Development of Vermiwash production technique, evaluation of its physicochemical parameters and its effect on overall plant growth

Abstract

Soil health is a critical component of sustainable agriculture. Agricultural soil faces numerous challenges, such as erosion, nutrient depletion, and contamination. Intensive farming practices such as mechanization, overuse of synthetic fertilizers and pesticides, and short crop rotation have severely impacted soil quality in terms of decreased fertility, less water retention, and loss of biodiversity. Vermiwash and vermicompost now emerge as effective solutions to restore soil health. Vermiwash is a liquid fertilizer derived from earthworm castings rich in bioavailable nutrients and growth hormones and has pesticide potency. The present course of the investigation focused on developing the vermiwash production technique, evaluating its physicochemical parameters, and its effect on overall plant growth. We have evaluated physicochemical parameters viz., mainly pH, EC, Total Organic Carbon, C: N Ratio, Macronutrients, Micronutrients, and microbiota in the vermiwash and vermicompost. We found almost similar values reported in the literature except for EC and NO_3. Significantly, our vermiwash has 1.47 of EC values, which was claimed as the most suitable range of EC for plant growth. Further, nitrate content was observed in our vermiwash, and such results were not published earlier. During the evaluation of our vermiwash for wheat growth, we noted 1.46 times higher plant crop growth than that of standard soil. This study proposed a single unit for developing vermicompost and vermiwash, i.e., a mono-unit serving the dual purpose that could eventually be integrated into sustainable agriculture.

Keywords: Soil health, sustainable agriculture, Vermiwash, vermicompost, Eisenia foetida

1. Introduction

The widespread use of chemical or synthetic fertilizers in agriculture has significantly increased crop yields and food production. However, the extensive application of these fertilizers has raised concerns about their long-term environmental and ecological impacts. Soil degradation is one of the primary concerns with chemical fertilizers. Synthetic fertilizers often supply a limited range of nutrients, primarily nitrogen (N), phosphorus (P), and potassium (K), leading to nutrient imbalances in the soil. Over time, the repeated use of these fertilizers can deplete essential micronutrients, reducing soil fertility and productivity (Kopittke et al., 2019). Further, the excessive use of fertilizers and pesticides results in a gradual loss of soil fertility and microbiological diversity (Samadhiya *et al*., 2013). Additionally, the continuous application of nitrogen-based fertilizers can lead to soil acidification, further impairing soil health, and crop yields (Guo *et al*., 2010). Chemical fertilizer usage can significantly contribute to environmental issues, such as excess nutrients, particularly nitrates and phosphates, leaching from agricultural fields into water bodies. Nitrate groundwater contamination poses serious health risks to humans and animals, including methemoglobinemia, also known as "blue baby syndrome" (Ward *et al*., 2018). Furthermore, the runoff of phosphorus-rich fertilizers into rivers and lakes can cause eutrophication, characterized by excessive algal blooms. These algal blooms deplete oxygen levels in the water, leading to hypoxic conditions or "dead zones," which severely impact aquatic life (Smith *et al*., 2017).

Chemical fertilizers can also adversely affect biodiversity in agricultural landscapes and surrounding ecosystems. Overusing nitrogen-based fertilizers can lead to the proliferation of certain plant species, often at the expense of others, thereby reducing plant diversity (Galloway et al., 2008). This shift in plant communities can have cascading effects on the entire ecosystem, including habitat loss for pollinators and other wildlife. Moreover, reducing plant diversity can make ecosystems more vulnerable to invasive species and less resilient to environmental changes (Tilman *et al*., 2002). The application of synthetic fertilizers contributes significantly to greenhouse gas emissions, particularly nitrous oxide (N_2O), a potent greenhouse gas with a global warming potential approximately 300 times that of carbon dioxide (CO_2) (Davidson, 2009). The microbial processes of nitrification and denitrification in soils receiving high levels of nitrogen fertilizers cause nitrous oxide emissions. These emissions contribute to climate change, aggravating the environmental footprint of agricultural practices (Reay et al., 2012). Chemical fertilizers, while crucial in boosting agricultural productivity, have well-documented negative impacts on soil health, water quality, biodiversity, and climate. Sustainable agricultural practices, including organic fertilizers and integrated nutrient management, are essential to mitigate these adverse effects and ensure the long-term viability of agricultural ecosystems.

People increasingly recognize sustainable agriculture as a necessary approach to address the challenges posed by conventional farming practices, which often heavily rely on chemical or synthetic fertilizers. While boosting crop yields, these fertilizers harm soil health, biodiversity, and ecosystems. In this context, organic alternatives like vermiwash—a liquid extract produced from the vermicomposting process—offer promising solutions. Sustainable agriculture emphasizes using practices that maintain and enhance the health of ecosystems over time. These practices include crop rotation, organic fertilizers, and biological pest control, all of which contribute to long-term soil fertility, water conservation, and biodiversity (Pretty, 2008). Gomiero, Pimentel, and Paoletti (2011) claimed that, unlike conventional methods, sustainable agriculture reduces reliance on external inputs and minimizes environmental damage, promoting resilience in agricultural ecosystems.

Vermiwash is a potent organic fertilizer made from earthworms breaking down organic matter. It contains enzymes, plant growth hormones, and essential nutrients (Khwairakpam & Bhargava, 2009). Unlike chemical fertilizers, a natural process produces vermiwash, enhancing soil health by improving its physical, chemical, and biological properties. The presence of beneficial microbes and enzymes in vermiwash aids in organic matter decomposition in the soil, improving plant nutrient availability (Ansari & Sukhraj, 2010). The vermiwash contains bioactive compounds secreted from the skin secretion of earthworms, coelomic fluid, and mucus, which defend pathogenic soil microbes against the worm and thereby protect the environment from the disease. Moreover, earthworms establish symbiotic relations with microbes by producing vital produce that supports the growth of plants and protects plants from probable root disease (Gudeta *et al*., 2021). As the global demand for sustainable agricultural practices grows, adopting earthworm-based vermiwash could be crucial in achieving long-term ecological balance and food security. Therefore, this research was conducted to provide insight into its production from organic waste material and its effectiveness on the growth parameters of the plants.

2. Materials and methods

The current research was conducted at D.LS. P.G. College Campus. The earthworm *Eisenia foetida* was obtained from Krishi Vigyan Kendra, Bhatapara. Dry leaves of trees present in the college garden, and other biomass from the campus were used as a substrate for the earthworms to produce vermiwash. We have developed the vermiwash production unit (VPU) using earthworms, cow dung, tanks/barrels with a 200-litre capacity, buckets with a 20-litre capacity, gravel, coarse sand, garden soil, and water.

The published patent protocol by Behar *et al*. (2022) (Patent application No. 20222103581; An innovative and cost-effective method to produce vermiwash for sustainable organic farming practices) guided the preparation of the VPU. We took a clean and clear tank with a bottom tap outlet, and it sequentially layered the gravel, coarse sand, soil, cow dung, earthworm mix, and partially digested or dry plant biomass. We placed the iron stand over the tank and positioned it in a water bucket with small holes at the bottom to evenly spray water into the tank, ensuring it remained moist. Figs. 1 and 2 visually present the VPU system. The VPU unit needed to spray 20 litres of water daily for 15 days. We collected the percolated water from the tank's bottom tape. The process was repeated with vermiwash collected from the effluent tape till the dark brown vermiwash was achieved. The final vermiwash liquid was stored in a cold and dry place and proceeded for the physical/chemical characterization. Finally, vermiwash's effectiveness in wheat cultivation was evaluated. We prepared a plastic tray with various soil and vermiwash combinations, arranged the wheat seeds in rows, and monitored the germination rate and crop yield.

Fig 1. Vermiwash setup

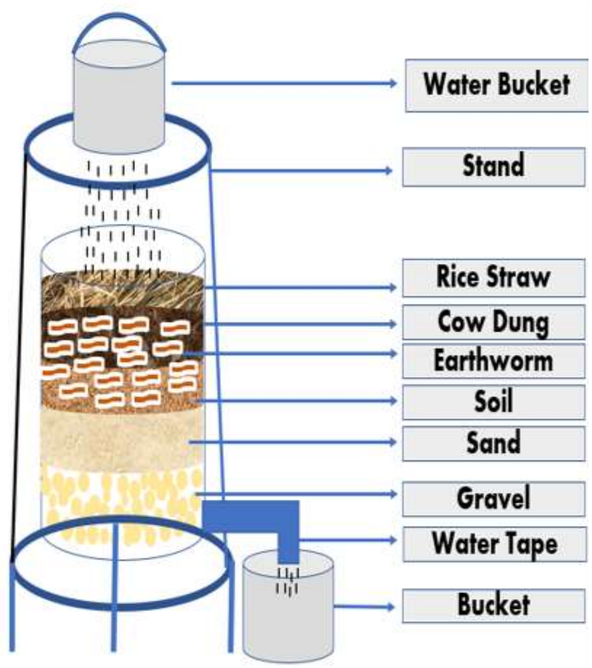

Fig 2. Layers in Vermiwash setup

Results and Discussion

This study proposed a single unit for developing vermicompost and vermiwash, i.e., a mono-unit serving the dual purpose. The Physico-chemical characteristics of Vermiwash, Vermicompost from the vermiwash unit, and vermicompost were done in Biotech Lab Training and Demonstration Centre, Ambikapur, C.G. and compared with the standard Value reported by Nayak *et al*. (2019). The comparative account is represented in Table 1. The observed value of physical/chemical characteristics of our sample is almost similar to the standard value as reported by Nayak *et al*. (2019) except for EC and NO_3**.** The EC value of our sample was 1.47 as compared to the reported 0.008.

Table 1 Comparatives tabulation of present findings (Physico-Chemical Characteristics) and Standard Report published by (Nayak *et al.,* 2019)

S. No.	Physical/Chemical Characteristics	Vermiwash	#Vermi-compost (VWU)	Vermicompost	*Standard Value
1.	pH	7.42	7.04	7.02	7.39-7.5
2.	EC (dsm¹)	1.47	2.4	2.3	0.008
3.	Moisture (%)	-	23.8	22.6	-
4.	Bulk density (cm^{-3})	-	0.834	0.826	-
5.	Total Organic Carbon (%)	0.005	13.95	14.25	0.25
6.	C: N Ratio	-	14.4	14.5	-
7.	Nitrogen (%)	-			0.01-0.001
8.	Nitrate (NO_3) (%)	0.007	0.94	0.97	-
9.	Phosphorus (P_2O_5) (%)	1.49	1.12	1.09	1.70
10.	Potassium (K_2O) (ppm)	24.0	1.10	1.13	26.0
11.	Sodium (ppm)	-	-	-	8.0
12.	Calcium (ppm)	2.0	-	-	3.0
13.	Magnesium (ppm)	136.0	-	-	160.0
14.	Manganese (ppm)	-	-	-	0.60
15.	Arsenic (ppm)	-	2.05	2.00	-
16.	Iron (ppm)	0.06	-	-	0.06
17.	Zinc (ppm)	0.02	18.05	17.90	0.02
18.	Copper (ppm)	0.01	9.88	9.62	0.01
19.	Nickel (ppm)	0.06	3.05	3.01	-
20.	Lead (ppm)	0.02	25.4	25.2	-
21.	Mercury (ppm)	-	0.02	0.02	-
22.	Cadmium (ppm)	-	0.22	0.19	-
23.	Chromium (ppm)	-	14.90	12.40	-
24.	Total heterotrophs	-	-	-	1.79×10^3
25.	*Nitrosomonas* (CFU/ml)	-	-	-	1.01×10^3
26.	*Nitrobacter* spp. (CFU/ml)	1.12×10^3	-	-	1.12×10^3
27.	Total Fungus (CFU/ml)	1.45×10^3	-	-	1.46×10^3

***Standard Value reported by Nayak *et al*. (2019); # Vermocompost from Vermiwash unit**

The growth of plants was measured over a period of 30 days under three different treatments: Normal Soil (Control), Vermicompost, and Vermiwash during the present research investigation. The results indicated significant differences in both the length of the plants and their relative growth rates across the treatments. At day 20, the average lengths of the plants were 13.7 cm ±0.21 for the Normal Soil (Control), 15.8 cm ±0.27 for Vermicompost, and 17.5 cm ±0.29 for Vermiwash. By day 25, the measurements showed continued growth, with lengths recorded at 14.2 cm ±0.26 for Normal Soil, 16.5 cm ±0.28 for Vermicompost, and 20.1 cm ±0.32 for Vermiwash. Finally, at day 30, the lengths were noted as 14.8 cm ±0.25 for Normal Soil, 17.7 cm ±0.26 for Vermicompost, and 21.6 cm ±0.31 for Vermiwash. The relative growth was assessed through fold increase calculations at each observation point. At day 20, Vermicompost showed a fold increase of 1.15, while Vermiwash exhibited a higher fold increase of 1.27. By day 25, the fold increase for Vermicompost was recorded at 1.16, and for Vermiwash, it rose to 1.41, indicating a more substantial enhancement in growth compared to the control treatment. By day 30, the relative growth for Vermicompost reached a fold increase of 1.19, whereas Vermiwash maintained its lead with a fold increase of 1.45. Overall, this analysis demonstrated that both Vermicompost and Vermiwash significantly enhanced plant growth compared to normal soil conditions throughout the study period. Notably, Vermiwash consistently outperformed both Normal Soil and Vermicompost in terms of plant length and relative growth rate, highlighting its potential effectiveness as a growth enhancer in agricultural practices.

Fig 3. Prepared Vermiwash

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Fig 4. Determination of the effectiveness of Vermiwash

However, the recent study by Waghmode *et al*. (2021) revealed that the EC value has varied from 0.98 to 1.69 as per the nature of horticulture biomass used to produce vermiwash and vermicompost. Similarly, another analysis by Kumar et al. (2022) divulged an EC value of 1.39 for vermiwash using cow dung with green and dry waste. Also, it claimed that the EC value at a range of 1.37–1.39 indicated a high cation-exchange capacity. Their results were very close to our present findings. The NO_3 content of our vermiwash was 0.007 %, which was absent in the above report. This was an essential aspect because the most recent study by Zhu et al. (2023) emphasized the benefit of nitrate for soil health and improving plant productivity in monocropping agriculture settings rather than ammonia. Further, the present results exposed that the soil sample with vermiwash had the highest plant growth. The plant grew about 22.4 cm, which was 1.46 times higher than that of standard soil.

Table 2. Determination of the effectiveness of vermiwash

Days	Length of the plant (in cm ±SD)			Fold increase in Relative growth	
	Normal Soil (Control)	Vermicompost	Vermiwash	Vermicompost	Vermiwash
20	13.7 ±0.21	15.8 ±0.27	17.5 ±0.29	1.15	1.27
25	14.2 ±0.26	16.5 ±0.28	20.1 ±0.32	1.16	1.41
30	14.8 ±0.25	17.7 ±0.26	21.6 ±0.31	1.19	1.45

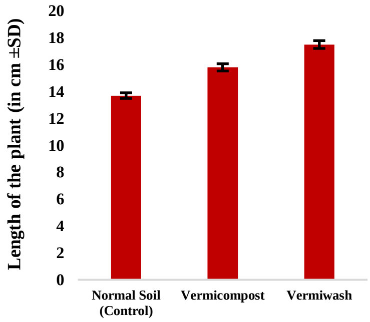

Fig 5 (a)

Length of the plants after 20 days

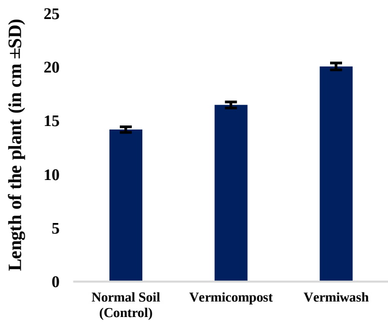

Fig 5 (b)

Length of the plants after 25 days

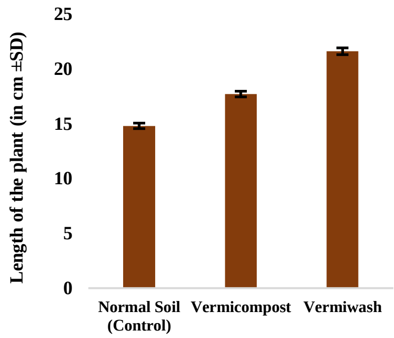

Fig 5 (c)

Length of the plants after 30 days

Fig 5. Length of the plants in different experimental setups

Makkar *et al*. (2017) have noted that the combined use of vermiwash and vermicompost has the highest plant yield with more branches, a higher number of capsules, a higher plant dry weight, improved root growth parameters, and enhanced soil physico-chemical, biological, and microbiological properties. Nandana *et al.* (2020) described the appropriate condition for producing good quality vermiwash, i.e. decomposed organic wastes and ten days old cow dung along with 1000 to 2000 juvenile or adult earthworms have to be present in vermiwash production unit with sufficient moisture level. Chandukishore (2023) suggested vermiwash as a potent substitute to chemical pesticides in *Capsicum annum* and reported a 78.3% increase in the rate of flowering as compared to standard, other parameters such as shoot length, number of leaves, and leaf damage scale also showed significant increase when combined with cow urine and plant extracts. Furthermore, studies have revealed that vermicompost enhances plants' root system and biomass production, thereby enhancing soil fertility (Manyuchi et al., 2013; Zaefarian and

Rezvani, 2016). Researchers have examined vermiwash liquid and found it rich in NPK components, micronutrients, plant growth hormones, microbes, and enzymes. Furthermore, its easy absorption by plant surfaces leads to its frequent use as a foliar spray (Manyuchi et al., 2013; Kaur et al., 2015). Verma *et al*. (2018) also described vermiwash's foliar application as a pesticidal and disease control action. Many studies have demonstrated the positive impact of vermiwash on soil health, ecosystem stability, soil aeration, water retention, and microbial activity. These factors all work together to produce higher crop yields without the harmful effects of chemical fertilizers (Sinha *et al*., 2010). Furthermore, Edwards (2004) documented that using vermiwash supports sustainable management of agricultural systems by promoting organic waste recycling, reducing dependency on synthetic inputs, and fostering biodiversity in the soil ecosystem. Henceforth, vermiwash offers a sustainable alternative to chemical fertilizers, providing numerous benefits to agriculture and ecosystems. Its use supports soil health, enhances crop productivity, and minimizes environmental damage.

Conclusion

Vermiwash and vermicompost have emerged as sustainable and practical solutions in soil fertilization and managing plant diseases and pests. Vermiwash, a liquid extract derived from vermicomposting, is rich in enzymes, hormones, and nutrients, which promote plant growth and enhance soil fertility. When used as a foliar spray, vermiwash supplies essential nutrients and stimulates the plant's immune system, making it more resistant to diseases and pests. Vermicompost, the organic product of the vermiculture process, significantly improves soil structure, water retention, and microbial activity, contributing to healthier plant growth. The rich nutrient content and beneficial microorganisms in vermicompost help suppress soil-borne pathogens and pests, reducing the reliance on chemical fertilizers and pesticides. Vermiwash and vermicompost offer a holistic approach to sustainable agriculture, enhancing crop yield, improving soil health, and providing an eco-friendly alternative to conventional agricultural practices. Their use promotes environmental sustainability and supports the health of ecosystems and the long-term productivity of agricultural lands.

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