International Journal of Plant & Soil Science

Volume 38, Issue 7, Page 259-265, 2026; Article no.IJPSS.159670
ISSN: 2320-7035

Effect of Value Added Vermiwash on Yield and Economics of Kharif Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2026/v38i76157

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here:https://pr.sdiarticle5.com/review-history/159670

Original Research Article

Received: 11/04/2026
Accepted: 08/06/2026
Published: 27/06/2026

Abstract

Sustainable nutrient management practices are gaining importance in maize cultivation because of rising fertiliser costs and concerns about soil and environmental health. Enriched vermiwash formulations containing beneficial microorganisms, botanical extracts and micronutrients may improve crop productivity and profitability. A field experiment was conducted at the Instructional Farm of GIET University, Gunupur, Rayagada, Odisha, during kharif 2025 to evaluate the effect of value-added vermiwash formulations on the yield and economics of kharif maize (*Zea mays* L.) variety DHM-206. The experiment comprised nine treatments arranged in a Randomised Complete Block Design (RCBD) with three replications. Treatments included plain water spray (T_1, control), plain vermiwash (T_2), vermiwash enriched with neem leaf extract, calotropis leaf extract, *Pseudomonas* + neem, and their combinations with zinc and boron (0.25% each), along with a *Glyricidia* leaf extract variant. Foliar sprays were applied at 45, 60 and 75 DAS with a uniform dose of 120:60:60 kg $N:P_2O_5$: K_2O ha^{-1}. Results showed that T_8 (vermiwash + 5% *Pseudomonas* + neem leaf extract + Zn + B at 0.25% each) recorded the highest kernel yield (9.10 t ha^{-1}), fresh stalk yield (9.93 t ha^{-1}), gross

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Cite as: *Acharya, R., & Das, N. (2026). Effect of Value Added Vermiwash on Yield and Economics of Kharif Maize (Zea mays L.). International Journal of Plant & Soil Science, 38(7), 259–265. https://doi.org/10.9734/ijpss/2026/v38i76157*

returns (₹2,27,500 ha^{-1}), net returns (₹1,38,604 ha^{-1}) and benefit-cost ratio (2.37), significantly outperforming the other treatments. Harvest index was inversely related to yield, with the lowest value under T_8 (47.82%) due to proportionally higher total biomass production. The study indicates the economic viability and productivity potential of enriched vermiwash as a sustainable foliar input for kharif maize cultivation in southern Odisha.

Keywords: Value-added vermiwash; Zea mays L.; kharif maize; foliar application; Pseudomonas; neem leaf extract; zinc; boron; kernel yield; benefit-cost ratio.

1. Introduction

Maize (*Zea mays* L.) is one of the most widely cultivated cereal crops globally and ranks next to wheat and rice in importance. On a global scale, maize is cultivated on about 197 million hectares, with an average yield of 6.14 t ha^{-1} and a total production of 1,210 million tonnes. Worldwide, the USA leads maize production, followed by China, Brazil, Argentina and India (Senthilnathan et al., 2025; Prusty et al., 2020). In India, the national average grain yield is 6,436 kg ha^{-1}, with total production recently recorded at 10.635 million tonnes (ICAR–IIMR, 2024; Bayar et al., 2024). In the upland tribal regions of Odisha, particularly Rayagada district, maize is predominantly grown during the kharif season under rainfed conditions with minimal external inputs, leading to sub-optimal yields.

The escalating cost of chemical fertilisers and their adverse effects on soil health and environmental quality have necessitated the adoption of sustainable alternative nutrient sources. Vermiwash, a liquid extract from vermicompost beds that is rich in plant growth regulators, macro- and micronutrients, beneficial microorganisms and enzymes, has emerged as an effective biostimulant for foliar application (Jandaik et al., 2015; Verma et al., 2018). Vermiwash contains bioactive compounds derived from earthworm skin secretions, coelomic fluid and mucus (Lal et al., 2025). These substances help protect earthworms against pathogenic soil microbes and may contribute to disease suppression in the surrounding environment (Gudeta et al., 2021). The composition and quality of vermiwash vary depending on the raw organic matter used for vermicomposting (Dubey et al., 2025). Enrichment of vermiwash with botanical extracts such as neem and *Glyricidia*, plant growth-promoting bacteria such as *Pseudomonas*, and micronutrients such as zinc and boron can further enhance its efficacy in promoting crop yield and economic returns.

Research on enriched vermiwash in kharif maize under the specific agro-climatic conditions of southern Odisha remains limited. The present study was therefore conducted to assess the effect of different value-added vermiwash formulations on yield, including kernel yield, stalk yield and harvest index, and on the production economics of kharif maize at Gunupur, Rayagada, Odisha.

2. Materials and Methods

2.1 Experimental Site and Soil Characteristics

The field experiment was conducted at the Instructional Farm (Farm-II) of GIET University, Gunupur, Rayagada, Odisha (19° 04’ 49.4″ N; 83° 48’ 31.6″ E), in the North Eastern Ghat Agro-Climatic Zone, during kharif 2025. Initial soil analysis indicated a slightly acidic pH (6.70), non-saline EC (0.21 dS m^{-1}), low organic carbon (0.243%), medium available N (407.68 kg ha^{-1}), medium available P_2O_5 (19.04 kg ha^{-1}), high K_2O (537.93 kg ha^{-1}) and sufficient boron (1.04 mg kg^{-1}).

2.2 Experimental Design and Treatments

The experiment was laid out in a Randomised Complete Block Design (RCBD) with nine treatments and three replications. Maize variety DHM-206 was sown on 28 July 2025 at 60 cm × 30 cm spacing with a plot size of 4.2 m × 3.0 m. A uniform recommended dose of 120:60:60 kg N:P_2O_5: K_2O ha^{-1} was applied to all plots. The nine treatments were: T_1 – Water spray alone (Control 1); T_2 – Vermiwash alone (Control 2); T_3 – Vermiwash + 5% neem leaf extract; T_4 – Vermiwash + 5% calotropis leaf extract; T_5 – Vermiwash + 5% (*Pseudomonas* +

neem leaf extract); $T_6 - T_3$ + (Zn+B) 0.25% each; $T_7 - T_4$ + (Zn+B) 0.25% each; $T_8 - T_5$ + (Zn+B) 0.25% each; $T_9 - T_5$ + 5% *Glyricidia* leaf extract. Foliar sprays were applied three times at 45, 60 and 75 DAS.

2.3 Observations Recorded

Yield parameters recorded included: (i) kernel yield (t ha^{-1}), obtained from the net plot area after sun-drying, shelling and adjustment to 14% moisture; (ii) fresh stalk yield (t ha^{-1}), measured as the weight of plant stalks with leaves after cob harvest; and (iii) harvest index (%), calculated as the ratio of kernel yield to total biological yield. Economics were assessed through cost of cultivation, gross returns, net returns and benefit-cost (B:C) ratio. Data were analysed using standard ANOVA, with treatment differences assessed using CD at the 5% significance level (Gomez & Gomez, 1984).

3. Results and Discussion

3.1 Kernel Yield (t ha^{-1})

Kernel yield of maize was significantly influenced by the different value-added vermiwash treatments, ranging from 6.89 t ha^{-1} (T_1) to 9.10 t ha^{-1} (T_8), with an overall mean of 8.05 t ha^{-1} (Table 1). T_8 (vermiwash + *Pseudomonas* + neem leaf extract + Zn + B at 0.25% each) recorded the highest kernel yield (9.10 t ha^{-1}), which was statistically on par with T_6 (8.98 t ha^{-1}), T_7 (8.75 t ha^{-1}) and T_9 (8.41 t ha^{-1}). The lowest kernel yield was recorded in T_1 (6.89 t ha^{-1}). The yield ranking was $T_8 > T_6 > T_7 > T_9 > T_5 > T_3 > T_4 > T_2 > T_1$, representing a 32.0% increase in T_8 over T_1.

The significant improvement in kernel yield under T_8 may be attributed to the combined effects of improved growth parameters, enhanced photosynthetic efficiency, better nutrient uptake and superior yield-contributing characteristics. The enriched vermiwash provided a continuous supply of essential nutrients, plant growth hormones and beneficial microorganisms that collectively enhanced the source-sink relationship in maize (Patnaik et al., 2022). *Pseudomonas*, as a plant growth-promoting rhizobacterium (PGPR), enhances phosphorus availability and produces growth hormones that improve root architecture, thereby increasing nutrient and water absorption capacity (Noumavo et al., 2016). Foliar application of Zn and B at critical growth stages ensured an adequate micronutrient supply during peak demand periods. Potarzycki and Grzebisz (2009) reported an approximately 18% increase in maize grain yield with Zn foliar application, and Wasaya et al. (2017) confirmed that foliar B + Zn application significantly improved maize grain yield under rainfed conditions.

3.2 Fresh Stalk Yield (t ha^{-1})

Fresh stalk yield followed a trend similar to that of kernel yield, ranging from 4.10 t ha^{-1} (T_1) to 9.93 t ha^{-1} (T_8), with an overall mean of 7.22 t ha^{-1} (Table 1). T_8 recorded the highest stalk yield (9.93 t ha^{-1}), which was statistically on par with T_6 (8.83 t ha^{-1}), T_7 (8.83 t ha^{-1}), T_9 (7.80 t ha^{-1}) and T_5 (7.17 t ha^{-1}). The minimum stalk yield of 4.10 t ha^{-1} was recorded in T_1.

The higher fresh stalk yield under enriched vermiwash treatments with micronutrients indicates greater biomass production driven by improved vegetative growth. The combined effect of vermiwash and *Pseudomonas* in enhancing nutrient use efficiency, along with the role of zinc in chlorophyll synthesis and the contribution of boron to the structural integrity of cell walls, collectively promoted stover accumulation (Cakmak, 2008; Mumivand et al., 2021). Dwivedi et al. (2022) similarly observed significant improvements in the stover yield of maize with the combined application of organic manures, zinc and boron.

3.3 Harvest Index (%)

Harvest index showed an inverse relationship with yield levels, ranging from 47.82% (T_8) to 62.83% (T_1) (Table 1). The highest harvest index under T_1 indicates that a greater proportion of assimilates was partitioned towards grain rather than vegetative biomass. In contrast, the reduced harvest index under T_8 suggests that, although total biomass increased substantially, a relatively larger share was allocated to stalk development. This is a typical outcome of nutrient-enriched treatments that promote vigorous vegetative growth alongside grain production.

The decline in harvest index with increasing nutrient enrichment may be attributed to enhanced nutrient availability and hormonal activity from enriched vermiwash, which promotes vigorous vegetative growth. The involvement of *Pseudomonas* spp. in improving nutrient uptake efficiency, along with the physiological roles of zinc and boron, contributed to this pattern of assimilate distribution. Similar trends of reduced harvest index with increased biomass production under integrated nutrient management have been reported by Dwivedi et al. (2022). It is important to note that T_8 produced the highest absolute grain yield despite the lowest harvest index, emphasising that total yield rather than harvest index is the more relevant productivity indicator.

Table 1. Effect of value-added vermiwash on yield and harvest index of kharif maize

Treatments	Kernel Yield (t ha⁻¹)	Fresh Stalk Yield (t ha⁻¹)	Harvest Index (%)
T_1: Water spray alone (Control)	6.89	4.10	62.83
T_2: Vermiwash alone	7.62	5.57	57.72
T_3: Vermiwash + 5% neem leaf extract	7.56	6.47	53.87
T_4: Vermiwash + 5% calotropis leaf extract	7.20	6.30	54.04
T_5: Vermiwash + 5% (Pseudomonas + neem)	7.94	7.17	52.54
T_6: T_3 + (Zn+B) 0.25% each	8.98	8.83	50.41
T_7: T_4 + (Zn+B) 0.25% each	8.75	8.83	49.76
T_8: T_5 + (Zn+B) 0.25% each	9.10	9.93	47.82
T_9: T_5 + 5% Glyricidia leaf extract	8.41	7.80	51.81
SEm±	0.35	0.47	1.49
CD (p=0.05)	1.06	1.40	4.47

3.4 Cost of Cultivation (₹ ha^{-1})

The cost of cultivation varied marginally among treatments, ranging from ₹92,361 ha^{-1} (T_1) to ₹95,867 ha^{-1} (T_8) (Table 2). The slightly higher cost in treated plots was attributable to the use of enriched vermiwash formulations and additional supplementary inputs (Zn, B and *Pseudomonas*). However, the marginal increase in input cost was largely offset by the higher yields obtained. The capacity to prepare enriched vermiwash on-farm using locally available materials represents an economic advantage for resource-limited farmers in the region.

3.5 Gross Returns (₹ ha^{-1})

Gross returns differed considerably among treatments. T_8 recorded the maximum gross returns (₹2,27,500 ha^{-1}), which was significantly superior to all other treatments, followed by T_7 (₹2,10,000 ha^{-1}) and T_6 (₹2,01,950 ha^{-1}). The minimum gross returns were recorded in T_2 (₹1,71,150 ha^{-1}). The higher gross returns in the superior treatments were primarily due to increased kernel and fresh stalk yields (Table 2).

3.6 Net Returns (₹ ha^{-1})

Net returns followed a trend similar to that of gross returns. T_8 achieved the highest net returns (₹1,38,604 ha^{-1}), followed by T_7 (₹1,14,336 ha^{-1}) and T_6 (₹1,06,298 ha^{-1}). Treatments T_5 (₹1,01,649 ha^{-1}) and T_9 (₹1,01,341 ha^{-1}) showed moderate returns, while the lowest net returns were recorded in T_2 (₹76,365 ha^{-1}). The variation in net returns reflects differences in both yield and input costs. Notably, even though T_2 (vermiwash alone) incurred higher input costs than T_1, its lower gross returns resulted in the minimum net returns among all treatments (Table 2).

3.7 Benefit-Cost Ratio

The B:C ratio differed notably among treatments, indicating variation in economic efficiency. T_8 recorded the highest B:C ratio (2.37), followed by T_7 (2.20), T_6 (2.11), T_3 (2.02) and T_4 (2.00). The lowest B:C ratio was recorded in T_2 (1.81), while T_1 recorded a B:C ratio of 1.93 (Table 2). The superior economic performance of T_8 confirms that the marginal increase in input cost over the control was more than compensated for by the substantial yield enhancement.

The economic advantage of T_8 is primarily explained by the fact that enriched vermiwash can be prepared on-farm using locally available materials at minimal additional cost, while Zn and B foliar sprays at 0.25% concentration require only modest quantities. Treatment T_9 (*Glyricidia*-enriched vermiwash without Zn + B) recorded a B:C ratio of 1.99, indicating that *Glyricidia* leaf extract also contributed positively to economic returns through its nitrogen-rich composition (Keya et al., 2021). However, the absence of micronutrient supplementation in T_9 resulted in lower yields compared with T_6, T_7 and T_8, confirming the important role of Zn and B. Similar findings on the economic benefits of integrated organic-micronutrient nutrition in maize were reported by Phonglosa et al. (2019) and Mahato et al. (2020).

Table 2. Effect of value-added vermiwash on economics of kharif maize production

Treatments	Cost of Cultivation (₹ ha^{-1})	Gross Returns (₹ ha^{-1})	Net Returns (₹ ha^{-1})	B:C Ratio
T_1: Water spray alone (Control)	92,361	1,78,325	85,964	1.93
T_2: Vermiwash alone	94,785	1,71,150	76,365	1.81
T_3: Vermiwash + 5% neem leaf extract	95,117	1,92,500	97,383	2.02
T_4: Vermiwash + 5% calotropis leaf extract	95,129	1,90,050	94,921	2.00
T_5: Vermiwash + 5% (Pseudomonas + neem)	95,417	1,90,050	1,01,649	1.99
T_6: T_3 + (Zn+B) 0.25% each	95,652	2,01,950	1,06,298	2.11
T_7: T_4 + (Zn+B) 0.25% each	95,664	2,10,000	1,14,336	2.20
T_8: T_5 + (Zn+B) 0.25% each	95,867	2,27,500	1,38,604	2.37
T_9: T_5 + 5% Glyricidia leaf extract	95,717	1,90,050	1,01,341	1.99

4. Conclusion

The study demonstrated that foliar application of value-added vermiwash enhanced the yield and economic returns of kharif maize. Treatment T_8 (vermiwash enriched with 5% *Pseudomonas* + neem leaf extract + Zn + B at 0.25% each), applied as a foliar spray at 45, 60 and 75 DAS, recorded the highest kernel yield (9.10 t ha^{-1}), fresh stalk yield (9.93 t ha^{-1}), gross returns (₹2,27,500 ha^{-1}), net returns (₹1,38,604 ha^{-1}) and benefit-cost ratio (2.37). The superiority of T_8 may be attributed to the combined contributions of vermiwash-borne growth regulators and nutrients, *Pseudomonas*-mediated nutrient mobilisation, neem extract bioactives, and the roles of zinc in enzyme activation, chlorophyll synthesis and auxin metabolism and boron in pollen viability, grain filling and cell wall integrity. Harvest index was inversely related to treatment intensity due to proportionally higher biomass production, while absolute grain yield remained highest under T_8. This value-added vermiwash formulation represents a sustainable and economically promising nutrient-management approach for kharif maize cultivation under the agro-climatic conditions of southern Odisha and comparable tribal upland environments.

5. Limitations

This study was conducted during a single kharif season at one location, which limits broader inference across years, soils, and maize-growing environments. The assessment focused mainly on yield and economics; soil biological changes, nutrient dynamics, grain quality, and long-term residual effects were not evaluated. Multi-location and multi-season validation is therefore required before wider recommendation.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/159670