**Influence of Integrated Nutrient Management on Growth, Yield and Economics of Chilli (*Capsicum annuum* L.) in Kandhamal, Odisha, India**

**ABSTRACT**

A field experiment was conducted during Kharif 2021 in Kandhamal district of Odisha to evaluate the impact of integrated nutrient management (INM) practices on the growth, yield, and economics of chilli (Capsicum annuum L.). The study, laid out in a Randomized Block Design with four treatments and five replications, compared farmers’ practices with soil test-based NPK application combined with FYM, vermicompost, and biofertilizers. Results revealed that the combined application of soil test-based NPK, vermicompost @ 5 t ha⁻¹, and biofertilizers (T4) significantly enhanced plant height (79.4 cm), number of fruits per plant (96.3), and green chilli yield (126.4 q ha⁻¹), along with the highest net return (₹2,95,300) and B: C ratio (1:4.0). Growth and yield parameters consistently improved across T2 to T4, compared to farmer’s practice (T1). These findings indicate that INM, particularly the inclusion of biofertilizers and vermicompost, can significantly boost chilli productivity and profitability under the agro-climatic conditions of Kandhamal.

*Key words: INM, biofertilizer, vermicompost, growth parameters, chilli yield, economics*

**INTRODUCTION**

“Chilli (*Capsicum annuum* L.) is one of the most important commercial high-value crops of India and belongs to the family *Solanaceae*. Chilli is famous for its pleasant aromatic flavour, pungency and high colouring substance. Pungency of chilli is due to crystalline and volatile alkaloid called capsaicin present in the placenta of fruit, which has diverse prophylactic and therapeutic uses in allopathic and ayurvedic medicines” (Parani and Nanthini, 2021) “Chilli is not only used as a food additive but also used for various medicinal purposes. The daily uses of chilli stimulate saliva and enables proper digestion and blood circulation. Both ripe and green chilli are important condiments used for imparting pungency and have great potentiality both for the domestic and international market” (Meena *et al.,* 2021). Chilli is rich in vitamin A, C and E with minerals like molybdenum, magnesium, potassium and copper and the fruits accumulate maximum ascorbic acid when it turn to maturity (Bindumadhabi and Bhattiprolu, 2011). “India is the world’s largest producer, consumer and exporter of chilli” (Kavitha *et al.,* 2018).

“Chilli is grown throughout the country in almost all the states with an annual production of 17.64 lakh tons from 7.33 lakh hectare area, which accounts for around 22.90 per cent of the total Indian spice production” (Sikarwar *et al.,* 2023). “The major chilli growing states are Maharashtra, Andhra Pradesh, Karnataka, Odisha, Tamil Nadu, Madhya Pradesh, West Bengal and Rajasthan” (Tripathy *et al.,* 2023). In Odisha, “it is cultivated in an area of 105.83 thousand hectares with an annual production of 122.38 thousand metric tonnes” (Anonymous, 2025).

Kandhamal is one of the tribal dominated districts of Odisha where chilli is cultivated throughout the year in an area of 2650 ha and annual production of 4060 tons. The low productivity of chilli in the district is mainly due to improper nutrient management practices and the use of suboptimal dose of organic manure. “Proper fertilizer application is one of the quickest and easiest ways of increasing the yield per unit area” (Nair *et al.,* 2023). “Studies have revealed that continuous use of sub-optimal doses of nutrients in an unbalanced proportion led to severe depletion of nutrient reserves in Indian soils, causing multiple nutrient deficiencies and decline in crop productivity” (Gokul et al. 2020)

Organic manure not only regularly supply macro, micro and secondary nutrients, but also improve the physical, chemical and biological properties of soil**.**

“Biofertilizers are substances containing a variety of microbes having the capacity to enhance plant nutrient uptake by colonizing the rhizosphere and make the nutrients easily accessible to plant root hairs. In recent years biofertilizers viz *Azospirillium*, *Azotobacter* and *Phosphate Solubilizing Bacteria* (PSB) are eco-friendly, low-cost inputs and also emerged as an integral component of the integrated plant nutrient supply system for vegetable production. Biofertilizers are also improve crop growth and quality of crops by producing plant hormones and phytoalexins” (Sajan *et al*., 2020). Vermicompost contains higher levels of organic carbon, total available NPK, micronutrients, microbial enzymes and plant growth regulators. Chilli requires higher amount of nutrients for its growth and production. “The chemical fertilisers are the main suppliers of major plant nutrients. Therefore, the rational and practical means to maintain soil fertility and to supply plant nutrients in balanced proportion is to practice integrated plant nutrients supply through the combined use of chemical and organic sources of plant nutrients” (Singh et al., 2022). Chilli production can be increased primarily by enhancing the productivity with balanced plant nutrition through integrated nutrient management practices (Sabir et al., 2017). “Use of judicious combinations of organic and inorganic fertilizer sources is essential, not only to maintain soil health but also to sustain the productivity. Nutrients from mineral fertilizers enhance the establishment of crops while those from mineralisation of organic manures promoted yield when both fertilizers were used combinedly” (Natsheh and Mousa, 2014). Hence, the present investigation was carried out to find out the Influence of Integrated Nutrient Management on Growth, Yield, and Economics of Chilli (Capsicum annuum L.)

This manuscript holds significant value for the scientific community as it provides empirical evidence on the effectiveness of integrated nutrient management (INM) practices in enhancing the growth, yield, and economic returns of chilli cultivation under real farm conditions. It contributes to sustainable agriculture by promoting the combined use of organic manure, biofertilizers, and chemical fertilizers. The study highlights the role of INM in enhancing soil health and improving nutrient use efficiency, which is crucial for maintaining long-term productivity. It addresses a critical yield gap in tribal-dominated regions, such as Kandhamal, Odisha, where traditional practices prevail. The findings can serve as a practical guide for agronomists, extension workers, and policymakers aiming to enhance chilli production in similar agro-climatic zones.

**MATERIALS AND METHODS**

A field experiment was conducted to assess the effect of integrated nutrient management practices on growth, yield and economics of chilli (*Capsicum annuum* L.) during Kharif 2021 at different farmer’s field in Kandhamal district of Odisha under Krishi Vigyan Kendra, Kandhamal, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar. The initial soil samples before conducting the trial were collected and analyzed. The pH was determined by a digital electric pH meter and available nitrogen was determined by alkaline permanganate method as reported by Piper (2019) and available phosphorus and potash by Bray’s No. 1 method and flame photometer method, respectively. The Electrical Conductivity (EC) was determined by Conductivity Bridge as described by Jackson (1967). The oxidizable soil organic carbon content (g kg-1 soil) was analyzed by the method proposed by Walkley and Black (1934). The available sulphur (0.15% CaCl2 extractable) was analyzed as proposed by Chesnin and Yien (1951). The soils of the experimental site were acidic in reaction and the pH varied between 5.15 and 5.43, sandy clay loam in texture and the content of available nitrogen, phosphorus, potassium and sulphur were varied between 215.4 and 234.6 kg ha-1, 10.3 and 12.4 kg ha-1, 261.3 and 297.8 kg ha-1and 5.8 and 7.3 mg kg-1, respectively. The organic carbon content at initiation of the experiment was in the range of 4.1 to 4.5 g kg-1 soil. The experiment was laid out in Randomized Block Design (RBD) consisting of four treatments with five replications. The treatments comprised of T1: Farmer’s practice (FYM @ 1 t ha-1 + 20-20-30 Kg N:P2O5:K2O ha-1, T2: Soil Test Based Fertilizer Recommendation (STBFR) NPK + FYM @ 5 t ha-1, T3: STBFR NPK + Vermicompost @ 5 t ha-1 and T4: STBFR NPK + Vermicompost @ 5 t ha-1 + Biofertilizer (*Azotobacter, Azospirillum* and *PSB* 1:1:1 @ 4 kg each ha-1). The hybrid chilli seedlings variety Daiya-619 were transplanted during August 2021 with a spacing of 0.60 m × 0.45 m. The NPK as per soil test recommendations was applied in T2, T3 & T4 treatments. The fertilizer @ 20-20-30 Kg N - P2O5 - K2O ha-1 and FYM @ 1.0 t ha-1 were applied in T1 (Farmer’s practice) whereas FYM @ 5 t ha-1in T2 and vermicompost @ 5 t ha-1 each in T3 and T4 were applied. The biofertilizers *viz.* *Azotobacter, Azospirillum* and *PSB* 1:1:1 @ 4 kg each ha-1 mixed with vermicompost were applied in T4 at the time of planting.

Half the dose of nitrogen and potassium as per the treatments were applied at transplanting as basal and rest 50% dose of N and K were applied in two equal splits as topdressing at 21days after transplanting (DAT) and 40 DAT. The full dose of P as per the treatments was applied as basal dose. Ten plants were randomly selected excluding the boundary area to record the observations for various growth and yield contributing characters of chilli. All the necessary cultural practices were uniformly carried out for successful harvest of the crop.

To determine the most economic treatment, the economics of each treatment were calculated based on the current market price of the produce and inputs used. Benefit cost ratio (B:C) for each treatment were determined after calculating the gross and net return. Gross return (₹ ha-1) was calculated by multiplying total produce (yield) by the relevant market prices at the time. The economic parameters were calculated by using the following formulae.

The data obtained during the trial were analyzed following the standard statistical procedure given for RBD by Panse and Sukhatme (1985). To evaluate whether there was a significant difference between the treatments, the Critical Difference (CD) at the 5% level was utilized.

**RESULTS AND DISCUSSION**

**Effect on growth parameters**

The integrated nutrient management (INM) practices significantly influenced the growth parameters of chilli. The data pertaining to plant growth of chilli are presented in Table-1 and significantly difference among the treatments were observed in the experiment. The result clearly shows that the application of soil test based NPK, vermicompost and biofertilizers (T4) recorded the taller plants (79.4 cm), however shortest plants (60.2 cm) were observed with T1 (Farmer’s practice) which received a fertilizer dose of 20-20-30 kg N-P2O5-K2O and FYM @ 1t ha-1. The treatment received soil test based NPK and vermicompost (T3) recorded the plant height of 69.8 cm. Further application of soil test based NPK along with FYM 5 t ha-1 recorded the plant height of 66.4 cm. The result was in conformity with the finding of Parani and Nanthini, 2021 who observed “increased plant height when use the inorganic fertilizers combined with cattle manure and poultry manure”.

Table 1. Effect of integrated nutrient management practices on growth parameters of chilli

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatments | Plant height (cm) | No. of primary branches plant-1 | Plant spread (cm) | Stem diameter(cm) | No. of leaves plant-1 | Root length (cm) |
| T1: Farmer’s practice | 60.2 | 8.2 | 61.3 | 1.14 | 237.8 | 16.4 |
| T2: STBFR\* NPK + FYM @ 5 t ha-1 | 66.4 | 9.3 | 67.1 | 1.39 | 251.4 | 19.1 |
| T3: STBFR NPK + Vermicompost @ 5 t ha-1 | 69.8 | 11.4 | 70.4 | 1.54 | 263.2 | 20.7 |
| T4: STBFR NPK + Vermicompost @ 5 t ha-1 + Biofertilizer\*\* | 79.4 | 12.8 | 77.8 | 1.73 | 284.5 | 23.3 |
| CD (0.05) | 1.42 | 0.89 | 2.14 | 0.12 | 5.17 | 0.96 |
| SEm± | 0.46 | 0.29 | 0.69 | 0.04 | 1.68 | 0.31 |

\*STBFR: Soil Test Based Fertilizer Recommendation

\*\*Biofertilizer: *Azotobacter, Azospirillum* and *PSB* 1:1:1 @ 4 kg each ha-1

Similarly, the other growth parameters like number of primary branches plant-1 (12.8), plant spread (77.8 cm), stem diameter (1.73 cm), number of leaves plant-1 (284.5) and root length (23.3 cm) were recorded highest value where soil test based NPK, vermicompost @ 5 tha-1 and biofertilizer @ 12 kg ha-1 were applied (T4) which is followed by T3 and T2. The lowest value of growth parameters like number of primary branches plant-1 (8.2), plant spread (61.3 cm), stem diameter (1.14 cm), number of leaves plant-1 (237.8) and root length (16.4 cm) were recorded under T1 (Farmer’s practice). The highest growth parameters were achieved under T4, which might be due to a better nutritional environment in the root zone for growth and development of plants. The similar results were also reported by Vinayak *et al.,* (2019), Reddy *et al.,* (2016) and Nair *et al.,* (2023). “The combined application of organic manures and inorganic fertilizers might have ensured all-around nutrient availability to the crop. The nutrients supplied through inorganic fertilizers were readily available and hence early crop growth and development were observed” (Patil *et al.,* 2012). The organic compounds might have improved the soil physical and biological condition for the plant growth along with increased availability of N and K at the early stage of crop growth, which might be the reason for the increased in plant growth in INM plots. These results are supported by the findings of Bharathi *et al.* (2011); Kashyap *et al.* (2014); Leelarani *et al.* (2015); Shiva *et al.* (2015); Guinoza *et al.* (2015); Alaboz *et al.* (2017); Sakthivel (2021); Sikarwar *et al.* (2023). Comparatively similar results were obtained by Singh *et al.* (2014); Dhanalakshmi *et al.* (2014) who described that “application of vermicompost on okra and chilli crop responded maximum number of branches plant-1”. “Vermicompost also provides better environment in the rhizosphere for the growth and extension of root” (Tripathi *et al*., 2023)

**Effect on yield attributes**

The data pertaining to yield attributes has been presented in Table-2. The highest number of fruits plant-1 (96.3), fruit length (6.4 cm), single fresh fruit weight (1.86 g), dry fruit weight (0.71 g) was observed under the treatment which received the soil test based NPK, vermicompost @ 5 tha-1 and biofertilizer @ 12 kg ha-1 (T4) which is followed by T3 and T2.

Table 2. Effect of integrated nutrient management practices on yield attributes and yield of chilli

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatments | No. of fruits plant-1 | Fruit length (cm) | Single fresh fruit weight (g) | Dry fruit weight (g) | Fresh fruit yield  (q ha-1) |
| T1: Farmer’s practice | 61.4 | 3.9 | 1.31 | 0.44 | 90.2 |
| T2: STBFR\* NPK + FYM @ 5 t ha-1 | 72.6 | 5.7 | 1.60 | 0.59 | 112.7 |
| T3: STBFR NPK + Vermicompost @ 5 t ha-1 | 81.5 | 6.1 | 1.74 | 0.64 | 118.4 |
| T4: STBFR NPK + Vermicompost @ 5 t ha-1 + Biofertilizer\*\* | 96.3 | 6.4 | 1.86 | 0.71 | 126.4 |
| CD (0.05) | 3.14 | 0.24 | 0.19 | 0.08 | 2.59 |
| SEm± | 1.02 | 0.08 | 0.06 | 0.03 | 0.84 |

\*STBFR: Soil Test Based Fertilizer Recommendation

\*\*Biofertilizer: *Azotobacter, Azospirillum* and *PSB* 1:1:1 @ 4 kg each ha-1

The treatment received soil test-based NPK and vermicompost recorded the yield attributes of chilli viz. number of fruits plant-1(81.5), fruit length (6.1 cm), single fresh fruit weight (1.74 g) and dry fruit weight (0.64 g). The lowest value of number of fruits plant-1(61.4), fruit length (3.9 cm), single fresh fruit weight (1.31 g) and dry fruit weight (0.44 g) were observed under Farmer’s Practice (T1). This could be attributed to the solubilization effect of plant nutrients by addition of organics, leading to increased uptake of NPK, as reported by Bharathi *et al.* (2011). “The higher value of yield attributes in T4 might be due to the addition of organic manures and biofertilizer to soil in combination with inorganic fertilisers, which increased the availability of nutrients considerably, result in positive effect on yield attributes” (Veena *et al.,* 2017). Balanced fertilization increased dry matter production through enhance photosynthetic efficiency in the chilli plant. Similar findings were also noticed by Srinivasan *et al.,* (2014) and Singh *et al.,* (2022). The increased in yield attributes might also be due better root proliferation, more uptake of nutrients and water, higher plant growth, more photosynthesis and enhanced food accumulation.

**Effect on yield**

With respect to the fresh fruit yield of chilli, it was observed that the treatment which received soil test based NPK, vermicompost and biofertilizer provided the highest green chilli yield (126.4 q ha-1) followed by T3 (118.4 q ha-1) and T2 (112.7 q ha-1). The lowest yield of 90.2 q ha-1 (Table-2) was recorded under T1 (Farmer’s Practice). The integrated supply and use of plant nutrients from chemical fertilizers and organic manures has been shown to produce higher crop yields. The synergistic effect of this combination might have caused the yield increment. “This increase in yield may be attributed to more availability of nutrients to plant and improvement in physico-chemical properties of soil due to addition of inorganic fertilizer and organic manure” (Meena *et al.* 2021). Das *et al.* (2025) reported that vermicompost enhances soil structure, promotes beneficial microorganisms, and provides nutrients such as nitrogen, phosphate, and potassium, hence increasing plant development and yield. Similar results have been reported by Kumar *et al.* (2015) who reported that integrated use of fertilizers had higher vegetative growth resulting better photosynthates which might increase the fruit yield of chilli.

**Effect on economics**

The average data pertaining to economic returns and benefit: cost ratio (B:C ratio) are presented in Table-3. The higher gross return (₹3,95,400), net return (₹2,95,300) and B:C ratio (1:4.0) were recorded under the treatment which received soil test based NPK, vermicompost and biofertilizer (T4) which was followed by T3 (Soil test based NPK and vermicompost application).

Table 3. Effect of integrated nutrient management practices on economics of chilli

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatments | Cost of cultivation  (₹ ha-1) | Gross return (₹ ha-1) | Net return  (₹ ha-1) | B:C ratio |
| T1: Farmer’s practice | 85100 | 270600 | 185500 | 3.2 |
| T2: STBFR\* NPK + FYM @ 5 t ha-1 | 90200 | 324900 | 234700 | 3.6 |
| T3: STBFR NPK + Vermicompost @ 5 t ha-1 | 98400 | 367800 | 269400 | 3.7 |
| T4: STBFR NPK + Vermicompost @ 5 t ha-1 + Biofertilizer\*\* | 100100 | 395400 | 295300 | 4.0 |

\*STBFR: Soil Test Based Fertilizer Recommendation

\*\*Biofertilizer: *Azotobacter, Azospirillum* and *PSB* 1:1:1 @ 4 kg each ha-1

The lowest amount of gross return (₹2,70,600), net return (₹1,85,500) and B:C ratio (1: 3.2) were observed under T1 (Farmer’s Practice). It might be due to the reason that the plant consumed nutrient provided directly through inorganic and organic fertilizer along with bio-fertilizer. Similar results for most of the characters were also reported by Manna *et al.* (2012); Samsangheile and Kanaujia (2014).

**CONCLUSION**

From the above result It was concluded that the application of soil test based NPK, vermicompost @ 5 t ha-1 along with biofertilizers (*Azotobacter, Azospirilum* and *PSB,* 4 kg each ha-1) positively influenced various aspects of plant growth, leading to superior performance in terms of height (cm), number of primary branches plant-1, plant spread (cm), stem diameter ( cm), number of leaves plant-1 and root length (cm). It significantly enhanced various yield parameters. These included number of fruits plant-1, fruit length (cm), single fresh fruit weight (g), dry fruit weight (g) and fresh fruit yield (q ha-1). The economic parameters evaluated in the study clearly indicate that the treatment T4, involving soil test based NPK, vermicompost @ 5 t ha-1 along with biofertilizers (*Azotobacter, Azospirilum* and *PSB,* 4 kg each ha-1) recorded highest gross monetary returns, net monetary returns, and the benefit-to-cost ratio.

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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