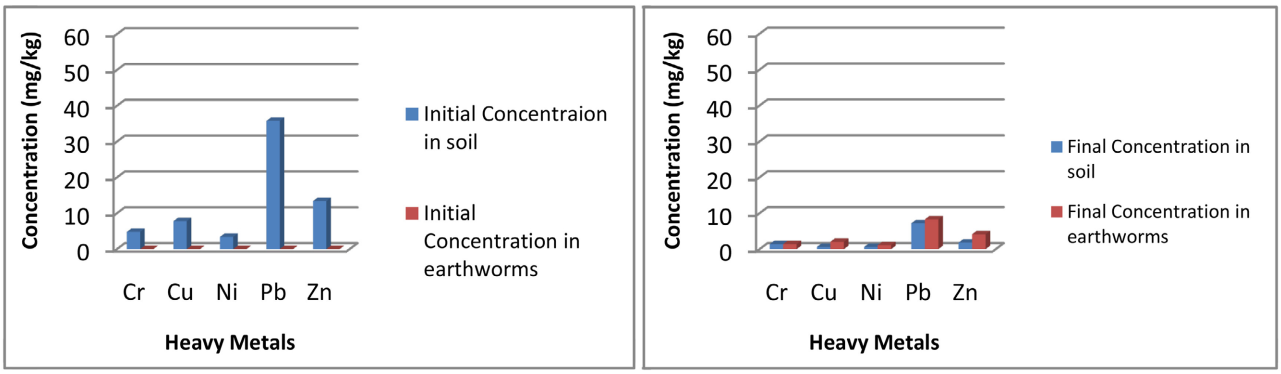
Table 4. Bioaccumulation factors in the cultivation soils

Heavy Metals / Cultivation soils	Cr	Cu	Ni	Pb	Zn
Soil 0	1.045	3.613	1.963	1.288	2.801
Soil 50	1.02	3.274	1.755	1.15	2.274
Soil 100	1.036	3.666	1.88	1.125	2.19
Soil 150	**0.945**	2.895	1.317	1.098	1.966
Soil 200	**0.818**	2.901	1.038	**0.906**	1.141
Witness	-	3.763	-	-	-

Cr: chromium; **Cu:** copper; **Ni:** nickel; **Pb:** lead; **Zn:** zinc; **Soil 0:** Soil removed immediately after the sidewalk; **Soil 50:** Soil taken 50 meters from the sidewalk; **Soil 100:** Soil removed 100 meters from the sidewalk; **Soil 150:** Soil taken 150 meters from the sidewalk; **Soil 200:** Soil removed 200 meters from the sidewalk; **Witness:** Soil taken from the Lamto reserve.


Concentration (mg/kg)
60
50
40
30
20
10
0
Cr Cu Ni Pb Zn
Heavy metals
Initial Concentraion in soil
Initial Concentration in earthworms
Concentration (mg/kg)
Cr Cu Ni Pb Zn
Heavy Metals
Final Concentration in soil
Final Concentration in earthworms

(a)


Concentration (mg/kg)
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50
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30
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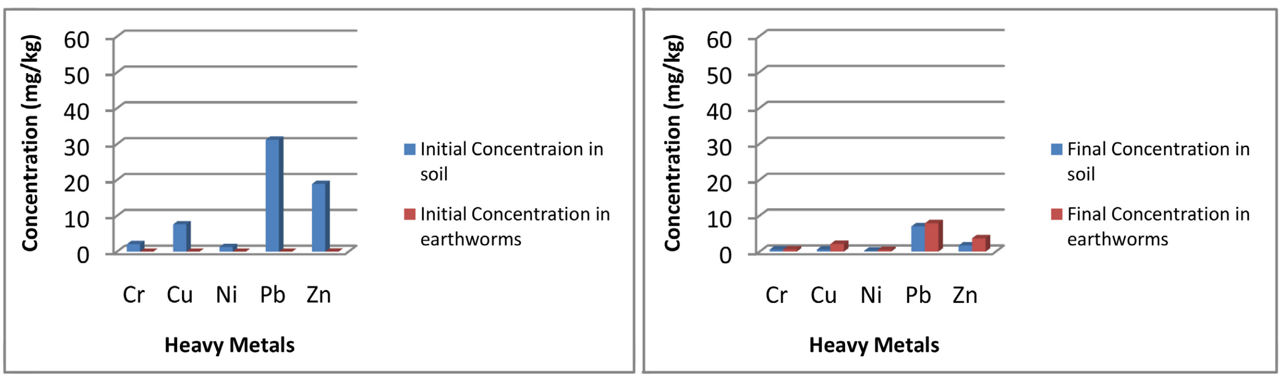
0
Cr Cu Ni Pb Zn
Heavy Metals
Initial Concentraion in soil
Initial Concentration in earthworms
Concentration (mg/kg)
Cr Cu Ni Pb Zn
Heavy Metals
Final Concentration in soil
Final Concentration in earthworms

(b)


Concentration (mg/kg)
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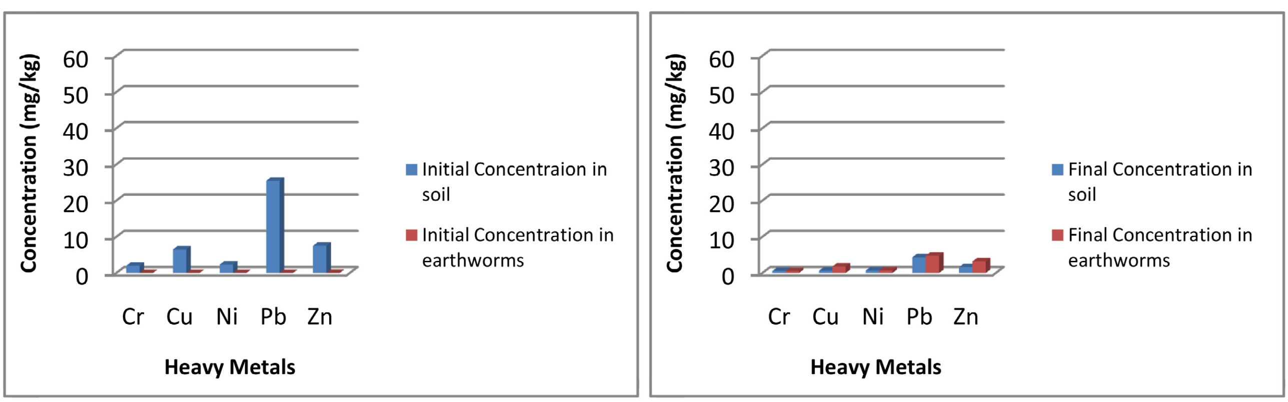
0
Cr Cu Ni Pb Zn
Heavy Metals
Initial Concentraion in soil
Initial Concentration in earthworms
Concentration (mg/kg)
Cr Cu Ni Pb Zn
Heavy Metals
Final Concentration in soil
Final Concentration in earthworms

(c)


Concentration (mg/kg)
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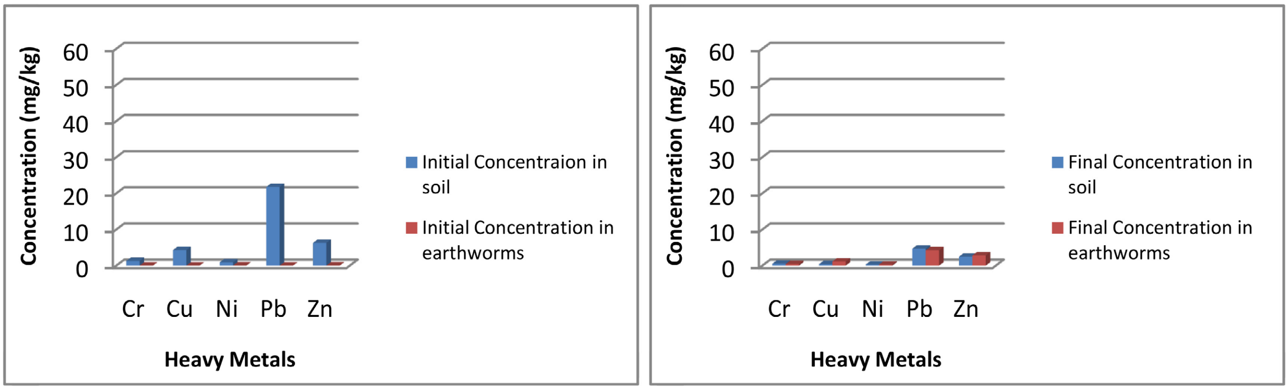
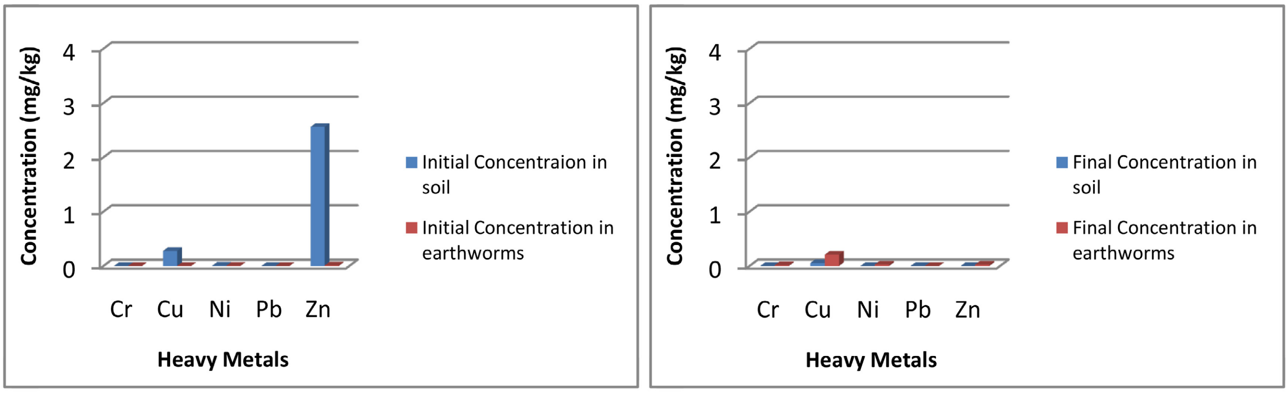
40
30
20
10
0
Cr Cu Ni Pb Zn
Heavy Metals
Initial Concentraion in soil
Initial Concentration in earthworms
Concentration (mg/kg)
Cr Cu Ni Pb Zn
Heavy Metals
Final Concentration in soil
Final Concentration in earthworms

(d)



(e)



(f)

Figure 4. (a) Concentrations of heavy metals in soils and earthworms at the beginning and at the end cultivation (Soil 0 m); (b) Concentrations of heavy metals in soils and earthworms at the beginning and at the end cultivation (Soil 50 m); (c) Concentrations of heavy metals in soils and earthworms at the beginning and at the end cultivation (Soil 100 m); (d) Concentrations of heavy metals in soils and earthworms at the beginning and at the end cultivation (Soil 150 m); (e) Concentrations of heavy metals in soils and earthworms at the beginning and at the end cultivation (Soil 200 m); (f) Concentrations of heavy metals in soils and earthworms at the beginning and at the end cultivation (Control soil).

[23]. It is not necessary to follow the growth until reaching the maximum size or to collect (in the case of natural individuals) with several periods. Environmental factors affecting growth can be controlled by seasonal collections, provided that either cohorts can be recognized or that the age of individuals can be estimated [23]. In the different cultivation environments, the growth of *M. omodeoi* follows the Gompertz model. Furthermore, the data fit well with this model. These results indicate that the population of earthworms grows first exponentially and then finally stabilizes with the time, approaching a ceiling value [25]. Among the growth parameters determined, the maximum mass reached at maturity, which showed significant variations in the different cultivation soils, better characterizes the growth of earthworms. Therefore, unlike the soils of the first 100 meters of the roadway, earthworms have a growth capacity which undergoes a major evolution from soils located at 150 meters. The observed differences in the growth of the earthworms, which have been raised under identical conditions, could probably be due to the pollutants contained in the different cultivation

soils. Indeed, the concentrations of the different heavy metals determined in the cultivation soils decrease as a function of the distance separating them from roadway. Thus, the immediate proximities of the roadway, which have been indicated as the areas of greatest influence of these heavy metals, could correspond to the first 100 meters as indicated by [26] and [27]. This would have led to the achievement of low maximum masses in the soils concerned, in contrast to the most remote soils and witness in which the heavy metals contents are lowest. For these earthworms, the fact that maximum predicted mature masses have not been reached on any of the soils during the cultivation period could be related to their longlife cycle [19] [28]. This indicates that the *M. omodeoi* have a K-type demographic strategy, as revealed by [19] in his studies of the determination of earthworms in the Lamto savannah. This author has considered the Megascolidae, of which the *M. omodeoi* belong, as strategists K because of their large size and long life cycle.

4.2. Bioaccumulation of Heavy Metals

The heavy metals have undergone a transfer of soil to the tissues of the earthworms during the cultivation period. Furthermore, this transfer was characterized by bioaccumulation factors (BAF), generally greater than 1. This expresses an important capacity of the *M. omodeoi* to accumulate the determined heavy metals. According to Van Hook [29], there is accumulation of substances (heavy metals) by earthworms when the ratio of the concentration of substances in the tissues to the concentration of substances in the soil is greater than 1. The capacity for accumulation of heavy metals by earthworms is defined by the following gradient: Cu > Zn > Ni > Pb > Cr. Indeed, the process of bioaccumulation of pollutants by earthworms depends on many parameters, such as the type of substance and its speciation, the physical and chemical properties of the soil, the season, the distance to the source of contamination [30] [31]. According to [32], earthworms can have a considerable difference in the content of substances in their tissues, mainly because of their mode of feeding in substrates and their physiological metabolisms. For the gradient thus obtained, the high accumulation capacity of Cu and Zn by the *M. omodeoi* could be related to the fact that these substances are required for cells in the normal metabolic pathways [33] [34]. The low capacity of accumulation of Pb and Cr by earthworms may be related to the fact that these substances do not have essential cellular function or are toxic and probably eliminated in the event of significant accumulation [34]. Bioaccumulation factors as well as concentrations of the different heavy metals decrease as one moves away from the roadway. This indicates that the accumulation of the different heavy metals by the *M. omodeoi* would depend on their content in soils. This result corroborates those of [33] and [31], which showed that the accumulation of pollutants by earthworms was relative to the level of soil contamination. The *M. omodeoi* can therefore be excellent bioindicators for the pollution of soils along the highway.

5. Conclusion

The application of the Ford-walford technique revealed that the Gompertz model is the most suitable to describe the growth of the *M. omodeoi*. This growth is characterised by a significant increase in the maximum mass of these earthworms from soils located 150 meters from the roadway and a demographic strategy of type K. Indeed life cycle of this species is long and its population densities vary slowly. During this growth, the *M. omodeoi* has a high heavy metals accumulation capacity.

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Conflicts of Interest

The authors have no conflicts of interest to disclose regarding the publication of this paper.

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