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Research Article

CONTRIBUTION TO THE VERMICULTURE TECHNIQUE IN THE KIKWIT REGION OF THE DEMOCRATIC REPUBLIC OF CONGO

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Abstract

The biological component of the soil provides ecosystem services that are considered today as a key to the implementation of ecologically intensive agriculture. In order to improve the productivity of the very poorly fertile and particularly acidic soils in the hinterland of the city of Kikwit in the DRC, the present study aims to produce earthworms in the pedoclimatic conditions of this area. The results obtained in this study show that earthworm production can be ensured without concern by the droppings of herbivores, including rabbit droppings. We observed in rabbit droppings on the 84th day of cultivation an average of 83 individuals, 3.6gr and 23.7cm per individual, respectively for abundance, weight and length. The average results of the environmental parameters observed in the rabbit droppings on the 84th day of culture were 25.01°C; 79.63% and 7.2, respectively for temperature, humidity and pH. Thus, rabbit droppings present an ideal substrate for earthworm rearing under the conditions of the Kikwit area. However, further study on the economic evaluation of this technology seems to be necessary before any promotion.

Keywords: Earthworms, Vermiculture, Organic substrates, Ecological agriculture, Kikwit.

INTRODUCTION

Slash-and-burn agriculture, the main agricultural practice in tropical regions, including overexploitation of soils, leads to their degradation and decrease in productivity and generates low yields per hectare. It promotes significant nutrient loss and is therefore not considered a sustainable agricultural practice (Brown et al., 1994; Blanchart *et al.,* 2008). In the vicinity of the town of Kikwit in Kwilu Province, DRC, the soils are acidic ferralitic, highly desaturated, poor in organic matter and available N and P. Indeed, the high content of iron and aluminum sesquioxides in these types of soils gives them a strong fixing power of available soil P (Mbala, 1990; Ratsiatosika, 2018). Thus, it is necessary to provide fertilizers to compensate for this low fertility. Soil fertility depends mainly on the quantity and quality of organic matter transformed by decomposer organisms. The efficiency of decomposers can be characterized by the rate of transformation of organic matter, which depends on environmental factors such as temperature, moisture, and the characteristics of the material to be decomposed (Francis *et al.,* 2003). Earthworms in the soil, play a primary role in the transformation of organic matter (Lavelle *et al.,* 1998; Francis *et al.,* 2003; Milau, 2016). Earthworms as decomposers facilitate the release of mineral elements through the breakdown of organic matter. They not only affect the availability of nutrients to plants, but also influence the entire rhizosphere (Darwin, 1881; Scheu, 2003; Blanchart *et al.,* 2008). If the manipulation of earthworms can be considered as an effective technique to alleviate the lack of soil fertility, the implementation of vermiculture can combine several benefits, including ensuring a protein intake in several animals raised, ensuring environmental protection through the management of household waste, carrying out vermicomposting and sourcing bait for fishing to improve fisheries and fish production (Djemel and Benlatreche, 2018).

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Indeed, the high protein content, from 55 to more than 70% in relation to the dry matter of earthworms, makes it a very interesting feed, not only for poultry but also for pigs. The content of essential amino acids, including those containing sulfur, is high: for example leucine (8.2%), lysine (7.5%), valine (5.2%), isoleucine (4.7%), threonine (4.7%), methionine (1.8%), the percentages representing the relative contents in relation to the total content of amino acids (Edwards, 1996) The results of several experiments have demonstrated the nutritional value of earthworms. Feed conversion ratios are superior: weight gain in poultry is achieved with lower amounts of earthworms compared to other feeds (Francis *et al.,* 2003, Byambas, 2020). According to the very recent work of Byambas, 2020, the nutritional intake of 100 g of earthworm dry matter represents 65.7g of crude protein, 4.3g of lipids, 1.9g of crude cellulose, 10.5g of ash, 17.5g of non-nitrogenous extract, 2997 kj of metabolizable energy AN, 0.4g of sodium, 0.5g of calcium, 0.6g of potassium. In addition to protein, earthworms are a source of total fatty acids (6.6 to 10.5 mg/g), iron (1050 to 2990 µg/g) and many other nutrients for livestock (Djemel and Benlatreche, 2018, Byambas, 2020). Vermiculture represents an appropriate technology to valorize crop residues as well as other plant waste mixed with animal manure from the farm. Different vermiculture systems have been designed to biologically treat organic waste and produce large quantities of vermicompost, which provides a homogeneous and effective amendment to increase soil fertility using available organic matter (Kita mbala *et al.,* 2017; Djemel and Benlatreche, 2018). In addition, vermicompost has much lower levels of pathogenic microorganism contamination than conventional compost (Francis *et al.,* 2003, Djemel and Benlatreche, 2018). Depending on the species used, the density, temperature, and thickness of the substrate can vary greatly and affect earthworm growth and reproduction (Morin, 1999). To facilitate its development, reproduction and growth, the earthworm needs a temperature between 25° and 28°C as well as a pH of 6.4 to 7.0 Humidity must be maintained between 70 and 85% by watering whenever necessary (Francis *et al.,* 2003; Munroe, 2010; Benlatreche, 2018). The majority of earthworms, feed on organic matter present on the soil surface (Bouché, 1972a; Lavelle, 1978; Blanchart, 2006). They can feed on the droppings of other soil organisms. However, a suitable feed is ground seeds or cereal by-products such as wheat germ, wheat bran, corn and oat flakes (Munroe, 2010; Byambas, 2020). In animal husbandry, feed can be provided to earthworms 1 to 2 times per week. The amount fed should be equal to the biomass of worms present. These authors report that microorganisms (bacteria) are a part of the earthworm diet. The food is sucked in through the mouth and the muscular pharynx, then stored in the crop and ground into very fine particles in the gizzard. The absorption of nutrients takes place in the gut and the unabsorbed portion continues to the anus (TRAN-VINH-AN, 1973; Byambas, 2020). The organic matter is mineralized in the gut into a form that can be absorbed by plants. Vermiculture is now well established in many parts of the world. But in most cases, in Africa, the literature is limited to a few works carried out in Benin (Anonymous, 1983), Cameroon (Rouschop, 1984), Ivory Coast (Lavelle, 1978 and Blanchart, 2006), Madagascar (Ratsiatosika, 2018), Gabon (Byambas, 2020), etc. To our knowledge, earthworm farming has never been the subject of an in-depth biological study in the Democratic Republic of Congo in general, except for a few works showing their importance (Anonymous, 1992; Kitambala *et al.,* 2017), their preliminary study (Pwema, 1996) and their biodiversity (Milau, 2016). However, in Kikwit, Kwilu Province in particular, data are almost non-existent. Among the constraints associated with this technology is the mastery of optimal rearing conditions. In the present study, we propose to determine the optimal environmental conditions for rearing and to choose a food substrate capable of ensuring good growth and reproduction of earthworms.

MATERIALS AND METHODS

The biological material consisted of earthworms collected in the agro ecosystems and on the lawn located at the University of Kikwit next to the amphitheater. Five organic substrates were compared including topsoil, *Tithonia diversifolia* leaves, chicken droppings, rabbit droppings and sheep droppings. Several equipments and laboratory materials were used to prepare the precomposting and rearing media, including plastic jars, mosquito netting, Tung Hsin brand balance, fine tweezers, Enaus Belgium brand oven; mimmert brand desiccator etc. To collect the earthworms in the field and during the observations, an equipment consisting of formalin diluted to 40%, alcohol, quadrat, water, watering can, syringes, scale, pH tester, etc. The culture of earthworms was carried out on the premises of the University of Kikwit, in a room of the guest house of the professors, located at 05°02' 184"South latitude and 018°49'326"East longitude at 490m of altitude. The town of Kikwit is located at 18°48' East longitude, 05°02' South latitude and at an altitude of 480 m (Fehr, 1990; Lubini and Kusehuluka, 1990. The figure below shows the study area. The Figure 1 below shows the map of the study sites. The city of Kikwit and its hinterland enjoy a humid tropical climate with a sub-equatorial trend and a three-month dry season. This region falls within the AW3 climate type according to the 1936 KOPPEN classification (Nicolai, 1963; Fehr, 1990; Lubini and Kusehuluka, 1990; Masens, 1997). The climate alternates between a nine-month wet season from mid-August to mid-May and a three-month dry season from mid-May to mid-August. There is usually a dry season inflection period between January 15 and February 15.

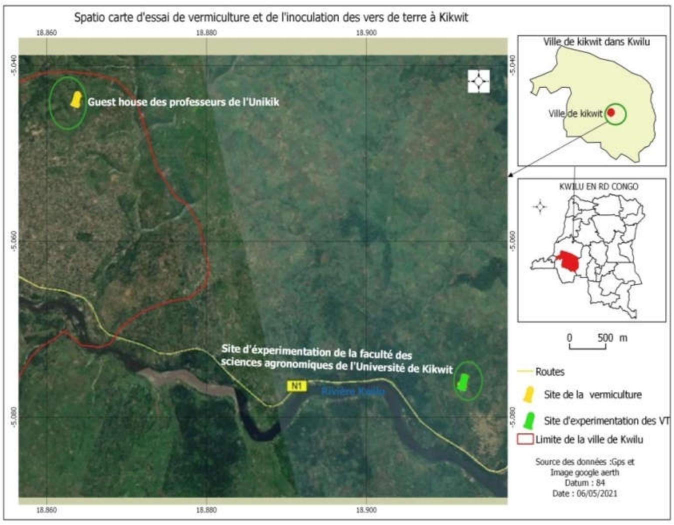

Figure 1. Map of the study area

The average rainfall varies from 1200 to 1500mm per year. The average temperature is between 24 and 25°C and the relative humidity is 85% (Nicolai, 1963; Fehr, 1990; Masens, 1997). The soil in the Kikwit area is ferralitic, characterized by a high proportion of Kaolinite associated with iron and aluminum sesquioxides. The soil texture is sandy-clay with an average total sand content of about 80.6%. The low clay content (colloids) makes this soil vulnerable to erosion (Mbala, 1990). The original vegetation cover of the hinterland of the city of Kikwit has been completely modified and destroyed as a result of anthropic pressures (Nicolai, 1963; Fehr, 1990; Lubini and Kusehuluka, 1990; Masens, 1997). Many methods have been developed to optimize earthworm extraction, (Cluzeau *et al.,* 1999; Peres, 2003; Pelosi, 2008). The collection of earthworms in this study was performed using the method described by Bouché (1972a) and adapted by Cluzeau *et al.,* (1999) and used by Milau (2016), which combines the chemical method and manual sorting. Chemical extraction was performed using 20 ml of 0.40% formalin diluted in 10 liters of water spread over a 1m2 area delimited by a wooden quadra. Each time, three applications were made at the same place, spaced 15 minutes apart. The earthworms irritated by the formalin came out of their galleries and were then picked up by fine tweezers to keep them in jars containing moist soil before they were transported to the culture media. Some individuals extracted by this method are intoxicated, become too weak and may die (Bouché and Gardner, 1986; Peres, 2003; Milau, 2016).

Thus, the chemical method was supplemented by manual sorting applied to a soil monolith with a volume of 0.0125m3 (0.25m x 0.25m x 0.20m deep). Studies have highlighted the effectiveness of manual sorting as satisfactory up to 93% for total abundance of individuals (Peres, 2003;Ratsiatosika, 2018). The presence of castings had been used as an indicator for the choice of sites to be retained for the collection of earthworms, especially since we were targeting earthworms that could influence agroecosystems. The experimental set-up was carried out in randomized complete blocks including 3 repetitions and 5 treatments. We experimented with 5 growing media, one containing potting soil (TE) and serving as a control and 4 others based on potting soil enriched with organic plant matter, including *Tithoniadiversifolia* leaves (FT), and rabbit droppings (CL), sheep droppings (CM) and chicken droppings (FP) as organic animal matter. A total of 15 plastic jars were used to accommodate the different treatments.

Preparation and precomposting of the rearing media

The different substrates prepared were previously sorted and separated from impurities and mixed in a ratio of 2:1:1, i.e. 2 units of substrates or 2 kg, 1 unit of potting soil or 1 kg and 1 unit of sawdust or 1 kg, considered as bedding. The mixture was placed in jars, arranged in three rows (replicates) of five, for a total of 15 jars placed on two long tables at 80 cm from the ground. The jars had holes in both sides and the substrates were placed on the screen cloth to allow aeration and prevent the worms from getting out. The lids were also punctured and the top was replaced with the mosquito net to ensure aeration. The culture media thus prepared underwent a 3 weeks precomposting with watering of 200 ml of water each every four days and a stirring, to reduce large amounts of heat which is harmful to earthworms. Previous studies show that the amount of food an earthworm is able to ingest on a daily basis varies primarily with the state of decomposition of the food (Munroe, 2005).

Cultivation of earthworms

Many scientists have pointed out that earthworms reproduce rapidly and double their population every 60-90 days if they keep the starting stocking density at 2.5kg.m-2, consume adequate food, evolve in humidity levels between 70-90% and if the temperature is maintained between 15°C and 30°C (Edward and Lofty, 1977; Gaddie *et al.,* 1985; Munroe, 2010). In this study, we had introduced 20g of earthworms, each weighing approximately 0.5g and measuring 5-10 cm long, into the substrates. We had watered our substrates with 200ml of water every four days to allow the animals to breathe well.

Harvesting and measuring the earthworms

The earthworms were harvested with fine tweezers every 21 days, successively on the 21st, 42nd, 63rd and 84th day of rearing. The choice of frequency was justified by the fact that from the deposition of cocoons to the presence of clitellum, which indicates sexual maturity, 21 days pass (Vigot and Cluzeau, 2014). At harvest, all contents were poured onto a large transparent bag and the worms were sorted by hand with forceps to determine their weight, length and number. Temperature and pH were measured by sticking the tip of the ST brand pH tester 2-5 cm deep for one minute into the culture substrates and then we moved on to the reading. While moisture was known by taking an average of 20g of fresh samples respectively at 5 and 10 cm depth in each organic substrate (P1). These fresh samples were oven dried at 105°C to a constant weight. Using well tared cans we weighed the dry samples (P2) after cooling in a desiccator. The relative humidity was calculated using the expression noted as follows:

Hr (%) = (P2 (f))/ (P1 (F)) x100

With Hr: relative humidity;
P1 (F): weight of the fresh sample or initial weight
P2 (f): weight of the dry sample or final or actual weight

In order to find the ideal environment for the culture of earthworms and the favorable conditions for growth, we used several statistical tests, in particular the Analysis of Variance (ANOVA) with one factor on the whole of the data at the significance level of 5% to check the homogeneity of the variances. The Student's t test was also used to compare the data.

RESULTS AND DISCUSSION

The different data collected in the field are grouped in tables 1, 2 and 3 below. In this study the results will concern the growth parameters, namely abundance (number), weight, length of earthworms, and environmental parameters such as temperature, humidity, pH and the quantity of castings observed in the culture substrates. Regarding the abundance of individuals, the ANOVA did not reveal significant differences between the average abundance of earthworms in the FP, FT and TE treatments on day 21 of cultivation (p=0.1252). The CL treatment had shown higher abundance, 39±2.8 and the CM treatment was in last position with 23.7±1.5. However, highly significant differences were revealed between the mean earthworm abundances at day 42 (p-value<0.001), while significant differences were obtained at day 63 (p-value<0.001) and day 84 (p-value<0.001) respectively up to 83±3 individuals (Table 1). Rabbit droppings had a higher average abundance than chicken droppings, followed by sheep droppings, Tithoniadiversifolia leaves, and soil (Table 1). This is explained by the fact that the consumption of nutrients in the topsoil by earthworms leads to their depletion, while in other substrates there was enrichment of nutrients through decomposition and mineralization of organic matter. Regarding the weight, the analysis of variance showed significant differences between the average weight of earthworms of different treatments on the 21st, 42nd, 63rd and 84th day of cultivation, at the threshold of 0.05%. Is that the highest weight was observed in CL medium on the 63rd and 84th day of culture, followed by FP and FT. The low weights were recorded in CM and lower in TE (Table 1).

This difference in weight may be due to the variation in physicochemical parameters of the culture substrates as well as the amount of organic matter administered to the earthworms as food resources. This would also be due to the fact that the earthworms had to take time to adapt to their rearing substrates before they could perform well. An average increase in earthworm weight was noted in Tithoniadiversifolia leaves on day 84 of rearing. This increase would explain that a prolonged precomposting could improve the performance of this substrate, by removing the bitterness contained in these leaves. The results also show that the highest weight was observed in the culture media based on organic materials of animal origin, especially rabbit droppings and chicken droppings. Considering the length of the earthworms, these results, visualize that on the 84th day of rearing, the highest average length was observed in CL, followed by FP, FT and CM and TE was in last position (Table 1). This observation would explain that these substrates had favorable nutrient and environmental conditions for the increase in length of earthworms. The FP was always second to the CL. This could be explained by the fact that chicken droppings are very rich in nitrogen, and their decomposition produces a lot of heat which creates stress for the earthworms. The rabbit droppings treatments gave a much more pronounced length than the other substrates. Regarding the environmental parameters, the ANOVA did not give significant differences between temperature, humidity and pH at the 0.05% threshold in the culture substrates. Nevertheless, the rabbit droppings, which performed well had presented the average temperature between 24 to 25°C, the average humidity observed varied from 74.9 to 91.3% and the average pH varied from 7.20 to 7.24 (Table 2). The analysis of variance shows that the average amount of castings produced according to the culture substrates is highly

Table 1. Average variation of earthworm growth parameters as a function of time

Parameters	number of earthworms (abundance)				weight of earthworms in (gr)				length of earthworms in (cm)			
Time	21st dr	42nd dr	63rd dr	84th dr	21st dr	42nd dr	63rd dr	84th dr	21st dr	42nd dr	63rd dr	84th dr
Treatments												
TE	29±2,5	31±4,1	29±4,1	25±1,5	0,2±0,03	0,2±0,04	0,18±0,04	0,13±0,01	6,46±0,16	6,44±0,11	6,39±0,04	6,34±0,04
FP	28±1,7	61±1,1	63±6,0	69±2	1,1±0,05	1,89±0,1	1,94±0,05	2,01±0,02	14,97±2,7	18,67±2,34	19,85±0,78	21,94±0,79
CL	39±2,8	75±4,5	77±4,1	83±3	0,76±0,02	1,48±0,2	3,03±0,32	3,62±0,31	16,45±1,8	19,43±2,6	21,6±0,58	23,76±1,44
CM	24±1,5	43±6	45±5,0	50±2	0,48±0,01	0,71±0,16	0,81±0,03	0,88±0,06	9,04±2	15,85±1,36	16,73±1,04	17±0,37
FT	24±1,5	45±5	47±1,1	54±8	0,38±0,08	0,62±0,25	1,1±0,28	1,56±0,35	12,1±1,5	13,69±0,83	16,27±0,44	18,84±1,72

Table 2. Average variation of environmental parameters in the culture substrates as a function of time

Parameter	Temperature (°C)				Humidity (%)				pH			
Time	21st dr	42nd dr	63rd dr	84th dr	21st dr	42nd dr	63rd dr	84th dr	21st dr	42nd dr	63rd dr	84th dr
Treatments												
TE	24,38±0,62	24,01±0,01	24,35±0,56	24,01±0,01	81,53±8,69	82,06±8,46	81,73±7,62	81,8±8,47	7,21±0,01	7,21±0,01	7,22±0,01	7,21±0,01
FP	24,64±0,26	25,08±0,1	24,51±0,51	24,57±0,38	91,16±7	91,36±8,54	91,26±7,09	90,46±7,32	7,21±0,01	7,22±0,01	7,21±0,01	7,22±0,01
CL	25,02±0,01	24,57±0,42	25,01±0,01	25,01±0,01	79,7±6,09	79,7±5,84	79,16±6,13	79,63±6,15	7,2±0,01	7,2±0,01	7,2±0,01	7,2±0,01
CM	24,82±0,37	24,35±0,57	24,51±0,5	24,6±0,1	87,9±2,7	87,7±3,04	87,93±3,09	87,83±2,83	7,23±0,01	7,24±0,01	7,24±0,01	7,23±0,02
FT	24,73±0,26	24,54±0,5	24,18±0,28	24,81±0,44	74,96±7,66	78,36±4,71	76,4±7,87	76,73±8,6	7,21±0,02	7,21±0,02	7,22±0,01	7,23±0,02

Table 3. Average amount of castings produced as a function of time

Time	21st day	42nd day	63rd day	84th day
Treatments				
TE	85,5±3,64	92,26±12,57	86,4±12,56	74,23±4,59
FP	84,3±5,75	184,1±18,14	190,13±18,17	207,16±5,95
CL	117,4±8,1	225,2±13,75	232,26±12,36	249,3±9,25
CM	59,6±4,36	130,5±15,02	136,2±15,18	150,16±6,15
FT	71,5±5,3	136,6±3,49	141,2±4,27	162,53±6

significant at day 21 of rearing (p-value = 0.001), day 42 (p-value<0.001), day 63, (p-value<0.001) and day 84 (p-value<0.001) at the 0.005 threshold (Table 3). Still in the rabbit droppings the earthworms produced a higher amount of castings than the other substrates, 249.3±9.25gr. The difference observed in the production of castings in the culture media would be due to the adaptation of the earthworms to the physicochemical parameters, the appreciation of the food substrates and especially to the presence of the quality and origin of the organic matter that constitutes the food source. The results obtained in this study showed that the abundance, weight and length of earthworms were elevated in culture substrates enriched with organic matter of animal origin, in this case in rabbit droppings. These results meet those of Gaddie *et al.,* 1985; Barcelo *et al.,* 1992; Pwema, 1996 and Munroe, 2010. According to these authors, earthworms easily increase their abundance, weight and length in animal droppings, especially those of rodent-herbivores, because the nitrogen content exceeded only by poultry manure, so it is nutritionally good and contains an excellent combination of vitamins and minerals; the perfect food for earthworms. The average abundance, average weight and average length of earthworms obtained on the 84th day of cultivation were respectively 83 individuals, 3.6 gr and 23.7 cm, observed in rabbit droppings. These results are somewhat higher than those of Reinecke and Venter, 1985, who found that at maturity earthworms can reach a weight ranging from 1.5 to 2.9 gr. But the results of the study are roughly consistent with those obtained by Pwema, 1996, who obtained 3.07 gr, 21.81 cm, and 70 individuals for mean weight, mean length, and mean abundance, respectively. The abundance of earthworms in the rabbit droppings at the end of the experiment led to an increase in the amount of castings produced, as they eat well, they produce abundantly the droppings. The environmental parameters, including temperature, humidity and pH associated with the organic substrates determine both the linear and weight growth of earthworms. The average results obtained on day 84 of culture for rabbit droppings are 25.01°C; 79.63% and 7.2 for temperature, humidity and pH respectively.

In fact, according to Reinecke and Viljaen, 1988, a better growth and reproduction of earthworms requires a temperature of 25°C, a humidity between 70 and 80% and a neutral pH of 7. While Pwema, 1996, who obtains the following results: 25.05 and 25.03°C for temperature, 70.19 and 79.66% for humidity and 7.2 and 7.2 for pH, respectively for guinea pig and rabbit droppings. We note that the results obtained in this study are roughly consistent with those of Pwema, 1996 and rabbit droppings show a better performance for earthworm rearing under the soil-climatic conditions of the study area. These results also agree with the statement of Rouschop, 1984; Reinecke and Venter, 1985; Pwema, 1996 and Munroe, 2010, that, the moisture of the environment where earthworms live affects food consumption and plays an important role on the maturation of these livestock. Many studies have been conducted around the world on vermiculture as reported by Francis *et al.,* 2003. These authors supported the results obtained in this work. They indicated that the tropical climate, where the study area is located, favors physiological activity and accelerates the development and reproduction of earthworms compared to climatic conditions in temperate regions. Exposure of earthworms to temperatures above 40°C results in high mortality rates. Moisture is an equally important environmental factor for earthworm emergence. Thus, Francis et al,2003 recognize that water reservoirs must be provided to allow regular wetting of growing substrates.

Conclusion

The objective of this work was to produce earthworms under the pedoclimatic conditions of the Kikwit region. The results obtained in this study allowed us to confirm that the edaphoclimatic conditions of this area are favorable for the growth and development of the biomass of earthworms both linear and by weight. The results also show that vermiculture is an inexpensive technology that can be successfully implemented in village settings with local materials. In Kikwit and its hinterland, all the conditions are met to ensure the growth and development of earthworms. For a good growth, it is necessary to maintain the rearing substrates at a temperature of 25.01°C, a humidity of 79.63% and a pH of 7.2. In this study, the droppings of rodent herbivores, in this case rabbit droppings, constitute an ideal substrate for earthworm culture. However, the economic benefit of vermiculture will depend on the production efficiency, the cost of the organic matter used as substrate and the infrastructure to be built.

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