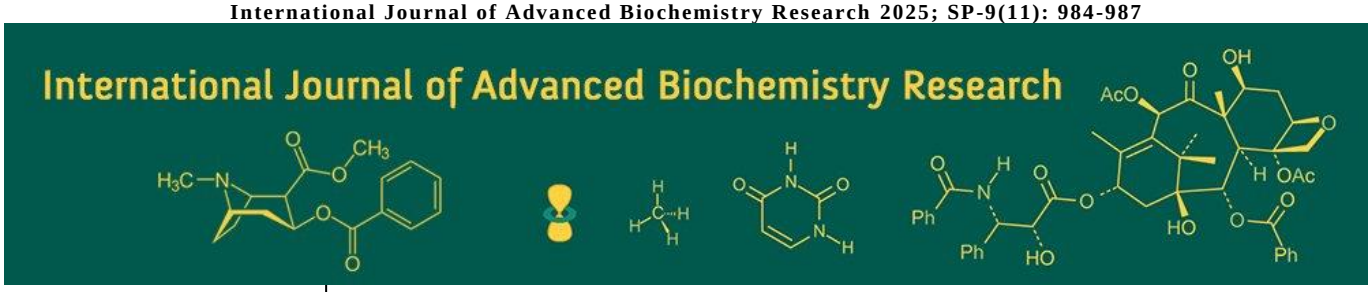

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(11): 984-987
www.biochemjournal.com
Received: 07-08-2025
Accepted: 11-09-2025

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Crop response to different nutrient management practices in maize-cowpea intercropping in Chhattisgarh

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i11Sm.6354

Abstract
Intercropping maize with cowpea can optimize resource use and enhance productivity, especially under varied nutrient management systems. A field experiment was conducted during for two consecutive years (2021-22) during kharif season IGKV-Krishi Vigyan Kendra, Mahasamund to examines how different nutrient management practices viz. Natural Farming, Conventional Farming, Integrated Nutrient Management (INM), Organic Farming (50% FYM + 50% Vermicompost), FYM (100%), and Vermicompost (100%), affects growth performance, crop yield, biomass yield and nutrient uptake and overall system productivity in a maize-cowpea intercropping system in Chhattisgarh. Recommended package of practices by IGKV, Raipur was adopted in this study. It was found that crop under INM significantly improves both maize and cowpea yields recorded the highest gross return and B:C ratio during both years, whereas Vermicompost 100% showed the lowest profitability due to high input cost. Additionally, INM practices reduced nutrient losses and environmental risks, promoting eco-friendly and sustainable farming systems. Natural Farming maintained moderate profitability owing to lower cultivation cost. These findings suggest that integrated nutrient management in maize-cowpea intercropping can boost productivity while supporting long-term soil fertility in Chhattisgarh's agro-ecosystems.

Keywords: Maize-cowpea intercropping, natural farming, INM, organic farming, FYM, Vermicompost

Introduction
Maize-cowpea intercropping is a widely adopted cropping system in central India due to its proven advantages in enhancing land-use efficiency, stabilizing yields, and improving soil health under rainfed as well as irrigated ecologies. Maize, being an exhaustive nutrient-demanding cereal, benefits substantially when grown in association with cowpea, a fast-growing legume which contributes to biological nitrogen fixation, improving soil fertility and reducing the need for synthetic fertilizers, which supports sustainable nutrient management (Mohanty, Meenakshi, 2024) [6]. Through biological nitrogen fixation, cowpea enriches the rhizosphere and contributes to a more balanced nutrient environment for the companion crop. The complementary growth habits, differential rooting depths, and varied nutrient requirements of maize and cowpea allow for efficient utilization of above-and below-ground resources, ultimately improving system productivity and sustainability.
Nutrient management practices play a crucial role in determining crop yield and system productivity in intercropping systems, especially under varying agro-climatic conditions. In recent years, multiple nutrient management approaches—including Natural Farming, Organic Farming, and Integrated Nutrient Management (INM)—have received increased attention due to rising concerns over soil degradation, input costs, and environmental sustainability. Natural farming emphasizes the use of locally available bio-resources such as Jeevamrit, Beejamrit, and mulching, aiming to restore soil microbiological activity and reduce dependence on external inputs. Natural Farming maintained moderate profitability attributed to lower cultivation costs and sustainable soil practices, aligning with findings from regional studies on zero budget natural farming effects on yield and soil fertility (Duddigan *et al.*, 2023) [3].

Organic farming focuses on the application of bulky organic manures such as FYM and vermicompost to improve soil structure and enhance nutrient availability. INM, on the other hand, combines chemical fertilizers with organic sources, offering an ecologically balanced yet productivity-enhancing alternative.

However, the response of maize-cowpea intercropping to these nutrient management practices varies significantly with soil type, climate, and management intensity. While several studies highlight yield benefits from organic and INM approaches, limited information exists on their comparative profitability, particularly in the context of Chhattisgarh plains where smallholders depend heavily on cost-effective and resilient production systems. Economic evaluation is crucial, not only for understanding treatment effects on yield but also for guiding farmers toward practices that offer maximum returns with minimum risk. Therefore, the present study was undertaken to compare six nutrient management treatments—Natural Farming, Conventional Fertilization, INM, Organic Farming (50% FYM + 50% VC), FYM (100%), and Vermicompost (100%)—with the objective of assessing their impact on the growth, yield, biomass production, nutrient uptake, and overall productivity of maize-cowpea intercropping of Chhattisgarh plains.

Materials and Methods

1. Study Area

The field experiment was conducted for two consecutive years during kharif seasons of 2021-22 and 2022-23 at Indira Gandhi Krishi Vishwavidyalaya, Krishi Vigyan Kendra, Mahasamund, Chhattisgarh. The study area comes under the Chhattisgarh Plains Agro-Climatic Zone, characterized by hot sub-humid climate with mild winters. The soil of the experimental field was sandy-loam, low in available nitrogen, medium in phosphorus, and moderate in potassium, with neutral pH. The average annual rainfall of the Mahasamund district is 1131 mm.

2. Experimental Design

The experiment was laid out in a Randomized Block Design (RBD) for six treatments and three replications were adopted. The cropping system consisted of maize hybrid NK-30 intercropped with cowpea variety Kashi Kanchan at recommended spacing Uniform agronomic practices such as irrigation, weed management, and plant protection were followed for all treatments.

Treatments

T_1: Natural Farming-Beejamrit, Ghanjeevamrit @ 250 kg/ha, Jeevamrit @ 500 L/irrigation twice a month, mulching @ 5 t/ha.

T_2: Conventional-Urea 210 kg/ha, DAP 130 kg/ha, MOP 66 kg/ha.

T_3: Integrated Nutrient Management (INM)-Urea 196 kg/ha, SSP 281 kg/ha, MOP 50 kg/ha + Vermicompost 250 kg/ha.

T_4: Organic Farming-FYM 12.5 t/ha + Vermicompost 4.2 t/ha + foliar spray of 10% cow urine and vermiwash at 30 and 50 DAS.

T_5: FYM 100%-FYM 25 t/ha.

T_6: Vermicompost 100%-Vermicompost 8.4 t/ha.

All organic and bio-inputs were prepared or procured as per standard IGKV. Raipur protocols.

3. Crop Management and Observations

Field preparation was done using two cross harrowings followed by planking. Line sowing was done at recommended seed rate and row spacing. Irrigation scheduling was uniform for all plots, with critical irrigations provided at CRI, tillering, flowering, and grain-filling stages. Standard IPM-based plant protection measures were adopted. Different crop performance parameters viz. plant height, no. of cobs/pods per plant, root length, grain yield (q/ha), stover yield (q/ha) were recorded as per standard methods. The cost economics was calculated for the selling price based on the prevailing local market for the organic produce whereas based on the MSP for the others. The crop condition is presented in the fig. 1.

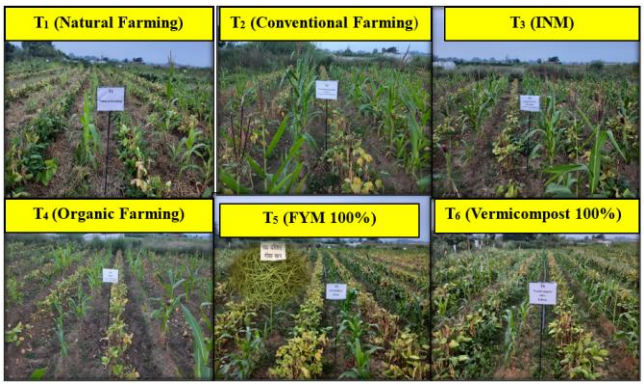

Fig 1: Crops under the different treatments in the study area

Results and Discussion

It was found that Integrated Nutrient Management (INM) was the most effective approach for optimizing maize-cowpea intercropping in terms of yield, profitability, and sustainability in Chhattisgarh's kharif season field experiments.

Table 1: Performance comparison of different treatments

Treatment	Yield	Profitability	Nutrient Loss & Risk	Suitability
INM	Highest	Highest	Low	Most recommended
Vermicompost (100%)	Moderate	Lowest	Low	Eco-friendly but costly
FYM (100%)	Moderate	Moderate	Low	Eco-friendly
Natural Farming	Moderate	Moderate	Low	Low-cost, moderate yield
Conventional Farming	Moderate	Moderate	Moderate	Not optimal for long-term

Performance of different nutrient management treatments on maize-cowpea intercropping regarding yield, cost, returns, and profitability for the year 2021-22 and 2022-23 is presented in Table 2 and Table 3 respectively.

1. Maize Grain Yield Performance

Integrated Nutrient Management (INM-T_3) consistently recorded the highest maize grain yield during both years of study. The superior performance of INM can be attributed to the balanced and timely supply of nutrients from both organic and inorganic sources. The partial substitution of chemical fertilizers with vermicompost not only enhanced nutrient availability but also improved soil physical properties, microbial activity, and root growth. This

synergistic effect resulted in better nutrient uptake and higher photosynthetic efficiency, ultimately leading to significantly higher grain yields compared with Natural, Organic, FYM, and Vermicompost treatments. Similar findings have been reported by Kumar *et al.* (2018) [5], who demonstrated that INM enhances yield potential by ensuring sustained nutrient release throughout the crop growth period.

Table 2: Crop performance parameters during 2021-22

Treatment	Maize grain yield (q/ha)	Cowpea pod (q/ha)	Cost of Cultivation (₹)	Gross return (₹)	B:C ratio
T_1: Natural Farming	15.6	7.2	24500	46428	1.89
T_2: Conventional	28.1	13.2	37200	72040	1.93
T_3: INM	30.4	14.8	38400	78560	2.04
T_4: Organic	26.3	12.8	47200	79199	1.67
T_5: FYM 100%	20.2	9.3	35294	60086	1.70
T_6: Vermicompost 100%	22.2	11.2	51600	67406	1.30

Table 3: Crop performance parameters during 2022-23

Treatment	Maize grain yield (q/ha)	Cowpea pod (q/ha)	Cost of Cultivation (₹)	Gross return (₹)	B:C ratio
T_1: Natural Farming	16.2	9.0	24500	50346	2.05
T_2: Conventional	28.9	14.9	37200	75680	2.03
T_3: INM	31.1	15.6	38400	80920	2.11
T_4: Organic	27.2	15.0	47200	84376	1.79
T_5: FYM 100%	21.5	11.2	35294	65775	1.86
T_6: Vermicompost 100%	23.4	13.6	51600	73562	1.43

2. Cowpea Pod Yield Response

Cowpea pod yield was significantly influenced by nutrient management practices. Treatments T_3 (INM) and T_4 (Organic Farming) remained statistically at par, indicating that both integrated and organic sources contribute substantially to legume productivity. The comparable performance of T_3 and T_4 may be explained by the fact that cowpea, being a legume, benefits strongly from organic matter additions, which improve nodulation, biological nitrogen fixation, and soil moisture retention. Foliar application of cow urine and vermiwash in T_4 further enhanced physiological processes and flower retention, resulting in pod yields similar to INM. These results corroborate earlier reports by Poswal and Sharma (1997) [7], highlighting that legumes exhibit strong yield responses to organic amendments and bio-stimulants.

3. Economic Performance and Profitability

Although Vermicompost 100% (T_6) produced moderate yields, it recorded the **lowest economic return and B: C ratio** across both seasons. This was primarily due to the high cost of vermicompost, which substantially increased the cost of cultivation without proportionally enhancing crop productivity. The low profitability under T_6 demonstrates that sole reliance on high-cost organic inputs may not be economically feasible for small and marginal farmers, despite their soil-health benefits.

In contrast, Natural Farming (T_1) showed comparatively lower yields but achieved high profitability due to **minimal input expenses**. These findings emphasize that profitability is influenced not only by yield but also by input cost structure, as also reported by Thakur *et al.* (2020) [10].

4. Overall Interpretation

Across both Kharif and Rabi seasons, INM emerged as the agronomically superior treatment, while Natural Farming proved economically superior due to lower production costs. Moreover, INM practices reduced nutrient losses and environmental risks, promoting eco-friendly and sustainable farming systems in line with agro-ecological sustainability goals (Mohanty, 2024) [6]. Organic systems such as T_4 performed well but were limited by higher input cost. Conversely, the Vermicompost 100% (T_6) treatment showed lower profitability primarily due to higher input costs despite its positive impact on soil health (Vukovic *et al.*, 2021) [11]. These results underscore the importance of balanced nutrient management strategies that combine productivity with economic viability under the Chhattisgarh Plains.

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Conclusion

The two-season evaluation of nutrient management practices under maize-cowpea intercropping (Kharif) and wheat (Rabi) clearly demonstrated that Integrated Nutrient Management (INM-T_3) is the most effective option for maximizing crop productivity in the Chhattisgarh Plains. INM consistently recorded the highest maize grain yield, cowpea pod yield, and wheat grain yield across years due to its balanced and sustained nutrient supply from both organic and inorganic sources. Natural Farming (T_1), though recording comparatively lower yields, achieved the highest B:C ratio in both seasons because of minimal input costs. This suggests that Natural Farming is a suitable choice for resource-poor and smallholder farmers who aim to reduce cultivation costs while maintaining moderate productivity. Organic Farming (T_4) and FYM 100% (T_5) produced favorable yields but were limited by high input requirements, which reduced overall profitability. These systems, however, remain important for long-term soil health improvement and sustainability. On the other hand, Vermicompost 100% (T_6) consistently recorded the lowest economic return and B:C ratio, despite moderate yield performance, due to the high cost of vermicompost. This indicates that the sole use of vermicompost is not economically viable for farmers under current market conditions.

Thus, integrating organic inputs with chemical fertilizers (INM) provides the most reliable strategy for improving productivity, profitability, and sustainability in cereal-legume-based cropping systems of Chhattisgarh.

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