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Original Article

Nutritional Status of Earthworm Castings from Diverse Ecological Habitats: A Comparative Study.

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Abstract

Casts produced by earthworms have high nutritional value and water holding capacity and act as an excellent soil ameliorating agent. In the present study, earthworm casts were collected from three different ecological habitats of Tumakuru by hand picking method and were analyzed for their nutritional status. The earthworm casts and surface soil samples were collected simultaneously from each study site (forest area, agriculture area and industrial area) in separate polythene-labelled bags. The collected samples were examined for physico-chemical parameters. The statistical values of all the parameters of castings and soil samples have shown that the worm cast collected from the forest site contains a significantly higher level of NPK than the worm cast collected from the other two study sites. Further, the nutritional quality of forest surface soil was higher than the other two sites. Among the three study sites the nutritional value of worm casts were in the order FS>AS>IS to their respective surface soil. However, the low nutritional value of vermicast in agriculture and industrial sites might be attributed to the application of chemical fertilizers and pesticides for cropping and dumping of industrial waste on the surface soil of respective sites. The study concludes that the nutritional status of earthworm casts contributes significantly to improving soil quality in a natural sustainable way.

Keywords: *Ameliorating agent, Casts, Earthworm, Nutritional value, Soil fertility.*

Introduction

Earthworms contribute to soil structure through their burrowing activities, which improves water movement, root development and nutrient cycling by enhancing soil aeration and infiltration. Earthworm casts (Vermicast) contain organic matter, microorganisms, and binding agents that improve soil fertility and aggregate stability, leading to increased nutrient availability and plant growth (Bhaskar, 2023). To understand more about the composition of earthworm cast and its surrounding soil, we need to analyze the physico-chemical and nutritional aspects of earthworm cast.

The earthworm casts provide 90-95% of the soil's nitrogen, 50% of its phosphorus, and 80% of its sulphur (Faniran & Areola, 1980).Soil fertility and productivity are enhanced by the rich humus in earthworm castings. Casts of earthworms exhibit clay's ability to bind and exchange cation nutrients and contain seven times more phosphorous, five times more nitrogen, eleven times more exchangeable magnesium, and one and a half times more calcium when compared with their surrounding soils (De vleeschaucler & Lal, 1981; Brady & Weil, 1999). The types of earthworms that inhabit different ecological habitats differ in their cast formation and their properties, as the nature of habitat and soil composition influence the nutritional values of earthworm casts. The casts of different earthworm species, belonging to different ecological categories, can vary in their nutrient

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concentrations, microbial community traits, and microstructural properties, which further affect soil fertility and carbon mineralization rates. Earthworm casts contribute to soil structure by shaping the porosity and coherence of soil, promoting soil water infiltration, and forming soil aggregates. They also contribute to nutrient cycling by excreting nutrient-rich mucus and releasing bacteria within casts (Jouni *et al.*, 2023). In agriculture, understanding casts composition and how it affects soil fertility is more important in planning management and utilizing this resource. Lowe *et al.* (2023) consider earthworms to have a direct role in world food production and soil rehabilitation, which will help in sustainable human development. The study aimed to collect and analyze the nutritional status of earthworm casts and its surface soil from three different ecological habitats of Tumakuru district. Earthworm biology and soil fertility research can benefit significantly from this study, which is the first of its kind.

Material and Methods

Study area

Earthworm casts and surface soil samples were collected from three distinct ecological habitats of Tumakuru, Karnataka. Tumakuru is in southeastern Karnataka, India lies between 13˚33´82´´ N latitude and 77˚10´14´´ E longitude. Annual rainfall of Tumakuru is about 630 to 900 mm. The agriculture area (AC), the forest area (FC) and the industrial area (IC) were the three different ecological habitats that were selected for the present study.

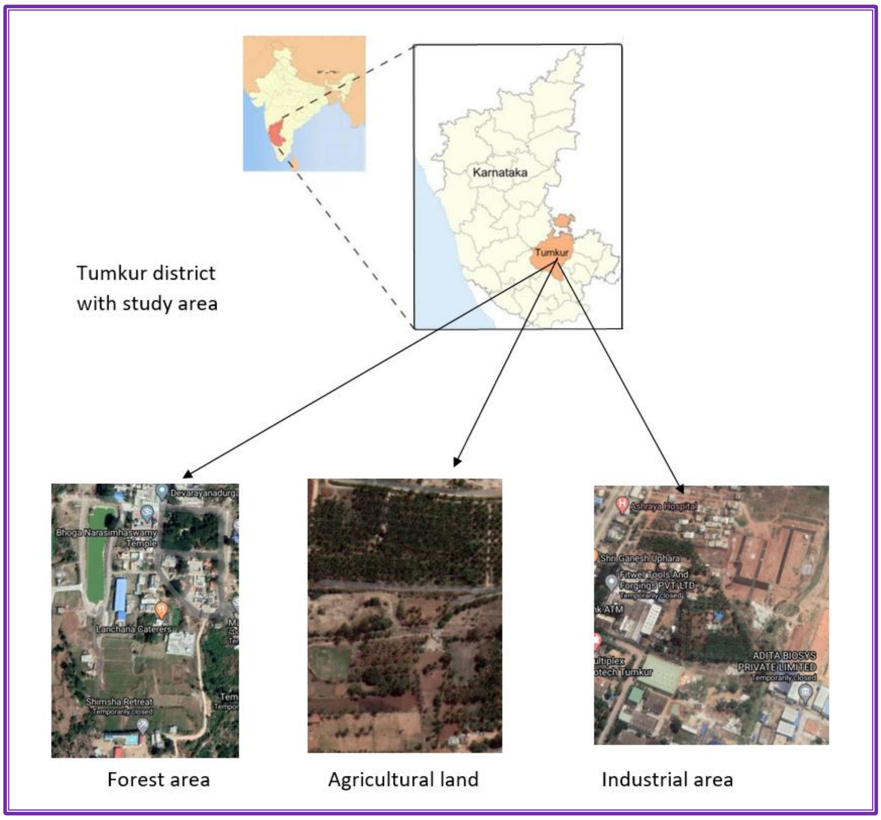

Fig. 1. Showing study areas Satellite Images taken from Google Earth

Agriculture area (AC): Agriculture land situated in Vaddarahalli (Kasaba), Belgumba (post), Tumakuru was vegetated by *Zea mays*, *Eleusine coracana*, *Cocos nucifera*, *Areca catechu* and it was about 6 km away from the main city.

Industrial area (IC): Worm cast and surface soil samples were collected from the land surrounded by industrial area, situated in Anthrasanahalli, Fitwel tools and forgings PVT.LTD behind Harkere (post), Tumakuru. It was about 5 km away from the city.

Forest area (FC): Worm casts and surface soil samples were collected from forest area, situated at the foothills of Devarayana Durga, a reserve forest of Tumakuru. The study area was about 18 km away from the city. The earthworm castings and surface soil collected from the selected land were free from pesticides, chemical fertilizers, and also pollution. The area is vegetated by *Tectona grandis*, *Mangifera indica*, *Bougainvillea glabra, Pongamia pinnata,* and *Duranta erecta.* The animals commonly found near the land are Bear, Hyena, Cheetah, Fox, Monkeys, etc. Average temperature of the study area is about 26˚C and the humidity of the atmosphere is about 32atm. The samples collected from this area was considered as control to compare the variations with AC and IC.

Fig. 2. Geo tag pictures of Earthworm casts seen in FC(A), AC(B) and IC(C)

Analysis of Nutrient composition

The earthworm casts and surface soil samples were air-dried till all the moisture evaporated. Casts and soil were ground by mechanical means to fine particle sizes and sieved through filter paper to obtain fine particle-sized casts and soil.

The samples were analyzed for the following Physico chemical parameters. pH, organic carbon (%OC), total % Nitrogen, % EC, %Potassium, % Phosphorus, % S, % Ca, % Mg, %Fe, % Mn, % Zn, %Cu, % As, % Pb, % Cd. Various techniques were employed to examine the cast and soil samples retrieved from the above-mentioned three distinct regions. 5 gms of soil was used for N,P,K analyses and 20gms for pH, micronutrients and heavy metals (Cunniff, 1995). N was assessed through general distillation, while P, Ca, and Mg were analyzed using a spectrophotometer. K was determined using a flame photometer, and heavy metals and micronutrients were measured using an atomic spectrophotometer. The values were tabulated and analyzed by a statistical method using mean, standard deviation and one-way ANOVA by using Excel version 2007. Further, the percentage change between control (FC) and other groups(AC and IC) were calculated using the formula:

$$Percentage\ change\ = \frac{Control\ -\ Experimental\ group}{Control} \times 100$$

Results

During the winter season, particularly in February, a substantial quantity of worm castings and soil samples were collected. It is important to highlight that the generation of castings reaches its zenith in the summer and monsoon periods (Wang *et al.* 2021). The colour of the collected soil samples varied from brown to dark brown, and the texture varied from sandy to gravelly. The values of different parameters analyzed in the earthworm casts collected from the Forest area (referred to as Control), Agricultural area, and Industrial area are given in Table 1. Parameters of surface soil analyzed in the Forest area, Agricultural area, and Industrial area are given in Table 2. The Forest area was chosen as the Control since it remains undisturbed by human activities.

Table 1: Comparison of mean values of all selected parameters of earthworm casts collected from Agriculture area (AC) and Industrial area (IC) with Forest (FC)

Parameters	FC (control)	AC	IC	P- value
pH	6.16 ± 0.802	6.7 ± 0.435 (+ 8.76 %)	7.03 ± 0.251 (+ 14.12 %)	0.199
ECdsml	0.35 ± 0.055	0.42 ± 0.055 (+ 20 %)	0.76 ± 0.672 (+ 117.14 %)	0.474
OC %	1.43 ± 0.493	0.46 ± 0.461 (- 67.83 %)	0.73 ± 0.378 (- 48.95 %)	0.168
N Kg/Ha	520.06 ± 179.006	172.6 ± 164.114 (- 66.81 %)	265.6 ± 136.980 (- 48.92 %)	0.173
P Kg/Ha	38.93 ± 22.348	38.13 ± 42.017 (- 2.05 %)	131 ± 162.144 (+ 236.50 %)	0.633
K kg/Ha	160 ± 55	201.66 ± 98.657 (+ 26.03 %)	74.16 ± 47.191 (- 53.65 %)	0.628
Ca ppm	988 ± 368.907	1236.66 ± 589.40 (+25.16%)	787.33 ± 565.817 (- 20.31%)	0.116
Mg ppm	193.33 ± 14.468	160 ± 37.749 (-17.23 %)	180.33 ± 8.386 (- 6.72 %)	0.627
S ppm	8.83 ± 1.527	14.16 ± 3.214 (+ 60.36 %)	9.83 ± 2.081 (+ 11.32 %)	0.897
Fe ppm	12.1 ± 1.039	14 ± 2.598 (+15.70 %)	13.66 ± 2.020 (+ 12.89 %)	0.013
Mn ppm	8.5 ± 1.732	8 ± 1(- 5.88 %)	7.83 ± 1.443 (- 7.88 %)	0.357
Zn ppm	0.76 ± 0.152	1.13 ± 0.650 (+ 48.68 %)	0.86 ± 0.057 (+ 13.15 %)	0.342
Cu ppm	0.33 ± 0.152	0.63 ± 0.115 (+ 90.90 %)	0.63 ± 0.305 (+ 90.90 %)	0.081
As ppm	0.53 ± 0.351	0.43 ± 0.321(-18.86%)	BDL	
Pb ppm	0.23 ± 0.057	0.36 ± 0.208 (+56.52%)	BDL	
Cd ppm	0.2 ± 0.173	0.04 ± 0.049 (-80%)	BDL	

Note: The values are represented as mean values ± standard error. The values in parentheses indicate the percentage change observed when compared with control. (BDL-Below detectable limit)

Table 2: Comparison of mean values of all selected parameters of surface soil collected from Agriculture area (AS) and Industrial area (IS) with Forest area (FS)

Parameters	FS (control)	AS	IS	P- value
pH	6 ± 0.264	7.16 ± 0.057 (+ 19.33 %)	6.73 ± 0.776 (+ 12.16 %)	0.526678
EC dsml	0.31 ± 0.089	0.78 ± 0.766 (+ 151.61 %)	0.79 ± 0.756 (+ 154.83 %)	0.524541
OC %	1.2 ± 0.173	0.8 ± 0.3 (- 33.33 %)	0.76 ± 0.305 (- 36.66 %)	0.524541
N Kg/Ha	435.4 ± 62.873	279.13 ± 92.77 (- 35.89 %)	267 ± 93.182 (- 38.67 %)	0.524541
P Kg/Ha	30.3 ± 13.546	66.2 ± 41.34 (+ 118.48 %)	127.4 ± 151.624 (+ 320.46 %)	0.67464
K Kg/Ha	218.5 ± 168.067	173 ± 63.69 (- 20.82 %)	92.33 ± 50.013 (- 57.74 %)	0.412395
Ca ppm	1035 ± 201.536	1227 ± 387.43 (+ 18.55 %)	864 ± 146.256 (- 16.52 %)	0.729027
Mg ppm	181 ± 27.838	181.33 ± 33.171 (+ 0.18 %)	182.66 ± 16.623 (+ 0.91 %)	0.620516
S ppm	7.83 ± 3.214	12.66 ± 2.466 (+ 61.68 %)	9.83 ± 3.329 (+ 25.54 %)	0.31292
Fe ppm	12.33 ± 1.755	11.5 ± 1 (- 6.73 %)	14.66 ± 4.424 (+ 18.89 %)	0.398256
Mn ppm	8.66 ± 0.288	8.66 ± 1.258(0)	8.66 ± 0.763(0)	0.576035
Zn ppm	0.93 ± 0.208	0.73 ± 0.305 (- 21.50 %)	0.56 ± 0.115 (- 39.78 %)	0.77419
Cu ppm	0.26 ± 0.115	0.5 ± 0.3 (+ 92.30 %)	0.33 ± 0.115 (+ 26.92 %)	0.446169
As ppm	0.66 ± 0.152	0.3 ± 0.1 (-54.54%)	BDL	
Pb ppm	0.26 ± 0.152	0.38 ± 0.292 (+46.15%)	BDL	
Cd ppm	0.23 ± 0.057	0.06 ± 0.011 (-73.91%)	BDL	

Note: The values are represented as mean values ± standard error. The values in parentheses indicates the percentage change observed when compared with the control. (BDL- Below detectable limit)

Soil pH, total N, available P, and organic C were significantly higher in earthworm casts than in soil. Compared to the casts of the other two sites, the forest cast contained significantly more total N, P, organic carbon, magnesium, and manganese. There was a statistically significant difference between the pH of the forest casts and that of the other sampling sites ($p<0.5$). For agriculture casts, the mean pH was 6.7, while for industrial casts, it was 7.03. There was a significant difference between the mean pH of AC and IC.

We observed a significant decrease in EC ($p < 0.5$) from agricultural cast (AC) to industrial cast (IC), as well as from the surface soil to worm cast across all three study sites (Table 2).

Organic carbon (OC) in the forest cast was significantly higher than the cast of the other two study areas and their soil carbon content is as follows FS>AS>IS. The nitrogen content of the forest cast was found to be significantly higher ($p<0.5$) compared to the casts of agricultural and industrial areas. In contrast, the nitrogen content of the forest cast exceeded that of its surface soil, while the agricultural and industrial casts showed lower nitrogen content than their respective surface soil.

The mean value of phosphorus content of the cast was more than the surface soil except the agricultural cast was shown to be less than its surface soil. The industrial cast was found to have the highest content of P than the cast of the other two study areas.

The mean K, Ca, S, Fe, Zn and Cu values of AC were more than the casts of forest and industrial areas and its surface soil showed a significant difference in these cations content than the other two study areas. Meanwhile, we found that the heavy metals like As, Pb and Cd were less in the worm cast of forest and agriculture sites than their surface soil and is congruent with the results of Singh *et al.* (2020).

Discussion

The values of soil pH, total N, available P, and organic C from our study area were found to be similar with the results of Singh *et al.* (2020), who found that fertilizers and pesticides used in agriculture may suppress earthworm activity and lower pH levels. The mineralization of nitrogen and phosphorous into nitrites or nitrates and orthophosphates altered pH value of industrial casts toward neutrality (Kaviraj and Sharma, 2003). The worm casts generally exhibit lower pH due to CO_2 and oxalic acid (De vleeschaucler & Lal, 1981). Enzymatic activity or/and microbial activity in the earthworm gut alter the pH of soil as it passes through it (Krishnamoorthy & Vajranabhaiah, 1986).

The presence of high levels of salt can lead to problems with plant toxicity. To determine if a particular soil is suitable and safe for agriculture, it is useful to measure its Electrical Conductivity (EC) (Villar *et al.,* 1993). The decrease in EC from our study areas may be attributed to the loss of organic matter and the release of various mineral salts, such as phosphate, ammonium, and potassium, in readily available forms. Our findings align with the results of Panjgotra *et al.* (2019), who also observed a decrease in EC from worm cast to surface soil. Works of Shao *et al.,* 2023 showed that layered application of earthworm casts with ECs 800 g/m2 reduced runoff, sediment yield, and nitrate nitrogen loss.

From our study, forest cast (FC) has shown to be increased OC as compared to the surface soil and it agrees with the earlier findings. Singh et al. (2020) reported a higher level of organic carbon content in worm cast as compared to surrounding soil. However, the percentage of OC of AC and IC were lesser than their respective surface soil this might be attributed to different compositions of soil organic matter and increased pesticides/insecticides/pollutants added to the parent soil. The concentrations of total organic carbon (TOC) and total nitrogen (TN) in casts were higher during warm months. However, the concentrations of available phosphorus (AP) and total phosphorus (TP) in casts were constant throughout the year. The nutrient concentrations in casts were 1.6–4.3-fold greater than those in bulk soils. The most significant effect of the activities of earthworms in the ecosystem is the cycling of organic matter and mineral nutrients. The higher organic C content in casts is likely to be due to food selection by the earthworms (Wang *et al.* 2021).

The increased nitrogen content in the worm cast may be attributed to the collaborative action of earthworms and microbes. Microbes fix nitrogen and the worm's gut adds it in the form of mucus, nitrogenous excretory substances, hormones, and enzymes during vermicomposting (Garg & Kaushik, 2005). However, the final nitrogen content of vermicompost generally depends on the initial nitrogen present in the soil and the extent of decomposition, as mentioned by Chauhan and Joshi (2010). Our study findings reveal that the surface soil of agricultural and industrial areas contains mean nitrogen values below the critical range. This could be due to excessive use of insecticides/pesticides or the disposal of industrial waste.

From the earlier findings, it has been observed that the total phosphorus level in the worm cast is more than the parent soil. The digestion process of earthworms can convert phosphorus in organic matter into a more easily usable form for plants. This could explain the increase in phosphorus levels observed in the vermicast. Earthworm casts have higher concentrations of total organic carbon, total nitrogen, available phosphorus, total phosphorus and nitrogen compared to bulk soils. The nutrient concentrations in casts are 1.6–4.3-fold greater than those in bulk soils (Hmar *et al*. 2014). The concentrations of total organic content and total nitrogen in casts are higher during warm months, while the concentrations of available and total phosphorus remain constant throughout the year (Iordache 2023). Further, Panjgotra & Sangha (2024) reported increased levels of nitrogen, phosphorous, potassium and organic carbon in the casts than in the surrounding soil.

About micronutrients, Edwards & Bohlen (1996) found that the impact of earthworms on certain cations, such as potassium, calcium, magnesium, and sodium, did not follow a consistent pattern. The effects were also less significant than what is typically observed in soil. This suggests that the higher levels of cations found in earthworm casts in natural environments are likely a result of the worms selectively feeding on materials that are rich in those cations. However, the levels of heavy metals such as As, Pb and Cd decrease in the vermicast due to earthworms storing heavy metals in their yellow tissue cells. The binding of metals with the ligands in these tissues varies, resulting in different levels of metal accumulation. Dang *et al.* (2023) also reported that earthworms can effectively mobilize arsenic through their casts.

The mineralization rates of fresh organic matter incorporated into the soil differed significantly from the mineralization rates of fresh organic matter incorporated into the casts (Quenea, 2022). Therefore, casts retain more organic content than surface soil. Feng *et al*., (2023) reported that dissolved organic matter in earthworm casts reduces the membrane lipid peroxidation levels and slows down the aging of plants. Pelosi *et al.,* (2024) propose an innovative Nature-based solution in agroecosystems where earthworms could be inoculated not only for their positive impact on soil structure and organic matter degradation but also to promote primary production by supplying beneficial fungi to plants.

The nutritional composition of earthworm castings provides valuable insight into the health and fertility of soil in different ecological regions. Nutrient cycling processes in soil are better understood by comparing earthworm castings from diverse ecosystems. Mastan (2020) reported the highest yield of worm castings with increased concentrations of NPK when soils were inoculated with *Perionix excavates* compared to other species.

Conclusion

The findings of this study indicate that earthworm casts possess distinct physical and chemical characteristics compared to the surrounding soil. The study strongly suggests that the gut of earthworms plays a significant role in altering the physicochemical properties of the cast soil. Furthermore, it is observed that FC and surface soil contain the highest nutrient content, particularly in terms of NPK levels, when compared to AC and IC. The nutritional value of worm cast is ranked as follows: forest cast > agriculture cast > industrial cast, and their respective surface soils. Our study supports the idea that the use of chemical fertilizers and pesticides in agricultural fields may suppress the activity of earthworms, while the dumping of industrial waste may decrease the nutritional quality of surface soil in and around industrial areas. To understand the impact of diverse ecologies on soil fertility and plant growth, it is imperative to examine the nutritional composition of earthworm castings. Using the nutritional composition of casts from different regions allows researchers to identify variations in nutrient availability and make informed decisions regarding soil management practices and agricultural productivity. However, further research is required to fully understand the influence of the earthworm gut in modifying the quality of the soil, which is consumed and converted into nutrient-rich casts that can enhance soil fertility. The knowledge derived from this study can ultimately contribute to the conservation of the environment and sustainable farming practices.

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Conflict of Interest

Authors claim no conflict of Interest.

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