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Effect of integrated nutrient management on growth, yield attributes and yield of broccoli (*Brassica oleracea* L. var. *italica*) under bundelkhand conditions

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Abstract

A field experiment was conducted during [2024-25] at the Chemical Research Farm, Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Bundelkhand University, Jhansi, to study the effect of integrated nutrient management (INM) on growth, yield attributes, and yield of broccoli (*Brassica oleracea* L. var. *italica*). Eight treatments were tested: T₀ (Control/RDF), T₁ (RDF + PSB), T₂ (10 t FYM + 100% RDF), T₃ (10 t FYM + RDF + PSB), T₄ (10 t VC + RDF), T₅ (10 t VC + RDF + PSB), T₆ (15 t FYM + RDF), and T₇ (15 t VC + RDF). Results revealed significant differences among treatments. Maximum plant height (38.02 cm at 45 DAT and 51.9 cm at harvest), plant diameter (1.89 cm at 45 DAT and 3.98 cm at harvest), plant spread (56.87 cm N-S, 53.15 cm E-W), and number of leaves (17.48) were recorded in T₇. Similarly, leaf length (47.02 cm), leaf width (17.90 cm), head length (18.69 cm), head diameter (16.08 cm), head weight (321.04 g), and yield (154.75 q/ha) were also highest under T₇, followed by T₆. Phenological observations indicated early head initiation (49.02 days) and maturity (72.61 days) in T₇, whereas delayed maturity was observed in control. Vermicompost-based INM treatments outperformed FYM-based treatments. The study concludes that the integration of Vermicompost with RDF enhances growth, accelerates phenology, and maximizes yield, making it a sustainable approach for broccoli cultivation under Bundelkhand conditions.

Keywords: Broccoli, integrated nutrient management, vermicompost, farmyard manure, growth parameters, and yield attributes

1. Introduction

Broccoli (*Brassica oleracea* L. var. *italica*) is a highly nutritious Cole crop valued for its antioxidant compounds, vitamins, minerals, and anticarcinogenic properties. Its cultivation is expanding rapidly in India owing to increasing consumer demand and health awareness. However, achieving higher productivity in broccoli requires judicious nutrient management. Sole dependence on chemical fertilizers often leads to nutrient imbalance, declining soil health, and reduced sustainability (Singh *et al.*, 2020) [16]. Integrated Nutrient Management (INM), which combines inorganic fertilizers with organic manures and bio fertilizers, is recognized as an eco-friendly approach to maintain soil fertility and enhance crop productivity (Meena *et al.*, 2021; Kumar *et al.*, 2022) [8, 10]. Vermicompost (VC) and Farmyard Manure (FYM) improve soil structure, microbial activity, and nutrient-use efficiency, while phosphate-solubilizing bacteria (PSB) mobilize phosphorus, contributing to sustainable crop growth and yield.

Broccoli (*Brassica oleracea* var. *italica*) is a nutrient-dense cool-season vegetable, highly valued for its abundant vitamins, minerals, and antioxidant compounds making it increasingly popular among health-conscious consumers in India. However, as an exhaustive Cole crop, broccoli demands balanced nutrition. Over-reliance on chemical fertilizers often leads to declining soil health and unsustainable production systems, underscoring the need for more sustainable nutrient management approaches. Broccoli (*Brassica oleracea* var. *italica*) is an important member of the Cole crop family, grown worldwide for its edible florets that are rich in vitamins, minerals, and bioactive compounds. It is considered a

“functional food” due to the presence of glucosinolates, flavonoids, carotenoids, and other phytochemicals that impart antioxidant, anticancer, and cardio-protective properties. In recent years, broccoli has gained popularity in India owing to the rising awareness of healthy diets, urbanization, and diversification of vegetable consumption patterns. Despite its nutritional and economic importance, broccoli production in India remains limited compared to other Cole crops like cabbage and cauliflower. One of the primary constraints is its high nutrient requirement. Broccoli is a heavy feeder that extracts large quantities of nitrogen, phosphorus, and potassium from the soil. Continuous reliance on chemical fertilizers, though beneficial in achieving higher yields, often leads to soil degradation, nutrient imbalance, and reduced fertilizer-use efficiency. This calls for sustainable nutrient management practices to maintain soil fertility while ensuring optimum crop productivity.

Integrated Nutrient Management (INM), which combines organic manures, bio fertilizers, and inorganic fertilizers in a balanced manner, has emerged as a viable approach to enhance productivity and sustainability. Organic sources such as Farmyard Manure (FYM) and Vermicompost improve soil organic matter, microbial activity, and nutrient availability. Bio fertilizers like Phosphate-Solubilizing Bacteria (PSB) enhance phosphorus uptake, while judicious use of chemical fertilizers supplies readily available nutrients during peak crop demand. Together, these components synergistically improve growth, yield, and quality of vegetables including broccoli.

Several studies have highlighted the effectiveness of INM in broccoli cultivation. Application of Vermicompost along with reduced doses of NPK has been reported to increase head size, weight, and yield compared to sole application of chemical fertilizers. Similarly, integrating FYM or compost with bio fertilizers improves plant growth, enhances soil health, and supports long-term sustainability. However, the performance of these nutrient combinations varies with agro-climatic conditions, soil fertility status, and management practices.

In the Bundelkhand region of Central India, soils are often low in organic matter, deficient in available nitrogen and phosphorus, and subjected to moisture stress. These conditions pose challenges for successful cultivation of high-value crops like broccoli. Research evidence on the role of INM practices, especially combinations of FYM, Vermicompost, and PSB in enhancing broccoli growth and yield under Bundelkhand conditions, is scarce. Generating such information is crucial for developing region-specific nutrient management strategies.

2. Materials and Methods

The experiment was carried out during [2024-25] at the Chemical Research Farm, Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.).

The field experiment was conducted in a Randomized Block Design (RBD) with three replications to minimize experimental error and ensure reliability of results and there were eight treatments: T₀: Control (100% RDF), T₁: RDF + PSB, T₂: 10 t/ha FYM + 100% RDF, T₃: 10 t/ha FYM + 100% RDF + PSB, T₄: 10 t/ha VC + 100% RDF, T₅: 10 t/ha VC + 100% RDF + PSB, T₆: 15 t/ha FYM + 100% RDF, T₇: 15 t/ha VC + 100% RDF. The treatments were tested at 5% level of significance. Different nutrient management treatments were assigned randomly within each block. Observations were recorded on a set of growth and yield parameters including plant height, plant diameter, plant spread, number of leaves, leaf length and leaf width, days to head initiation, days to maturity, head length, head diameter, head weight, and yield. Data obtained from the experiment were subjected to statistical Analysis of Variance (ANOVA) as per the standard procedure for RBD, and treatment means were compared at a 5% level of significance ($p \leq 0.05$) to determine the significance of differences among treatments.

3. Results and Discussion

3.1 Growth Parameters

The results of growth parameter of broccoli presented below on table 3.1. The present investigation revealed that Integrated Nutrient Management (INM) exerted a significant influence on the vegetative growth of broccoli. Among the different treatments, T₇ (15 t/ha Vermicompost + 100% RDF) recorded the maximum values for all the growth attributes. The highest plant height (38.02 cm at 45 DAT and 54.10 cm at harvest), plant diameter (1.89 cm at 45 DAT and 3.98 cm at harvest) and plant spread (56.87 and 53.15 cm), were observed in T₇, whereas the control (T₀) consistently exhibited the lowest values. The improvement in vegetative growth under T₇ may be attributed to the synergistic effect of Vermicompost and inorganic fertilizers, which ensured a steady supply of macro and micro-nutrients throughout the crop growth period. Vermicompost also enhances soil microbial activity, improves soil physical structure, and facilitates efficient nutrient uptake, thereby leading to robust plant growth and development (Kumar *et al.*, 2019; Meena *et al.*, 2021)^[1, 9, 10]. These findings are in close agreement with the results reported by Sharma *et al.* (2020)^[13], who also observed increased vegetative vigor of broccoli under combined organic and inorganic nutrient management practices.

Table 1: Effect of integrated nutrient management on vegetative growth parameters of broccoli

Treatment	Plantheight		Plantdiameter (cm)		Plant Spread (cm)	
	At 45 DAT	At Harvest	At 45 DAT	At Harvest	(N-S)	(E-W)
T ₀	15.10	34.70	1.33	3.15	44.60	42.99
T ₁	19.90	39.89	1.65	3.53	49.90	46.19
T ₂	25.20	41.20	1.69	3.60	50.63	46.91
T ₃	24.30	43.20	1.77	3.64	51.98	48.26
T ₄	28.94	46.60	1.76	3.71	53.01	49.28
T ₅	32.80	47.78	1.81	3.77	53.67	49.95
T ₆	35.50	51.90	1.82	3.79	56.11	52.39
T ₇	38.02	54.10	1.89	3.98	56.87	53.15
SEm±	1.54	1.49	0.14	0.22	0.82	0.83
C.D.at5.0%	3.14	2.98	0.43	0.53	1.65	1.70

3.2 Leaf Characteristics

Leaf morphological traits such as leaf length and leaf width were also significantly influenced by INM treatments and presented below in table 3.2. T₇ recorded the maximum leaf length (43.25 cm) and leaf width (22.63 cm), closely followed by T₆ (15 t/ha FYM + 100% RDF). The broader and longer leaves under these treatments resulted in a larger photosynthetic surface area, which ultimately enhanced assimilate production and translocation towards developing heads. In contrast, control plots produced shorter and narrower leaves, limiting the photosynthetic efficiency of plants. Similar enhancement in leaf morphological traits under integrated nutrient application has also been reported in cauliflower and cabbage by Singh *et al.* (2022)^[15, 16] and Yadav *et al.* (2023)^[18].

3.3 Phonological Development

The influence of INM on the phonological parameters of broccoli was also pronounced and presented below in table 3.2. Plants receiving integrated nutrient treatments attained earlier head initiation and maturity compared to those under control. The minimum number of days required for head initiation (49.02 days) and physiological maturity (72.61 days) were observed in T₇, while the control plants exhibited delayed phonological development, with head initiation and maturity recorded at 65.23 and 83.11 days, respectively. This advancement in phenology under integrated nutrient supply may be attributed to the continuous and balanced availability of nutrients, which enhanced metabolic activities and improved physiological efficiency of the crop. Similar trends were reported by Choudhary *et al.* (2020)^[7] in broccoli and by Pandey *et al.* (2021)^[11] in cabbage.

Table 2: Effect of integrated nutrient management on leaf characteristics and phonological development of broccoli

Treatment	Leaves plant ⁻¹	Leaf length (cm)	Width of leaf (cm)	Days to first head initiation	Days to 50% head Initiation	Days to 50% head maturity	Head maturity duration (days)
T ₀	11.43	32.42	14.70	55.68	65.23	83.11	25.00
T ₁	12.41	36.31	16.45	53.95	60.88	79.91	23.74
T ₂	12.93	36.50	17.70	53.67	59.57	79.50	22.63
T ₃	13.03	37.37	18.34	52.99	58.81	78.49	21.36
T ₄	13.07	39.60	18.51	52.05	57.77	77.11	20.98
T ₅	14.46	41.38	19.63	51.73	57.42	76.63	20.85
T ₆	14.98	42.62	21.75	49.78	55.26	73.76	19.74
T ₇	15.05	43.25	22.63	49.02	54.41	72.61	19.59
SEm±	0.42	0.47	0.93	0.34	0.36	0.46	0.12
C.D.at 5.0%	1.13	1.38	1.91	1.01	1.06	1.36	0.36

3.4 Head Traits

The improvement in vegetative and physiological traits under INM was presented below in table 3.3 which were positively reflected in head growth and development. T₇ recorded the maximum values for head length (18.69 cm), head diameter (16.08 cm), and head weight (321.04 g), which were significantly higher than those recorded in the control plots. This remarkable improvement in head traits under T₇ could be explained by the enhanced supply of photosynthetic to the sink organs, which promoted efficient head development and accumulation of dry matter. The balanced nutrient environment created by the combined application of Vermicompost and RDF also improved soil health and nutrient mineralization, thereby ensuring better head formation. Comparable findings have been reported by Meena *et al.* (2021)^[10] in broccoli and Singh *et al.* (2022)^[15, 16] in cauliflower, wherein INM treatments improved head compactness and marketable yield attributes.

3.5 Yield

The positive impact of INM on growth, leaf traits, and head development ultimately translated into higher yields which was shown below in table 3.3. The maximum yield (154.75 q/ha) was obtained in T₇, followed by T₆ (153.42 q/ha), while the control recorded the lowest yield (91.35 q/ha). The enhanced yield under vermicompost-based INM is a result

of synergistic effects between organic and inorganic nutrient sources, which improve nutrient-use efficiency, plant vigour, and photosynthetic efficiency (Singh *et al.*, 2021; AbouelMagd *et al.*, 2019)^[1, 21]. Biofertilizers such as PSB enhance phosphorus availability, supporting curd formation and metabolic processes essential for high yield (Bhat *et al.*, 2022)^[6]. Moreover, the combined application of organic and inorganic nutrients maintains a favourable microclimate in the root zone, stimulating microbial activity and nutrient cycling, which ultimately supports higher head weight and total yield (Adeleye *et al.*, 2010; Asghar *et al.*, 2016)^[2, 3].

Overall, the results demonstrate that the integration of vermicompost, FYM, PSB, and RDF not only improves vegetative growth and leaf development but also enhances head characteristics and productivity of broccoli. Among all treatments, T₇ (15 t ha⁻¹ vermicompost + 100% RDF) consistently outperformed other treatments, highlighting the importance of INM as a sustainable and effective strategy for achieving higher yield and superior quality in broccoli under semi-arid Indian conditions. These findings are in agreement with previous studies emphasizing the role of organic amendments, biofertilizers, and balanced chemical fertilization in improving both yield and nutrient-use efficiency in cole crops (Anonymous, 2018; Bhardwaj *et al.*, 2018; Bahadur *et al.*, 2017)^[4, 5].

Table 3: Effect of integrated nutrient management on yield and head attributes of bocelli

Treatment	Head length (cm)	Head diameter (cm)	Head weight (g)	Yield (q/ha)
T ₀	11.54	10.72	182.96	91.35
T ₁	14.66	12.15	205.40	111.62
T ₂	15.87	13.35	231.42	114.35
T ₃	16.14	13.62	239.36	117.95
T ₄	16.64	14.10	254.58	124.85
T ₅	17.20	14.64	271.94	132.69
T ₆	18.30	15.94	305.06	153.42
T ₇	18.69	16.08	321.04	154.75
SEm±	0.20	0.20	7.86	2.68
C.D.at5.0%	0.59	0.58	23.15	80.7

Conclusion

The study clearly demonstrated that integrated nutrient management significantly improved the growth, phenological stages, yield attributes, and yield of broccoli. The treatment 15 t/ha Vermicompost + 100% RDF (T₇) proved most effective, followed by 15 t/ha FYM + RDF (T₆). Vermicompost-based INM not only enhanced productivity but also reduced crop duration, indicating its suitability for sustainable broccoli production under Bundelkhand agro-climatic conditions.

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