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## Effect of integrated nutrient management on yield and quality characters of Cowpea [*Vigna unguiculata* (L.) Moench]

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**Abstract**

The present investigation entitled "Effect of Integrated Nutrient Management on Yield and Quality Characters of Cowpea (*Vigna unguiculata* (L.) Moench)" was conducted during the Rabi season of 2022-23 at the Horticulture Research Farm, School of Agriculture Science, Technology and Research, Sardar Patel University, Balaghat, Madhya Pradesh, to evaluate the effect of integrated application of inorganic fertilizers, organic manures and biofertilizers on the growth, yield and quality of vegetable cowpea. The experiment was laid out in a Randomized Block Design (RBD) with eight treatments and three replications. The treatments comprised different combinations of the recommended dose of fertilizers (RDF), farmyard manure (FYM), vermicompost, *Rhizobium* and phosphate-solubilizing bacteria (PSB). The observations were recorded on important growth, yield and quality parameters and analyzed statistically using analysis of variance.

The results revealed that integrated nutrient management significantly influenced all the recorded parameters. Among the treatments, T<sub>6</sub> (50% RDF + FYM @ 12 t ha<sup>-1</sup> + *Rhizobium* + PSB) proved to be the most effective, recording the maximum plant height (83.62 cm), number of branches per plant (8.95), number of pods per plant (19.45), pod length (16.82 cm), pod weight (124.65 g plant<sup>-1</sup>), pod yield (4.36 kg plot<sup>-1</sup>), pod yield (109.00 q ha<sup>-1</sup>) and number of seeds per pod (14.15). The same treatment also resulted in earlier flowering (51.24 days), first harvest (62.45 days) and last harvest (83.12 days), indicating enhanced crop earliness. The superior performance of T<sub>6</sub> was attributed to the synergistic interaction of inorganic fertilizers, FYM and biofertilizers, which improved soil fertility, nutrient availability, biological nitrogen fixation, phosphorus solubilization and overall nutrient use efficiency. The combined application of FYM with reduced chemical fertilizers enhanced soil physical properties, microbial activity and nutrient uptake, thereby promoting better vegetative growth, reproductive development and higher marketable yield.

The study concludes that the integrated application of 50% RDF + FYM @ 12 t ha<sup>-1</sup> + *Rhizobium* + PSB is an efficient and sustainable nutrient management strategy for improving the productivity and quality of vegetable cowpea while reducing dependence on chemical fertilizers and maintaining soil health.

**Keywords:** Cowpea, Integrated nutrient management, Farmyard manure, Biofertilizers and Pod yield

**Introduction**

Cowpea (*Vigna unguiculata* (L.) Moench) is one of the most important multipurpose leguminous vegetable crops cultivated throughout tropical and subtropical regions of the world. It is valued for its tender green pods, dry seeds, fodder, and its ability to improve soil fertility through biological nitrogen fixation. Cowpea belongs to the family Fabaceae (Leguminosae) and is often referred to as the "poor man's meat" because of its high nutritional value and affordable source of dietary protein. The crop is highly adaptable to diverse agro-climatic conditions, including drought-prone and marginal soils, making it an important component of sustainable agricultural systems. In vegetable production, immature pods are consumed as a nutritious vegetable, whereas mature seeds serve as a rich source of protein and carbohydrates. In addition to human consumption, cowpea haulms provide quality fodder for livestock and contribute organic matter to the soil, thereby enhancing soil productivity (FAOSTAT, 2024) [6].

Globally, cowpea is cultivated on approximately 15-16 million hectares, producing nearly 9-10 million tonnes annually, with an average productivity of around 600-700 kg ha<sup>-1</sup> for grain production. Africa accounts for more than 80% of global cowpea production, with Nigeria, Niger, Burkina Faso, Ghana and Mali being the major producers. India is one of the important cowpea-growing countries in Asia, where the crop is cultivated both as a vegetable and pulse. According to recent estimates, cowpea occupies approximately 0.55-0.65 million hectares in India with an annual production of nearly 0.40-0.50 million tonnes, although productivity varies considerably among states due to differences in climate, management practices and varieties. Major cowpea-producing states include Rajasthan, Karnataka, Tamil Nadu, Kerala, Uttar Pradesh, Madhya Pradesh and Odisha. The increasing demand for protein-rich vegetables and sustainable cropping systems has enhanced the importance of cowpea cultivation in India (FAOSTAT, 2024; Directorate of Economics and Statistics, 2024)<sup>[6, 4]</sup>.

Cowpea possesses remarkable nutritional significance owing to its balanced composition of proteins, carbohydrates, vitamins and minerals. Fresh green pods contain approximately 85-90% moisture, 2.5-3.5% protein, 6-8% carbohydrates, appreciable amounts of dietary fibre, calcium, phosphorus, iron and vitamin C. Dry seeds contain 22-28% protein, making cowpea an excellent plant-based protein source for vegetarian diets. The crop also contains antioxidants, phenolic compounds and essential amino acids that contribute to human health by reducing the risk of several chronic diseases. Due to its low-fat content and high digestibility, cowpea is increasingly recognized as an important functional food crop (Boukar *et al.*, 2019)<sup>[2]</sup>.

Being a leguminous crop, cowpea establishes symbiotic association with *Rhizobium* bacteria, enabling biological nitrogen fixation that can contribute between 40 and 150 kg nitrogen ha<sup>-1</sup> under favourable conditions. This characteristic not only reduces dependence on synthetic nitrogen fertilizers but also improves soil fertility for succeeding crops. Nevertheless, biological nitrogen fixation alone cannot meet the complete nutrient requirement of high-yielding vegetable cultivars, particularly under intensive cultivation. Balanced application of nitrogen, phosphorus and potassium along with organic manures and beneficial microorganisms is therefore essential for achieving higher productivity and maintaining soil health (Hungria *et al.*, 2022)<sup>[7]</sup>.

The intensive use of chemical fertilizers over several decades has substantially increased crop productivity; however, their indiscriminate and continuous application has resulted in declining soil organic carbon, nutrient imbalance, deterioration of soil physical properties, reduced microbial activity and environmental pollution. Such practices have also decreased fertilizer use efficiency and adversely affected long-term soil fertility. Consequently, modern agricultural research emphasizes the adoption of sustainable nutrient management strategies that integrate organic and inorganic nutrient sources to enhance crop productivity while conserving natural resources (Lal, 2020)<sup>[9]</sup>.

Integrated Nutrient Management (INM) has emerged as an effective approach for sustainable crop production by combining inorganic fertilizers with organic manures and biofertilizers. INM aims to optimize nutrient availability throughout the crop growth period, improve nutrient use

efficiency, maintain soil fertility and minimize environmental degradation. Organic manures such as farmyard manure (FYM) and vermicompost improve soil structure, increase water-holding capacity, enhance cation exchange capacity and stimulate beneficial microbial populations. They also supply macro- and micronutrients in a slow and sustained manner, thereby improving nutrient availability and crop growth (Choudhary *et al.*, 2021)<sup>[3]</sup>.

Farmyard manure serves as a valuable source of essential nutrients and organic matter. It enhances soil aggregation, improves aeration and promotes root development, resulting in better nutrient uptake by plants. Vermicompost, produced through the decomposition of organic wastes by earthworms, is rich in humic substances, plant growth regulators, enzymes and beneficial microorganisms. Application of vermicompost has been reported to improve seed germination, plant growth, flowering, pod development and overall yield in several vegetable crops. Furthermore, vermicompost enhances microbial activity and nutrient mineralization, thereby increasing nutrient availability throughout the crop growth period (Edwards *et al.*, 2021)<sup>[5]</sup>. Biofertilizers constitute another important component of integrated nutrient management. *Rhizobium* inoculation enhances nodulation and atmospheric nitrogen fixation, leading to improved nitrogen availability and plant growth. Phosphate Solubilizing Bacteria (PSB) convert insoluble forms of phosphorus into plant-available forms through the production of organic acids and phosphatase enzymes. The combined application of *Rhizobium* and PSB not only increases nutrient availability but also improves root growth, nutrient uptake, photosynthetic efficiency and ultimately crop yield. Numerous studies have demonstrated synergistic interactions among biofertilizers, organic manures and chemical fertilizers in leguminous crops (Bhardwaj *et al.*, 2022)<sup>[1]</sup>.

The integration of reduced levels of recommended chemical fertilizers with FYM or vermicompost along with *Rhizobium* and PSB inoculation has shown promising results in improving growth, yield attributes and quality parameters of cowpea. Such integrated nutrient management practices increase pod length, pod weight, number of pods per plant, seed protein content, nutrient uptake and economic returns while reducing dependence on chemical fertilizers. Moreover, integrated nutrient management contributes to sustainable soil health by increasing soil organic carbon, microbial biomass and nutrient availability for subsequent crops (Singh *et al.*, 2023)<sup>[12]</sup>.

Despite considerable research on nutrient management in legumes, region-specific recommendations for integrated use of chemical fertilizers, organic manures and biofertilizers in vegetable cowpea remain limited, particularly under varying agro-climatic conditions. Therefore, evaluating suitable combinations of inorganic fertilizers, farmyard manure, vermicompost, *Rhizobium* and phosphate solubilizing bacteria is essential for developing sustainable nutrient management strategies that maximize productivity, improve pod quality and maintain long-term soil fertility.

Keeping these considerations in view, the present investigation entitled "Effect of Integrated Nutrient Management on Yield and Quality Characters of Cowpea (*Vigna unguiculata* (L.) Moench)" was undertaken to evaluate the effect of different combinations of inorganic fertilizers, farmyard manure, vermicompost, *Rhizobium* and

phosphate solubilizing bacteria on yield and quality parameters of cowpea and to identify an efficient integrated nutrient management practice for sustainable production.

## Materials and Methods

### Experimental Site

The present investigation entitled "Effect of Integrated Nutrient Management on Yield and Quality Characters of Cowpea (*Vigna unguiculata* (L.) Moench)" was conducted during the Rabi season of 2022-23 at the Horticulture Research Farm, School of Agriculture Science, Technology and Research, Sardar Patel University, Balaghat, Madhya Pradesh, India. The initial soil was slightly alkaline in reaction (pH 7.81), contained 0.42% organic carbon, 148.0 kg ha<sup>-1</sup> available nitrogen, 15.15 kg ha<sup>-1</sup> available phosphorus and 226.30 kg ha<sup>-1</sup> available potassium.

### Experimental Materials

The experiment was carried out using the vegetable cowpea variety 'Swarna Harita', a high-yielding variety recommended for vegetable production. Healthy and uniform seeds were procured from a reliable source. Before sowing, the seeds were treated with Captan @ 2 g kg<sup>-1</sup> seed to minimize seed-borne diseases. Thereafter, seeds were inoculated with *Rhizobium* and Phosphate Solubilizing Bacteria (PSB) as per the treatment schedule before sowing.

### Experimental Design and Treatments

The experiment was laid out in a Randomized Block Design (RBD) comprising eight treatments with three replications, resulting in a total of 24 experimental plots. Each plot measured 2.0 × 2.0 m with a plant spacing of 45 × 30 cm. The recommended seed rate of 20 kg ha<sup>-1</sup> was followed. The crop was sown during the first fortnight of October.

The treatments were formulated by integrating different levels of the recommended dose of fertilizers (RDF), farmyard manure (FYM), vermicompost and biofertilizers (*Rhizobium* and Phosphate Solubilizing Bacteria, PSB). Treatment T<sub>1</sub> served as the control and received 100% recommended dose of fertilizers (40:40:30 kg N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O ha<sup>-1</sup>). Treatment T<sub>2</sub> consisted of 100% RDF along with seed inoculation of *Rhizobium* and PSB @ 4 kg ha<sup>-1</sup>. Treatments T<sub>3</sub> and T<sub>4</sub> received 75% RDF and 50% RDF, respectively, in combination with *Rhizobium* and PSB inoculation. Organic nutrient sources were integrated in treatments T<sub>5</sub> to T<sub>8</sub>, wherein T<sub>5</sub> received 75% RDF + FYM @ 10 t ha<sup>-1</sup> + *Rhizobium* + PSB, T<sub>6</sub> received 50% RDF + FYM @ 12 t ha<sup>-1</sup> + *Rhizobium* + PSB, T<sub>7</sub> comprised 75% RDF + vermicompost @ 6 t ha<sup>-1</sup> + *Rhizobium* + PSB, and T<sub>8</sub> consisted of 50% RDF + vermicompost @ 8 t ha<sup>-1</sup> + *Rhizobium* + PSB. These treatment combinations were designed to evaluate the effect of integrating inorganic fertilizers with organic manures and biofertilizers on the yield and quality attributes of vegetable cowpea under the agro-climatic conditions of Balaghat, Madhya Pradesh.

### Observations Recorded

Five healthy and representative plants were randomly selected from the central rows of each experimental plot for recording observations throughout the crop growth period. Observations on yield attributes included the number of pods per plant, pod length (cm), average pod weight (g), number of seeds per pod, pod yield per plant (g), pod yield per plot (kg) and total green pod yield (q ha<sup>-1</sup>). The quality

parameters of the harvested pods were also determined using standard laboratory procedures. The observations recorded for each parameter were averaged and subjected to statistical analysis to evaluate the influence of different integrated nutrient management practices on the yield and quality performance of cowpea. The experimental data were analyzed following the analysis of variance (ANOVA) technique appropriate for the Randomized Block Design, and treatment means were compared at the 5% level of significance.

### Statistical Analysis

The recorded experimental data were subjected to analysis of variance (ANOVA) appropriate for the Randomized Block Design (RBD) as described by Panse and Sukhatme (1985). Treatment means were compared using the Critical Difference (CD) test at the 5% level of significance ( $P = 0.05$ ) wherever the F-test indicated significant differences among treatments.

## Results and Discussion

### Plant Height at Harvest (cm)

Plant height is an important growth parameter that reflects the overall vigor and nutrient status of the crop. The data presented in Table 1 revealed that integrated nutrient management treatments exerted a significant influence on plant height at harvest. The maximum plant height (83.62 cm) was recorded under treatment T<sub>6</sub> (50% RDF + FYM @ 12 t ha<sup>-1</sup> + *Rhizobium* + PSB), which was significantly superior to all other treatments. This was followed by T<sub>7</sub> (80.24 cm), T<sub>8</sub> (78.85 cm) and T<sub>5</sub> (77.25 cm). The minimum plant height (69.15 cm) was observed under the control treatment (T<sub>1</sub>), which received only the recommended dose of chemical fertilizers. Similar improvements in plant height through integrated use of organic manures and biofertilizers were also documented by Singh *et al.* (2023) <sup>[12]</sup> and Bhardwaj *et al.* (2022) <sup>[1]</sup>, who attributed enhanced growth to improved nutrient availability and increased microbial activity in the rhizosphere.

### Number of Branches per Plant

The results indicated significant differences among nutrient management treatments. The highest number of branches per plant (8.95) was recorded under T<sub>6</sub> (50% RDF + FYM @ 12 t ha<sup>-1</sup> + *Rhizobium* + PSB), followed by T<sub>7</sub> (7.74), T<sub>8</sub> (7.26) and T<sub>5</sub> (7.05). The control treatment (T<sub>1</sub>) recorded the lowest number of branches (5.14).

These findings corroborate those of Hungria *et al.* (2022), who emphasized the beneficial role of biological nitrogen fixation in enhancing vegetative growth of legumes. Similar results were also reported by Sharma *et al.* (2021) <sup>[11]</sup> and Singh *et al.* (2023) <sup>[12]</sup>, who observed a significant increase in branch production in legumes under integrated nutrient management involving organic manures and biofertilizers.

### Number of Leaves per Plant

The number of leaves per plant differed significantly among the treatments. The highest number of leaves (62.12) was recorded under T<sub>7</sub> (75% RDF + Vermicompost @ 6 t ha<sup>-1</sup> + *Rhizobium* + PSB), which was statistically at par with T<sub>6</sub> (60.17) and T<sub>8</sub> (59.83) but significantly superior to the control (47.54 leaves).

The present findings are in close agreement with those of Edwards *et al.* (2021) <sup>[5]</sup>, who reported that vermicompost

improves vegetative growth through enhanced microbial activity and nutrient mineralization. Similar observations were also made by Choudhary *et al.* (2021)<sup>[3]</sup> and Singh *et al.* (2023)<sup>[12]</sup>, who reported increased leaf production in vegetable crops under integrated nutrient management practices.

#### Days to 50% Flowering

Integrated nutrient management significantly influenced the number of days required for 50% flowering. The earliest flowering (51.24 days) was observed in T<sub>6</sub>, followed by T<sub>7</sub> (53.49 days) and T<sub>8</sub> (53.92 days), whereas the control treatment (T<sub>1</sub>) required the maximum time (60.74 days) to attain 50% flowering.

Adequate phosphorus availability accelerates root development, energy metabolism and flower initiation, while nitrogen supplied through biological fixation ensures vigorous early growth without causing excessive vegetative delay. Farmyard manure improves soil physical properties and microbial activity, enabling efficient nutrient uptake and favorable hormonal balance. Consequently, plants attain physiological maturity earlier, leading to timely flowering and ultimately extending the harvesting period. These results are consistent with the findings of Sharma *et al.* (2021)<sup>[11]</sup>, who observed earlier flowering in legumes with combined application of FYM, phosphorus and biofertilizers.

#### Days to First Harvest

The data presented in Table 1 revealed that integrated nutrient management significantly influenced the number of days required for first harvest of cowpea. Among the different treatments, T<sub>6</sub> (50% RDF + FYM @ 12 t ha<sup>-1</sup> + Rhizobium + PSB) recorded the earliest first harvest (62.45 days), followed by T<sub>7</sub> (63.14 days), T<sub>8</sub> (64.72 days) and T<sub>5</sub> (66.92 days). In contrast, the control treatment T<sub>1</sub> (100% RDF) required the maximum number of days (69.95 days) for first harvest. Treatments receiving only inorganic fertilizers along with biofertilizers (T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub>) showed intermediate values.

#### Days to Last Harvest

The duration of harvesting was also significantly affected by different integrated nutrient management treatments. The minimum number of days to last harvest (83.12 days) was recorded under T<sub>6</sub>, followed by T<sub>7</sub> (84.17 days), T<sub>8</sub> (85.12 days) and T<sub>5</sub> (85.98 days), whereas the control treatment (T<sub>1</sub>) required the maximum duration (88.65 days) to complete harvesting. The remaining treatments exhibited intermediate values ranging from 86.52 to 87.95 days.

#### Number of Pods per Plant

The number of pods per plant is one of the most important yield-contributing characters because it directly determines the productivity of vegetable cowpea. The results clearly indicated that integrated nutrient management significantly increased the number of pods per plant. The maximum number of pods (19.45) was recorded under T<sub>6</sub> (50% RDF + FYM @ 12 t ha<sup>-1</sup> + Rhizobium + PSB), which was significantly superior to all other treatments. This was followed by T<sub>7</sub> (18.62), T<sub>8</sub> (17.18), T<sub>5</sub> (17.04) and T<sub>4</sub> (16.58). The lowest number of pods (14.12) was recorded under the control treatment (T<sub>1</sub>).

The present findings are in conformity with those reported by Pargi *et al.* (2018)<sup>[10]</sup>, who observed significant improvement in pod number of cowpea following the combined application of FYM, recommended fertilizers and seed inoculation with *Rhizobium* and PSB. Similar results were reported by Sharma *et al.* (2021)<sup>[11]</sup>, who found that integrated application of organic manures and biofertilizers significantly increased pod production in legumes. Singh *et al.* (2023)<sup>[12]</sup> further concluded that integrated nutrient management enhances flowering, pod set and reproductive efficiency by maintaining balanced nutrient availability and improving soil biological health.

#### Pod Length (cm)

Pod length is an important marketable quality parameter in vegetable cowpea because longer pods generally possess greater consumer preference and contribute directly to higher market value. The data presented in Table 1 indicated that integrated nutrient management significantly influenced pod length. The maximum pod length (16.82 cm) was recorded under T<sub>6</sub> (50% RDF + FYM @ 12 t ha<sup>-1</sup> + Rhizobium + PSB), which was significantly superior to all other treatments. This was followed by T<sub>7</sub> (15.67 cm), T<sub>8</sub> (15.02 cm) and T<sub>5</sub> (14.97 cm), whereas the shortest pods (11.98 cm) were recorded under the control treatment (T<sub>1</sub>).

#### Pod Weight (g plant<sup>-1</sup>)

Pod weight is one of the principal determinants of green pod yield in vegetable cowpea. The results revealed significant differences among the treatments. The highest pod weight (124.65 g plant<sup>-1</sup>) was obtained under T<sub>6</sub>, followed by T<sub>7</sub> (121.95 g), T<sub>8</sub> (119.57 g) and T<sub>5</sub> (114.68 g). The lowest pod weight (96.85 g) was observed under the control treatment.

#### Pod Yield (kg plot<sup>-1</sup>)

Green pod yield per plot was significantly influenced by different nutrient management treatments. The maximum pod yield (4.36 kg plot<sup>-1</sup>) was recorded under T<sub>6</sub>, which was statistically superior to all other treatments. The treatments T<sub>7</sub> (4.27 kg), T<sub>8</sub> (4.18 kg) and T<sub>5</sub> (4.01 kg) also produced significantly higher yields compared to the control (3.39 kg).

#### Pod Yield (q ha<sup>-1</sup>)

Pod yield per hectare represents the overall productivity of the crop and is the most important economic parameter. The results clearly demonstrated significant variation among the nutrient management treatments. The highest pod yield (109.00 q ha<sup>-1</sup>) was recorded under T<sub>6</sub>, followed by T<sub>7</sub> (106.75 q ha<sup>-1</sup>), T<sub>8</sub> (104.50 q ha<sup>-1</sup>) and T<sub>5</sub> (100.25 q ha<sup>-1</sup>). The lowest yield (84.75 q ha<sup>-1</sup>) was recorded under the control treatment.

#### Number of Seeds per Pod

The number of seeds per pod is an important yield-contributing character that reflects the efficiency of pollination, fertilization and assimilate translocation during reproductive growth. The data indicated significant differences among the treatments. The maximum number of seeds per pod (14.15) was recorded under T<sub>6</sub>, followed by T<sub>7</sub> (13.65), T<sub>8</sub> (13.01) and T<sub>5</sub> (12.41), whereas the minimum number (9.42) was observed under the control treatment. The increase in seeds per pod under T<sub>6</sub> may be attributed to improved flowering, enhanced pollen viability and better

nutrient availability during reproductive development. Adequate phosphorus promoted successful fertilization and seed formation, whereas nitrogen fixed through *Rhizobium* supported protein synthesis and embryo development. Farmyard manure improved soil biological activity and maintained a continuous nutrient supply, ensuring efficient seed filling. Moreover, improved photosynthetic efficiency under integrated nutrient management enhanced carbohydrate translocation toward developing seeds, thereby increasing seed number per pod.

These results agree with the findings of Pargi *et al.* (2018)<sup>[10]</sup>, who observed increased seeds per pod with integrated application of FYM, recommended fertilizers and biofertilizers. Similar observations were reported by Sharma *et al.* (2021)<sup>[11]</sup> and Singh *et al.* (2023)<sup>[12]</sup>, who concluded that integrated nutrient management significantly improves reproductive efficiency and yield attributes in legumes.

### Conclusion

The findings of the present investigation clearly demonstrated that integrated nutrient management significantly improved the growth, yield and quality of vegetable cowpea compared with the sole application of recommended chemical fertilizers. The combined use of inorganic fertilizers, farmyard manure and biofertilizers created a balanced nutrient supply, enhanced soil biological activity and improved nutrient use efficiency, resulting in superior crop performance.

Among the eight nutrient management treatments, T<sub>6</sub> (50% RDF + Farmyard Manure @ 12 t ha<sup>-1</sup> + *Rhizobium* + PSB) proved to be the most effective and consistently recorded the highest values for plant height, number of branches, pod length, pod weight, number of pods per plant, pod yield and number of seeds per pod. The same treatment also promoted earlier flowering and harvesting, indicating accelerated crop growth and better reproductive efficiency. The enhanced performance under T<sub>6</sub> may be attributed to the synergistic effects of farmyard manure in improving soil physical and biological properties, *Rhizobium* in fixing atmospheric nitrogen and phosphate-solubilizing bacteria in increasing phosphorus availability, together with the balanced supply of mineral nutrients through inorganic fertilizers.

The results further indicate that 50% of the recommended chemical fertilizer could be successfully substituted with FYM when combined with *Rhizobium* and PSB inoculation without compromising crop productivity. Instead, this integrated approach resulted in significantly higher yield than the sole application of recommended chemical fertilizers, while offering additional benefits in terms of improved soil fertility and sustainability.

Therefore, under the agro-climatic conditions of Balaghat, Madhya Pradesh, the integrated application of 50% RDF + FYM @ 12 t ha<sup>-1</sup> + *Rhizobium* + PSB may be recommended as an economically viable and environmentally sustainable nutrient management practice for achieving higher yield and better quality of vegetable cowpea. Adoption of this practice can reduce dependence on synthetic fertilizers, improve soil health and contribute to sustainable vegetable production systems.

### References

1. Bhardwaj D, Ansari MW, Sahoo RK, Tuteja N. Biofertilizers function as key players in sustainable agriculture by improving soil fertility, plant tolerance,

and crop productivity. *Microb Cell Fact.* 2022;21(1):1-20.

2. Boukar O, Belko N, Chamarthi S, Togola A, Batiemo J, Owusu E, *et al.* Cowpea (*Vigna unguiculata*): genetics, genomics and breeding. *Plant Breed.* 2019;138(4):415-424.
3. Choudhary M, Meena VS, Panday R, Mondal T. Integrated nutrient management for improving soil health and crop productivity. *Indian J Agric Sci.* 2021;91(5):641-648.
4. Directorate of Economics and Statistics. Agricultural statistics at a glance 2024. New Delhi: Ministry of Agriculture & Farmers Welfare, Government of India; 2024.
5. Edwards CA, Arancon NQ, Sherman R. Vermiculture technology: earthworms, organic wastes and environmental management. 2nd ed. CRC Press; 2021.
6. Food and Agriculture Organization of the United Nations. FAOSTAT: crops and livestock products database. 2024. <https://www.fao.org/faostat/>
7. Hungria M, Nogueira MA, Araujo RS. Biological nitrogen fixation in grain legumes: recent advances and future perspectives. *Plant Soil.* 2022;474:1-22.
8. Khan VM, *et al.* Effect of vermicompost and biofertilizers on growth, yield and quality of cowpea. *Legume Res.* 2015;38:600-605.
9. Lal R. Soil organic matter and sustainable agriculture. *J Soil Water Conserv.* 2020;75(6):161A-170A.
10. Pargi KL, Patel JC, Patel KP, Patel RN. Effect of integrated nutrient management on growth and yield of summer cowpea (*Vigna unguiculata* L.). *Int J Chem Stud.* 2018;6(5):1808-1812.
11. Sharma A, Kumar R, Singh V, Meena BS. Effect of integrated nutrient management on growth, yield and nutrient uptake of pulse crops: a review. *Legume Res.* 2021;44(9):1001-1009.
12. Singh AK, Kumar R, Sharma S, Verma VK. Integrated nutrient management improves growth, yield, nutrient uptake and soil fertility in vegetable legumes: a review. *Legume Res.* 2023;46(8):987-996.