Colegio de Postgraduados

Use of vermicompost in the production of crops with emphasis on *Coffea arabica* L.

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ABSTRACT

Objective: To obtain a comprehensive view of the impact and applications of the use of vermicompost in agriculture in different types of crops and especially in the production of *Coffea arabica* L.

Design/methodology/approach: Data were obtained from the Scopus data metabase, using the concepts "crop", "vermicompost" and "coffee" to search in the title, abstract and keywords, and considering scientific articles and book chapters. The main journals, countries and institutions that have published on the subject were recognized. The data was analyzed using the VOSviewer software to determine the co-occurrence of the terms.

Results: India contributed 47% of the publications, followed by China with 4% and Mexico with 3%. Research on vermicompost focuses on the characterization of its physicochemical properties, and evaluations for use as substrates, organic amendments and organic fertilizer. It is an agent of biological control of pests and diseases transmitted by the soil; it is a technological alternative for in situ stabilization of heavy metals; and, in addition, it is a viable option to mitigate greenhouse gases: ammonia (NH_3) and carbon dioxide (CO_2).

Study limitations/implications: This study did not consider other academic search engines as Google Scholar, Science Direct, among others.

Findings/conclusions: Vermicompost is increasingly used to improve soil nutrition and fertility in horticultural systems. In coffee (*Coffea arabica* L.), it is used in seed germination and as a substrate for seedlings in nursery.

Keywords: soil organic carbon (SOC), fertility, organic fertilizers, nutrient recycling.

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INTRODUCTION

In the presence of a growing demand for quality foods within the context of climate change, loss of arable lands, increase and degradation of soils, it is essential to generate alternatives that strengthen a more sustainable agricultural and forestry production.

Vermicompost is a stable product that is generated through recycling of organic residues by way of using earthworms with organic matter feeding habits, such as: *Eisenia andrei*, *Eisenia fetida*, *Dendrobaena veneta*, *Eudrilus eugiensis*, *Perionyx ceylanesis*, *Lumbricus rubellus*, *Lampito mauritii*, among others [1,2,3]. These grind and enrich organic matter through

their digestive tract with many beneficial microorganisms that support the regeneration and improvement of soil fertility [3].

In addition to its agronomic value, vermicompost has been considered a viable option to mitigate CO_2 emissions, since it promotes retention, stabilization and an increase in soil organic carbon (SOC). It also contributes to decreasing the volatilization of greenhouse gases such as carbon dioxide (CO_2) and ammonia (NH_3) [4].

Other studies have demonstrated the potential of vermicompost to control nematodes of the root knots (*Meloidogyne incognita*) through antagonist bacteria, such as *Peribacillus frigoritolerans* and *Lysinibacillus fusiformis*; these microorganisms produce chitinase and protease that prevent the normal development of eggs and second-stage juveniles [5]. Vermicompost has been studied to reduce and relieve the dissemination of resistance genes to antibiotics generated by animal feces in agricultural production due to their microbial load [6]. It has also been used in the remediation of lands contaminated by pesticides, such as atrazin which is degraded by *Proteobacteria*, *Firmicutes* and *Actinobacteria* present in vermicompost [5,7]. It has also been used as a technological alternative to stabilize heavy metals in situ such as cadmium, lead, chrome, arsenic, in contaminated soils, minimizing their negative effects on the production of grains and foods of global importance [8,9]. In addition, it has been proven to be useful for the reduction of salinity and the increase of drought tolerance, when improving the stability of cellular membranes and antioxidant enzymatic activity [10,11]. Because of this, a review was conducted to define an integral view of the impact and applications of the use of vermicompost in agriculture in different types of crops, primarily in the production of *Coffea arabica* L.

MATERIALS AND METHODS

This literature review followed a quantitative analysis, using two methods: scientific mapping by using bibliometric software and yield through the analysis of publications in function of authors, countries and institutes. The metasearch engine chosen was Scopus because of its broad coverage to recover information. The study was conducted with words such as "vermicompost" and "crop" for a general search, and "vermicompost" and "coffee" for the specific search, referring to scientific articles and book chapters in title, abstract and keywords. No time constraints were established, since the intention was to visualize these two concepts in the entire period. In the general exploration, 1533 references were found and 41 in the specific one (1990 by September 23, 2024) (Figure 1).

For the bibliometric study and the performance analysis of journals, countries and institutes, the cutting point was 10 publications. Likewise, 10 articles were selected that referred to the application of vermicompost on main crops and fruit trees, highlighting the "dose" and "benefits" that it contributes to production. Similarly, according to the specific search, 10 articles were selected that referred to the application of vermicompost in coffee production (*Coffea arabica* L.).

Content analysis

For each search (general and specific), a co-occurrence analysis was conducted. For the general analysis, the frequency value of $\geq$10 registries was used as minimum value

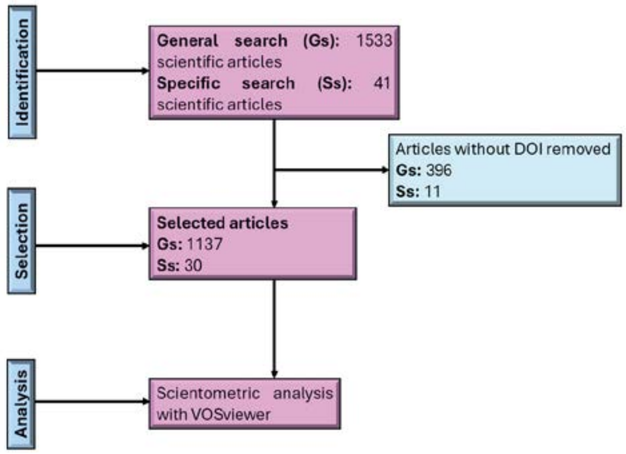

Figure 1. Flowchart of the bibliometric review (prepared by the authors).

and cluster size of 15 [12]. For the specific analysis, a frequency value of 5 was used. To refine terms in both processes, concepts related to the research process were eliminated (for example, statistical design, method, etc.). The algorithm is designed to place the terms that appear in the same year closer one to another, and for those with higher frequency value to be placed in circles with greater diameter. The terms that were not relevant for the map were eliminated [13].

RESULTS AND DISCUSSION

The number of publications analyzed was 1137, which addressed the use of vermicompost in crop nutrition in the period of 1990-2024.

Analysis of the study period

Publications in the period of 1990 to 2006 were fewer than 20 per year. Starting in 2010, an increase in manuscripts addressing the topic begins, and the maximum peak was observed in the years 2022 and 2023 with an average of 150 publications per year (Figure 2). For the entire period, the mean was 52.86±49.58 articles, with a minimum of 1 (1990-1999) and a maximum of 151 (2022).

Table 1 shows the ten main journals, countries and institutes with publications on "vermicompost" and "crop". From a total of 160 journals, the ones that concentrated the largest number of publications were Indian Journal of Agricultural Sciences, Indian Journal of Agronomy, Communications in Soil Science and Plant Analysis, Plant Archives, and Ecology Environment and Conservation, representing 20% of the total.

Regarding the countries that have developed more research in the topic from 1990-2024, they were: India (890), China (88), United States (84), Iran (69), and Mexico (65).

The contributions from the authors cover 160 institutions, with India standing out as one of the main countries in this field. Among the institutions, there are the following: ICAR - Indian Agricultural Research Institute, New Delhi, Indian Council of Agricultural Research, CCS Haryana Agricultural University, Banaras Hindu University, and Bidhan Chandra Krishi Viswavidyalaya, which lead with the largest number of publications.

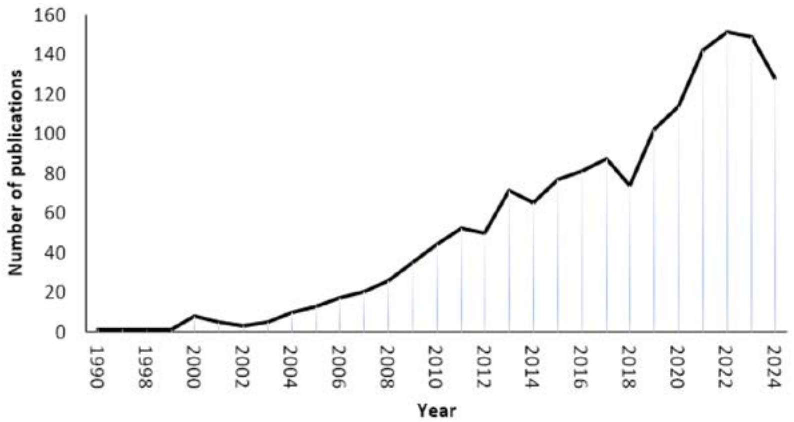

Figure 2. Behavior of publications on “vermicompost” and “crop” (1990-2024).

Scientific cartography

The co-occurrence analysis provided a general view of the research areas, identifying the key themes addressed. This analysis was carried out using the VOSviewer software. The co-occurrence network of keywords “vermicompost” and “crop” shows 5 clusters: organic residues used and technological innovation in the process of vermicomposting (yellow), integrated management of nutrients: combination of vermicompost with nitrogenous synthetic fertilizers in the application on crops (red), its effects on the morphology and physiology of plants according to the variables considered (green), enzymatic activity (purple), and microbial biomass and its beneficial effects on the rhizosphere of plants (blue) (Figure 3).

The concept where the four clusters intercept is “soils Meath”, because the use of vermicompost improves the quality and the health of soils [14,15,16].

Table 1. Performance analysis: main journals, countries and institutes that have carried out research on “vermicompost” and “crop” (1990 to September 23, 2024).

Place	Megazine	Pub.	Country	Pub.	Institute	Pub.
1	Indian Journal of Agricultural Sciences	58	India	890	ICAR - Indian Agricultural Research Institute, New Delhi	70
2	Indian Journal of Agronomy	55	China	88	Indian Council Of Agricultural Research	60
3	Communications in Soil Science and Plant Analysis	51	United States	84	CCS Haryana Agricultural University	37
4	Plant Archives	33	Iran	69	Banaras Hindu University	36
5	Ecology Environment and Conservation	32	Mexico	65	Bidhan Chandra Krishi Viswavidyalaya	31
6	Agronomy	30	Pakistan	49	Central Institute of Medicinal and Aromatic Plants India	28
7	Journal of Plant Nutrition	24	Spain	49	ICAR - Research Complex for North Eastern Hill Region, Umiam	28
8	Bioresource Technology	22	Saudi Arabia	37	Annamalai University	27
9	Legume Research	20	Turkey	35	Krishi Vigyan Kendra	24
10	Annals Of Biology	19	Bangladesh	34	Tamil Nadu Agricultural University	24

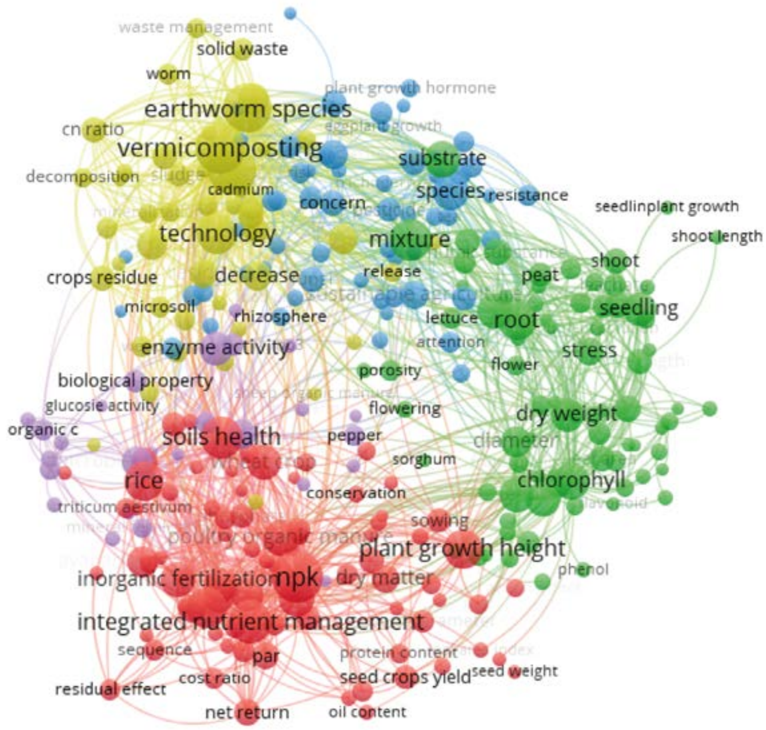

Figure 3. Superimposed visualization of VOSviewer for "vermicompost" and "crop" from 1990 to 2024.

In the specific search "vermicompost" and "coffee", with a minimum frequency value of 5, the co-occurrence analysis shows 3 clusters: the use of residues from the coffee industry in vermicomposting (red), incorporation of vermicompost as substrate for the production of coffee seedlings (blue), and its effect on morphological and physiological development (green) (Figure 4).

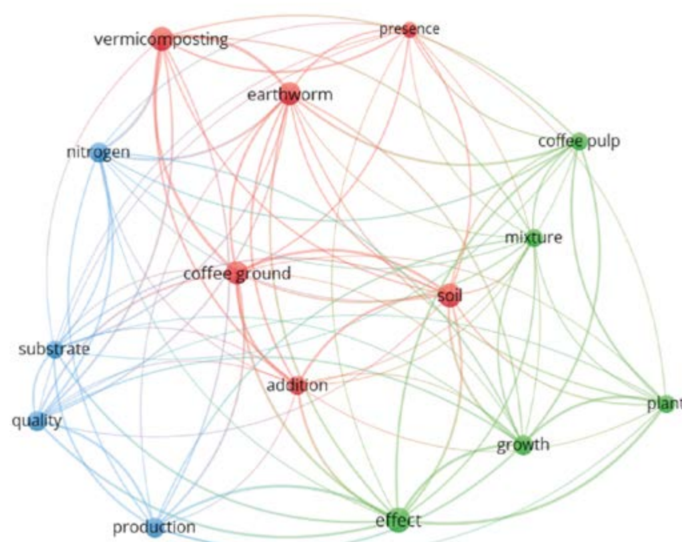

Figure 4. Superimposed visualization of VOSviewer for "vermicompost" and "coffee" from 1990 to 2024.

In the vermicomposting process of organic residues derived from the coffee agroindustry, the earthworms used are *Eisenia fetida*, *Eisenia andrei* and *Dendrobaena veneta* [2,17,18]. Bio-residues from the agroindustry, such as coffee grounds, mostly worry because of their damaging effects due to their high degradability and content of harmful compounds, such as phenols, caffeine, and tannins [19].

Because of this, options to reuse them have been sought, in order to decrease their environmental impact through vermicompost production for nutrient recycling and exploitation in the agricultural sector [18,20].

In the agricultural sphere, vermicompost is presented as a sustainable alternative used in various agricultural and forestry crops as substrate, organic amendments, soil improver, and organic fertilizer [4,21,22]. The general review revealed that a significant percentage of the articles refer to its use in vegetable production, due mainly to its contribution in organic carbon, beneficial micronutrients and microorganisms, which favor the increase in microbial biomass, higher availability of nutrients, and metabolic activity of plants [16,23,24]. In addition, vermicompost has positive effects on the soil health, improving its resilience while facing adverse conditions such as stress from drought, salinity and contamination by heavy metals: Cadmium (Cd), Chromium (Cr), Nickel (Ni), Lead (Pb), Copper (Cu), Arsenic (As), and silver (Ag) [9, 25, 26]. In addition, it has been studied for its significant contribution of N and micronutrients, considering it as a nitrogenous fertilizer [15,19,27]. However, its combined use with synthetic fertilizers is common, since they complement each other effectively to achieve higher yields, improving the quality of foods and regenerating the soil health [26,28,29].

It has also been used in the production of cereals, mainly in basic foods, such as corn (*Zea mays* L.), wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), and basic grains like bean (*Phaseolus vulgaris* L.) in Mexico. Its use happens in combination with synthetic fertilizers (NPK), with biofertilizers (*Azospirillum*, *Trichoderma*) and different composts based on the crop's requirements and the soil fertility [26,30,31]. Table 2 lists some studies that refer to these strategic crops, presenting the benefits that vermicompost contributes in general, and the doses with which experiments have been performed.

This organic amendment has been scarcely used in fruit production fields. Some of the causes that can be interfering with it to develop this way is the amount needed to tend to one hectare, since a greater proportion is required compared to vegetables and cereals. Another reason can be the long time necessary to evaluate the variables, as well as the increase in total costs of the studies; to evaluate the impact of vermicompost on fruit quality and yield in fig production (*Ficus carica* L.), 10 kg/tree/year [32] were needed, at the same time that in plum (*Prunus salicina* L.) nutrition, 22.5 kg/tree/year [33] were necessary to increase the fruit yield.

The use of vermicompost in coffee production (*Coffea arabica* L.) has been scarcely studied. Of the 41 articles found through the search with the concepts "vermicompost" and "coffee", only 3 address its use as substrate for germination, development and growth of the seedlings in nursery [39,40,41]. In addition, no article was found that analyzes its impact on the nutritional management of coffee plantations established in the field, or about its

Table 2. Main crops and fruit trees where the use of vermicompost as soil improver and source of organic nutrition has been evaluated.

Crop	Benefits	Dose	Reference
Corn (*Zea mays* L.)	Significantly improved growth characteristics, quality parameters, and green forage yield attributes.	50% farm manure and 50% vermicompost.	[34]
	Improved the physical and chemical properties of the soil. Increased grain yield, straw yield, and harvest index (41.53%).	62.5N-60P-30K kg ha^{-1} more 10 t ha^{-1} of farmyard manure, 2 t ha^{-1} of vermicompost, and Azotobacter.	[24]
Rice (*Oryza sativa* L.)	It improved soil properties, increased the diversity and composition of the bacterial community, mitigated the adverse effects of Cd on plants, and increased rice grain yield (38%).	3 and 6 t ha^{-1}	[8]
	It improved soil properties (COS=78.7%) and increased grain and straw yields by 74.5% and 46.1%, respectively.	Equivalent to 80 kg N ha^{-1}, 2.5 t ha^{-1} of wheat crop residue and biofertilizers.	[31]
Bean (*Phaseolus vulgaris* L.)	Improved the physical and chemical properties of the soil, improved the physiological properties of the plant, and increased grain yield.	10 t ha^{-1} (75% vermicompost, 25% organic carbon)	[35]
	It had a positive impact on development, growth, and productivity.	50%, 75% y 100% of the contents of the pot	[36]
Wheat (*Triticum aestivum* L)	Saline and non-saline soil: increased the physical and chemical properties of the soil (COS by 52%, 18%), improved physiological characteristics, increased grain yield (50%, 44%), and increased CO_2 emissions.	11.8 t ha^{-1}	[37]
	It improved morphological, physiological, and biochemical characteristics under drought stress conditions.	4, 6 and 8 t ha^{-1}	[11]
Plum (*Prunus salicina* Lindl.)	It improved the physical and chemical properties of the soil (18% increase in COS) and increased fruit quality.	70% of the recommended dose of N per tree + 22.5 kg of vermicompost + Jeevamrit (2 liters per tree).	[33]
Coconut (*Cocos nucifera* L.)	It improved the physical and chemical properties of the soil and increased the microbial population. It increased the yield of nuts per plant per year (19%).	250N-320P-120K grams per plant + 50% of N supplied with vermicompost.	[38]

effects on the morphological growth, physiological, and physicochemical properties of the soil, the yields and the quality of fruits in producing coffee trees.

Although Mexico is among the main producing countries of organic coffee in the world, there is very little or no information regarding this topic [42]. These results can be attributed to the fact that different composts foreign to vermicompost are being used, and there is a lack of knowledge or documentation of those studies.

From the articles found in the specific search, 88% refer to nutrient recycling of organic residues from the coffee agroindustry (pulp, parchment, and coffee grounds), through vermicomposting and conventional composting, where different proportions of this type of residues are mixed with residues from different crops (banana leaves, palm fiber, straw, etc.), food waste, and excretes from different animals (sheep, goats, cattle, horses), to research their physicochemical and biological properties, their impact on yields and the quality of foods, as well as their impact on soil health [2,18,44] (Table 4).

Table 3. Use of vermicompost in the nutrition of *Coffea arabica* L. and *Coffea canephora*.

Coffee (seedlings)	Benefits	Dose	Reference
Coffea arabica L.	The morphological and physiological development of the seedlings improved.	40% of the total volume of the bag.	[39]
Coffea arabica L.	It improved the morphological variables of the seedlings (number of leaves, stem diameter, root diameter, total number of secondary roots).	10% concentration (liquid).	[40]
Coffea arabica L., *Coffea canephora*	Improved soil chemical properties (CO, total P, and available N) and plant biomass.	0.14 kg/pot	[41]
Coffea canephora	It improved the chemical properties of the soil (total nitrogen) and the morphological variables of the seedlings (height, number of leaves, root length).	100%	[43]

Table 4. Nutrient recycling through vermicomposting of residues from the coffee agroindustry and its use in food production.

Waste from the coffee agroindustry	Crop	Benefits	Dose	Reference
Coffee pulp	Chili pepper (*Capsicum annuum* L.)	It improved the physical and chemical properties of the soil and the morphological characteristics of the plants. It increased yield by 97.86%.	15 t ha^{-1}	[2]
Coffee pulp	Tomato (*Solanum lycopersicum* L.)	Seed germination improved, possibly due to increased microbial diversity.	40%	[45]
Coffee grounds	Crop (*Zea mays* L.)	It improved seed germination and enriched the physicochemical properties of vermicompost.	100%	[46]
Coffee grounds	Lettuce (*Lactuca sativa*)	It improved morphological characteristics and increased biomass. It decreased the Zn, Cu, and Fe content in plants.	7.5%	[47]
Coffee husk and pulp	Not applicable	Vermicomposting reduced the concentration of caffeine, chlorogenic acid, and tannins. It increased the microbial load of microorganisms that promote plant growth.	Not applicable	[1]
Coffee grounds	Not applicable	Recycling coffee grounds through vermicomposting substantially reduced caffeine content and increased P, K, and Mg content.	Not applicable	[20]
Coffee grounds	Not applicable	Vermicompost made from coffee grounds exhibited favorable physical and chemical properties for use as organic amendments to agricultural soils.	Not applicable	[19]

CONCLUSIONS

Vermicompost is valued for its contribution to total N, micronutrients, and organic carbon in organic agriculture. It is frequently used as biofertilizer due to its high microbial load. In addition, it is recommended for vegetable production since it contains different beneficial fungi and bacteria that solubilize P and mineralize N. It also contributes to the bioremediation of contaminated soils and the decrease of salinity of the soils, among others.

Vermicompost not only improves the quality of foods, but also maintains and even increases the yields per hectare throughout time.

This review emphasizes the potential of vermicompost as an innovative and sustainable alternative in agricultural systems, offering solutions in the presence of challenges in the agrifood sector.

The advantages vermicompost offers due to the microbial populations present represent an area of opportunity for future studies. In subtropical and tropical countries, there is the potential to evaluate its properties in various crops under changing environmental conditions, and to promote nutrient recycling strategies through vermicomposting of organic residues, which would contribute to the agroecological management of the crops.

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