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Economic Viability of Vermicompost and Micronutrient Management in Mustard (*Brassica juncea* L.) Under Semi-arid Conditions of Rajasthan

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ABSTRACT

Mustard (Brassica juncea L.) is one of the most important oilseed crops cultivated in India and plays a crucial role ensuring in edible oil and improving farmer's income. How ever decreasing of soil fertility, improper nutrient management and increased cultivation costs have become major constraints affecting productivity and profitability to farmers. The use of organic manure and micro nutrients has beneficial for a sustainable approach to improve performance of crop and economic viability of different levels of vermicompost and micronutrients application in mustard under semi-arid conditions of Rajasthan.

The filed experiment consisted of four vermicompost and micronutrient treatments involving sulphur, zinc sulphate and ferrous sulphate. Economic indicators such as gross return, net return and benefit-cost ratio were computed based on prevailing market prices, Results will be revealed that vermicompost and micronutrients application significantly influenced the profitability of mustard cultivation. In given vermicompost treatments, application of vermicompost at 7.5 t ha^{-1} recorded the highest net return (₹49,337 ha^{-1}), whereas vermicompost at 5.0 t ha^{-1} has received highest benefit-cost ratio (2.20), Among micronutrients treatments combined application of sulphur@ 40kg ha^{-1}, zinc sulphate @25 kg ha^{-1} and ferrous sulphate @15 kg ha^{-1} recorded the highest net return (₹56, 185 ha^{-1}) and benefit-cost ratio (2.49), Enhanced profitability under these treatments was attributed to improved nutrients availability, better nutrient uptake, increased yield and superior quality characteristics.

The study showed that integrated nutrient management involving vermicompost and balanced micronutrients application can substantially improve economic returns from mustard cultivation. Adoption of these nutrient management practices may therefore contribute to sustainable productivity enhancement and increased farm profitability in mustard growing regions.

Keywords: *Mustard, Vermicompost, Sulphur, Zinc sulphate, Ferrous sulphate, semi-arid, yield, Net returns, Economic analysis, Benefit-cost ratio.*

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INTRODUCTION

Agriculture remains the backbone of the Indian economy, providing livelihood support to as a substantial proportion of the rural population. Among various agricultural enterprises, oilseed crops occupy a prominent position due to their contribution to nutritional security, industrial development and export earnings. Indian mustard (*Brassica juncea* L.) is one of the most important rabi oilseed grown in India and contributes significantly to the country's edible oil production. The crop is widely cultivated in northwestern India, particularly in Rajasthan, Haryana, Uttar Pradesh and Madhya Pradesh, owing to its adaptability to diverse agro-climatic condition and high economic value.

Mustard seed contains approximately 30 to 45% oil and 20 to 25% protein making it an important source of edible oil and livestock feed. Besides its nutritional importance, mustard cultivation generates substantial employment opportunities and serves as a profitable source for small and marginal farmers. Despite its significance, the productivity of mustard in many regions remains below its genetic potential due to several biotic and abiotic constraints. Among these factors, nutrient deficiency and soil fertility degradation are considered major limitations affecting crop growth, yield and profitability.

Continuous cultivation coupled with excessive dependence on chemical fertilizers has resulted in deterioration of soil health and nutrient imbalance. While macronutrients such as nitrogen, phosphorus and potassium are commonly applied the role of organic nutrient sources and micronutrients is often neglected. Consequently, deficiencies of sulphur, zinc and iron have become increasingly prevalent in agricultural soils particularly under intensive cropping systems. Such deficiencies adversely affect crop metabolism, nutrient uptake and overall productivity.

Organic manures have gained renewed attention as sustainable nutrient sources capable of improving soil fertility while maintaining environmental quality. Among various organic amendments, vermicompost has emerged as one of the most efficient and environmentally friendly nutrient sources. Vermicompost is produced through the biological decomposition of organic waste by earthworms and microorganisms. It contains essential plant nutrient in readily available forms along with beneficial microbial populations, enzymes and plant growth regulators. Application of vermicompost improves soil structure, water holding capacity, aeration and microbial activity, thereby enhancing nutrient availability and crop performance.

The beneficial effects of vermicompost on crop productivity have been documented in numerous studies. Vermicompost not only supplies nutrients but also stimulates root growth and improves nutrient uptake efficiency. Enhanced availability of nitrogen, phosphorus, potassium and micronutrients from vermicompost contributes to vigorous plant growth, increased biomass accumulation and higher yields. Incorporation of vermicompost improves the soil organic carbon status and supports long term sustainability of agricultural production systems.

In addition to organic nutrient sources, micronutrients play a crucial role in regulating physiological and biochemical processes in plants. Sulphur is considered the fourth major nutrient after nitrogen, phosphorus and potassium and is particularly important for oilseed crops. Sulphur is involved in the synthesis of amino acids, proteins, vitamins and enzymes and significantly influences oil formation in mustard. Adequate sulphur nutrition improves seed yield, oil content and quality characteristics thereby increasing economic returns.

Recent research has emphasized the importance of integrated nutrient management involving organic manures and micronutrients for achieving sustainable crop production. Integrated nutrient management enhances nutrient use efficiency, improves soil fertility

and reduces dependence on synthetic fertilizers. Moreover, balanced nutrient application helps to maintain ecological stability while improving crop productivity and profitability.

Economic analysis is critical component of agriculture research because the adoption of any production technology largely depends in its profitability. Farmers are increasingly interested in nutrient management practices that not only improve yields but also maximize economic returns. Therefore, assessment of economic indicators such gross returns, net returns, benefit-cost ratio is essential for evaluating the feasibility of different nutrient management strategies.

Considering the importance of sustainable nutrient management and the need for enhancing profitability in mustard cultivation, the present study was undertaken with the objective of evaluating the economic performance of vermicompost and micronutrients applications in mustard. The findings of this investigation are expected to provide useful recommendations for improving farmers income and ensuring sustainable mustard production under semi-arid agro ecological conditions.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted during the Rabi season under the semi-arid agro climatic condition of Rajasthan, India. The region is characterized by hot summers, mild winter and low to moderate rainfall. The climate is generally dry and making nutrient management a critical factor influencing crop productivity and profitability.

Experimental Design and Treatments

The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications. The treatments were allotted to 48 plots with 8 rows per plot, the layout plan experiment with allocation of 16 number of treatments.

The Experimental Treatments levels are Given below

Vermicompost Levels

- V_1: Control
- V_2: Vermicompost @2.5 t ha^{-1}
- V_3: Vermicompost @ 5.0 t ha^{-1}
- V_4: Vermicompost @ 7.5 t ha^{-1}

Micronutrient Levels

- M_1: Sulphur @ 40 kg ha^{-1}
- M_2: Sulphur @ 40 kg ha^{-1} + Ferrous sulphate @ 15 kg ha^{-1}
- M_3: Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 25 kg ha^{-1}
- M_4: Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 25 kg ha^{-1} + Ferrous sulphate @ 15 kg ha^{-1}

RESULTS AND DICUSSION

Economic Analysis

The economic of treatments is the prime consideration before making any recommendations to the farmers for its adoption. Economic viability of treatments was assessed by calculating cost of cultivation, gross returns, net returns and benefit-cost ratio based on prevailing market prices of inputs and produce. Hence's, to evaluate the effectiveness and profitability of the treatments, comprehensive economics in terms of net returns (₹ ha^{-1}) and B:C ratio was calculated so that most effective and remunerative treatment could be recommended.

Net Returns (₹ ha^{-1}) = Gross Returns – Cost of Cultivation

Benefit-Cost Ratio = Gross Returns (₹ ha^{-1}) / Cost of Cultivation (₹ ha^{-1})

Effect of Vermicompost on yield and Economic Returns

Yield is the primary determinant of profitability in any crop production system. The present investigation describes that vermicompost application significantly influenced seed yield and stalk yield of mustard. However, harvest index remained statistically unaffected.

Table 1: Effect of Vermicompost on Yield and Harvest Index of Mustard

Treatment	Seed Yield (kg ha^{-1})	Stalk Yield (kgha^{-1})	Harvest Index (%)
Control	1137	4029	22
Vermicompost @ 2.5 t ha^{-1}	1475	4748	23.70
Vermicompost @ 5.0 t ha^{-1}	1884	5784	24.56
Vermicompost @ 7.5 t ha^{-1}	1971	6129	24.33
SEm±	49	214	0.31
CD (P=0.05)	141	618	NS

*NS = non-significant

The highest seed yield (1971 kg ha^{-1}) and stalk yield (6129 kg ha^{-1}) were recorded with vermicompost application at 7.5 t ha^{-1}. The increase in yield may be attributed to improved soil physical properties, enhanced microbial activity and greater nutrient availability. Vermicompost acts as a slow-release nutrient source, supplying both macro and micro nutrients throughout the crop growth period. Improved nutrient availability promotes photosynthetic activity, biomass accumulation and reproductive development resulting in higher seed production. Economic analysis showed a significant influence of vermicompost on profitability.

Table 2: Effect of Vermicompost on Protein content, Oil content, Net Return and B:C Ratio of Mustard

Treatment	Protein (%)	Oil (%)	Net Return (₹ ha^{-1})	B:C Ratio
Control	14.70	32.95	36,963	2.43
Vermicompost @ 2.5 t ha^{-1}	15.65	34.29	26,190	1.57
Vermicompost @ 5.0 t ha^{-1}	17.11	36.81	49,055	2.20
Vermicompost @ 7.5 t ha^{-1}	17.73	37.96	49,337	2.08
SEm±	0.34	0.53	2998	0.07
CD (P=0.05)	0.99	1.54	8658	0.21

The highest net return (₹49,337 ha^{-1}) was recorded with the Vermicompost application at 7.5 t ha^{-1} and which was statistically a part with vermicompost at 5.0 t ha^{-1}. The higher profitability was primarily due to enhanced seed and stalk yields achieved under these treatments. Interestingly the highest benefit-cost ratio (2.20) was observed with the vermicompost application at 5.0 t ha^{-1}. This suggest that although the 7.5 t ha^{-1}treatment generated slightly greater returns, the additional cost involved reduced economic efficiency. Therefore, vermicompost at 5.0 t ha^{-1} appears to be the most economically efficiency dose under the conditions of the study. These findings corroborate earlier reports indicating that vermicompost improves crop productivity and profitability through enhanced nutrient use efficiency and improved soil health.

Effect of Micronutrients on yield and Economic Returns

Micronutrients application significantly influenced mustard productivity and profitability. Progressive addition of zinc and iron along with sulphur resulted in substantial improvements in yield.

Table 3: Effect of Micronutrients on Yield and Harvest Index of Mustard

Treatment	Seed Yield (kg ha^{-1})	Stalk Yield (kgha^{-1})	Harvest Index (%)
Sulphur @ 40 kg ha^{-1}	1316	4400	23.02
Sulphur @ 40 kg ha^{-1} + Ferrous sulphate@15 kg ha^{-1}	1616	4858	24.96
Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 25 kg ha^{-1}	1942	5209	27.15
Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 25 kg ha^{-1} + Ferrous sulphate@15 kg ha^{-1}	2020	6224	24.56
SEm±	49	214	0.31
CD (P=0.05)	141	618	NS

*NS = non-significant

The highest seed yield (2020 kg ha^{-1}) and stalk yield (6224 kg ha^{-1}) were recorded under the combined application of sulphur, zinc sulphate and ferrous sulphate. This treatment significantly outperformed all other micronutrient treatments.

The enhanced yield can be explained by the complementary physiological functions of sulphur, zinc and iron. Sulphur is essential for amino acid synthesis and oil formation; zinc plays a critical role in enzymes activation and growth hormone synthesis. While iron contributes to chlorophyll formation and photosynthetic efficiency. The synergistic interaction among these nutrients improved nutrient uptake, biomass production and yield formation.

Table 4: Effect of Micronutrients on Protein content, Oil content, Net Return and B:C Ratio of Mustard

Treatment	Protein (%)	Oil (%)	Net Return (₹ ha^{-1})	B:C Ratio
Sulphur @ 40 kg ha^{-1}	13.75	32.03	29,996	1.83
Sulphur @ 40 kg ha^{-1} + Ferrous sulphate@15 kg ha^{-1}	14.95	33.94	34,569	1.92
Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 25 kg ha^{-1}	15.68	34.95	40,759	2.04
Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 25 kg ha^{-1} + Ferrous sulphate @15 kg ha^{-1}	16.81	37.09	56,185	2.49
SEm±	0.34	0.53	2998	0.07
CD (P=0.05)	0.99	1.54	8658	0.21

The combined application of sulphur, zinc sulphate and ferrous sulphate recorded the highest net return (₹56,185 ha^{-1}) and benefit-cost ratio (2.49). The treatment significantly outperformed all other micronutrient combinations. The superior profitability under these treatments was mainly associated with increased seed yield, improved oil content (37.09%) enhanced protein content (16.81%) and better nutrient uptake. The balanced supply of sulphur, zinc and iron optimized metabolic process, resulting in greater productivity and economic returns.

Comparative Assessment of Economic Viability

- Economic viability is determined not only by crop productivity but also by the relationship between production cost and monetary returns. The present study clearly demonstrated that nutrient

management practices substantially influenced both parameters.

- Among vermicompost treatment application of 5.0 – 7.5 t ha^{-1} emerged as the most profitable strategy. While the highest net return was obtained at 7.5 t ha^{-1} the highest benefit-cost ratio was achieved at 5.0 t ha^{-1}, indicating optimum economic efficiency at this level.
- Similarly, among micronutrients treatments integrated application of sulphur, zinc sulphate and ferrous sulphate proved superior to individual nutrient application. The highest net return and benefit-cost ratio obtained under this treatment suggest the balanced micronutrient management can significantly improve farm profitability.
- These findings indicate that integrated nutrient management involving organic amendments and micronutrients offers a sustainable approach for maximizing returns from mustard cultivation.

Influence of Nutrient Management on Farm Profitability

- Profitability is one of the most important factors influencing adoption of agricultural technologies by farmer. Nutrient management practices that increase yield without proportionately increasing cultivation cost generally results in higher benefit-cost ratios.
- The positive economic response observed under vermicompost application may be attributed to gradual nutrient release, improved soil fertility and enhanced nutrient use efficiency. Organic matter supplied through vermicompost also improves soil moisture retention which is particularly beneficial under semi-arid conditions.
- Likewise, micronutrient supplementation corrected hidden nutrient deficiencies and improved physiological functions with in the crop. Enhanced photosynthetic activity, nutrient translocation and metabolic efficiency resulted in higher seed yield and better-quality produce.
- The combined effects of organic nutrient sources and micronutrients therefore contributed substantially to improving profitability and sustainability of mustard production.

DISCUSSION

The present findings are in agreement with earlier studies reporting positive effects of organic manure and micronutrients on mustard productivity and profitability. Several researchers have observed significant improvement soil fertility and nutrient availability. The superior performance of sulphur-zinc-iron combinations has also been enhanced yield, oil content and economic returns. The findings support the concept that integrated nutrient management is essential for achieving sustainable crop production and maximizing farm income.

Under semi-arid conditions where nutrient deficiencies are widespread application of vermicompost and micronutrients can play a crucial role in improving productivity and profitability. Therefore, nutrient management strategies should focus on both yield enhancement and economic sustainability.

CONCLUSION

The present investigation demonstrated that both vermicompost and micronutrients application significantly influenced the economic performance of mustard cultivation under semi-arid conditions. Among vermicompost treatments applications of vermicompost at 7.5 t ha^{-1} recorded the highest return of ₹49,337 ha^{-1}, while vermicompost at 5.0 t ha^{-1} achieved the highest benefit-cost ratio of 2.20. This indicates that moderate to higher levels of vermicompost application can substantially improve profitability through enhanced nutrient availability and improved crop performance.

Among micronutrient treatments combined application of Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 25 kg ha^{-1} + Ferrous sulphate @15 kg ha^{-1} proved most effective

recording the highest net return of ₹56,185 ha^{-1} and benefit-cost ratio of 2.49. The treatment enhanced nutrient uptake improved physiological efficiency and resulted in superior economic returns.

Overall, the study established that integrated nutrient management involving vermicompost and balanced micronutrients application is an economically viable strategy for mustard cultivation. Adoption of these nutrient management practices can contribute to higher farm income, improved soil health and sustainable agricultural production under semi-arid agro-climatic conditions.

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Conflict of Interest:

The authors declare that they have no competing interests.

Author Contributions:

All authors contributed to manuscript preparation, critical revision, and final approval.

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