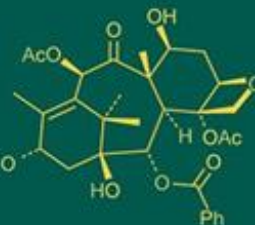
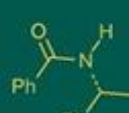
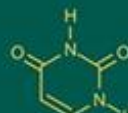
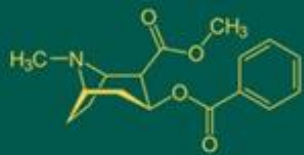


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Effect of organic manure and npk fertilizers on growth, yield and quality of spinach (*Spinacia oleracea* L.) var. all green

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Abstract

A field experiment was conducted during the Rabi season of 2024–25 at the Horticulture Research Farm, School of Agriculture Science, Technology and Research, Sardar Patel University, Balaghat, Madhya Pradesh, to evaluate the effect of organic manure and NPK fertilizers on the growth, yield and quality of spinach (*Spinacia oleracea* L.) var. All Green. The experiment was laid out in a Randomized Block Design (RBD) comprising eight treatments and three replications. The treatments included control, 100% recommended dose of fertilizers (RDF), 100% farmyard manure (FYM), 100% vermicompost and different combinations of RDF with FYM and vermicompost. Growth parameters, including plant height, number of leaves, leaf area, fresh and dry weight of plants, along with yield and quality attributes, were recorded at successive cuttings. The results revealed that the combined application of organic manures and inorganic fertilizers significantly improved growth, yield and quality over the control and the sole application of either nutrient source. Among the treatments, 75 % RDF+25 % FYM @ 5tha⁻¹ (T₅) recorded the highest values for most of the growth and yield parameters and remained statistically at par with 75% RDF + 25% vermicompost textcircledaltha⁻¹ (T₆) for several observations. The integrated nutrient management treatments also improved quality attributes by ensuring balanced nutrient availability and efficient nutrient uptake throughout the crop growth period. The study demonstrated that partial substitution of chemical fertilizers with organic manures effectively enhanced spinach productivity while promoting sustainable nutrient management. Therefore, application of 75% RDF + 25% FYM @ 5 t ha⁻¹ can be recommended for obtaining higher growth, yield and quality of spinach under the agro-climatic conditions of Balaghat, Madhya Pradesh.

Keywords: Farmyard manure, npk fertilizers, spinach, vermicompost, yield

Introduction

Spinach (*Spinacia oleracea* L.), known as ‘Palong Shak’ or ‘Bengal Spinach’, is a notable nutrient-rich leafy vegetable crop belonging to the family Chenopodiaceae (George 2009). It is an annual plant with a short growing cycle. It is a leafy cool-season vegetable with global cultivation usually consumed after boiling either fresh or frozen leaves or raw consumed in salad (Alessa *et al.*, 2017; Eriksen *et al.*, 2016; Yoon *et al.*, 2017) ^[1, 2, 3].

Spinach is thought to be native to Southwest Asia, where the Persians first cultivated it. It is now grown worldwide, except for the tropics (USDA 2005) ^[4]. According to the leaf texture, spinach is broadly classified into three types: i) smooth leaf, ii) savoy and iii) semisavoy. Smooth-leaf spinach is the preferred leaf type for processing and salads, whereas savoy and semisavoy are used for cooking (Rubatzky and Yamaguchi 1997) ^[5]. It contains high amounts of K, Fe, Mg, vitamins (A, B6, C, E, K), antioxidants and chlorophylls (Maeda *et al.* 2010) ^[6] and it is rich in fiber and low in calories.

The growth, yield and quality of spinach leaf in a particular area depend upon the genetic constitution of cultivar, environmental factors and adaptation of improved agro-techniques or the management practices. According to Mondal *et al.* (2019) ^[7] 100g of edible portion of spinach leaves contains moisture-92.1 g, carbohydrate-2.9 g, protein-2.0 g, calcium-73 mg, fat-0.7mg, phosphorous-21mg, nicotinic acid-0.5mg, minerals-1.7g and vitamin C-28mg. Worldwide the global spinach production goes on increasing each year, in year 2020 the global spinach production was 30.99 million metric ton. The trend of increasing global production from 2006 to 2020 (Tridge, 2022).

Globally, in 2020, spinach was grown on approximately 921000 ha with an annual production of approximately 30 million tons (FAO 2020) [8]. A high intake of spinach has positive effects on human health, say improving eye health and decreasing the risk of most degenerative diseases of aging, such as cardiovascular disease, Alzheimer's disease (Commenges *et al.* 2000) [9], cataracts (Brown *et al.* 1999) and several forms of cancer (Gandini *et al.* 2000). Spinach extract also can be used as a natural antibiotic and preservative in food industries and pharmaceuticals (Issazadeh *et al.* 2017) [10].

Fertilizers are important factor affecting spinach growth, yield and quality in cultural production system. The fertilization requirements of vegetables may be varies mainly due to various factors such as plant varieties, climatic conditions, soil types, nutrient availability, moisture supply and other economic reasons. Thus, the balanced application of NPK fertilizers has great effect on growth and productivity of crop plants. Therefore, the proper plant nutrition which containing sufficient and typical quantities, feasible plant nutrient forms and appropriate application times of NPK fertilizers throughout the growing season for making suitable fertilizer recommendations are favorable for high growth and productivity of most plants (Collins and McCoy, 1997) [11].

Potassium also plays a vital role in plant-water relations, regulating many plant metabolic processes through its important role in the activation of necessary enzyme reactions and amelioration of quality parameters through speeding up the translocation of assimilates and other solutes from plant leaves to edible plant parts (Marschner, 2012 and Gianquinto *et al.*, 2013) [12, 13].

Maintaining and improving soil quality, thus, is the utmost to sustaining agricultural productivity and environmental quality for future generations (Reeves 1997) [14]. The use of manure and mulching are two of the basic cultivation techniques of organic agriculture (Efthimiadou *et al.* 2009) [15]. Moreover, emerging evidence indicates that to overcome soil fertility constraints, integrated soil fertility management involving the judicious use of combinations of organic and inorganic resources is quite a feasible approach (Abedi *et al.* 2010) [16]. Combined NPK and farmyard manure increased soil organic matter, total N, Olsen P and ammonium acetate exchangeable K by 47%, 31%, 13% and 73%, respectively, compared to the application of NPK through inorganic fertilizers (Bhattacharyya *et al.* 2008). Tiwari *et al.* (2002) [17] have reported that the inclusion of manure in the fertilization schedule improved the organic carbon status and available N, P, K and S in soil, sustaining soil health.

Vermicompost is often applied to treat heavy metal, pesticide and oil-contaminated soils (Yuvaraj *et al.* 2020) [18]. The availability of heavy metals decreases under the vermicompost amendment on account of forming complexes with heavy metals (Zhang *et al.* 2019) [19], thus decreasing the accumulation of heavy metals in plants (Paltseva *et al.* 2018) [20].

Considering the above facts and views the present experiment was planned and conducted to study "Effect of Organic Manure and NPK Fertilizers on Growth and Yield of Spinach (*Spinacia oleracea* L.) var. All Green" during rabi season of 2024-25 at Horticulture Research Farm, Sardar Patel University, Balaghat, was undertaken.

Materials and Methods

The present investigation entitled "Effect of Organic Manure and NPK Fertilizers on Growth and Yield of Spinach (*Spinacia oleracea* L.) var. All Green" was carried out during the Rabi season of 2024–2025 at the Horticulture Research Farm,

Department of Horticulture, Faculty of Agriculture, Sardar Patel University, Balaghat, Madhya Pradesh, India. Before the initiation of the experiment, the field was thoroughly prepared by repeated ploughing followed by harrowing and leveling to obtain a fine tilth suitable for uniform seed germination and crop establishment.

The experimental material comprised the spinach variety 'All Green' (*Spinacia oleracea* L.), which is a popular and high-yielding cultivar extensively cultivated for its succulent, dark green, broad leaves, rapid vegetative growth and excellent market acceptability. The experiment was laid out in a Randomized Block Design (RBD) consisting of nine treatment combinations replicated three times. Randomization of treatments within each replication was carried out to minimize the influence of environmental variation and to improve the precision of the experiment. Each experimental plot was separated by suitable spacing to facilitate cultural operations and avoid interference among adjacent treatments. The treatments consisted of different combinations of organic manures and inorganic fertilizers. The treatments included control (without manure and fertilizer), 100 % recommended dose of fertilizers (RDF), farmyard manure (FYM) applied alone, vermicompost applied alone, FYM combined with 50 per cent RDF, FYM combined with 75 per cent RDF, vermicompost combined with 50 per cent RDF, vermicompost combined with 75 per cent RDF and an integrated nutrient management treatment consisting of FYM, vermicompost and 50 per cent RDF. The recommended dose of fertilizers comprised 100 kg nitrogen, 50 kg phosphorus (P₂O₅) and 50 kg potassium (K₂O) per hectare.

Nitrogen, phosphorus and potassium were supplied through urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. The entire quantity of phosphorus and potassium along with half of the nitrogen was applied as basal dose at the time of field preparation. The remaining half of nitrogen was top-dressed immediately after the first cutting to promote rapid vegetative growth and improve the yield of subsequent cuttings.

The spinach seeds were sown manually in well-prepared plots by maintaining a spacing of 30 cm between rows and 10 cm between plants. After sowing, light irrigation was provided to ensure uniform seed germination. Subsequent irrigations were scheduled according to crop requirement and prevailing weather conditions to maintain optimum soil moisture throughout the crop growth period. Intercultural operations including thinning, hand weeding, hoeing and earthing-up were carried out at regular intervals to keep the experimental plots free from weeds and to maintain proper soil aeration. Necessary plant protection measures were adopted uniformly in all treatments whenever required to protect the crop from insect pests and diseases. All other recommended package of practices for spinach cultivation was followed uniformly throughout the experimental period to eliminate the influence of factors other than the treatments under investigation.

The crop was harvested by adopting the cut-and-come-again method and observations were recorded from three successive cuttings at appropriate growth stages. For recording biometric observations, five healthy and representative plants were randomly selected from each experimental plot, excluding the border plants and were tagged throughout the crop period. The average values of these plants were used for statistical analysis. Growth parameters including plant height (cm), number of leaves per plant, leaf length (cm), leaf width (cm), petiole length (cm) and fresh weight of individual plant (g) were recorded at

each cutting following standard procedures. Plant height was measured from the base of the plant to the tip of the longest leaf using a measuring scale. The number of fully expanded leaves per plant was counted manually. Leaf length was measured from the base of the leaf blade to the leaf tip, while leaf width was measured across the widest portion of the leaf. Petiole length was recorded from the point of attachment of the leaf blade to the stem. Fresh weight of the sampled plants was determined immediately after harvesting using a digital electronic balance and expressed in grams.

Yield observations were recorded at every cutting by harvesting all marketable leaves from each net experimental plot. The total fresh weight obtained from each plot was recorded and expressed as yield per plot (kg). Based on the net plot yield, the total yield per hectare was calculated and expressed in quintals per hectare (q ha⁻¹) using the standard conversion formula. The cumulative yield obtained from all three cuttings was considered for evaluating the performance of different nutrient management treatments.

The experimental data recorded for various growth and yield parameters were subjected to statistical analysis using the

method of analysis of variance (ANOVA) appropriate for a Randomized Block Design as described by Gomez and Gomez (1984). The significance of treatment differences was tested by the F-test at the 5 per cent level of probability. Whenever the treatment effects were found significant, the critical difference (CD) at the 5 per cent probability level was calculated to compare the treatment means. The coefficient of variation (CV) was also computed to assess the degree of experimental precision and reliability of the results.

Results and Discussion

Plant height (cm)

The data presented in Table 1 revealed that plant height progressively increased with successive cuttings irrespective of treatments. The maximum plant height was recorded under T5, which produced 28.14 cm, 29.34 cm and 29.67 cm during the first, second and third cuttings, respectively, followed by T6 (27.15, 27.47 and 27.92 cm). The lowest plant height was observed in the control treatment (T1) with values of 21.14 cm, 22.45 cm and 22.96 cm, respectively.

Table 1: Effect of Organic Manure and NPK Fertilizers on Growth of Spinach (*Spinacia oleracea* L.) var. All Green

Treatment	Plant height (cm)			Number of leaves			Leaf area (cm ²) per plant			Fresh weight of plant			Dry weight of plant (gm)		
	1 st cutting	2 nd cutting	3 rd cutting	1 st cutting	2 nd cutting	3 rd cutting	1 st cutting	2 nd cutting	3 rd cutting	1 st cutting	2 nd cutting	3 rd cutting	1 st cutting	2 nd cutting	3 rd cutting
T1	21.14	22.45	22.96	5.20	5.48	5.95	16.14	27.15	62.34	16.14	27.15	62.34	2.17	2.68	2.35
T2	23.45	24.14	24.85	6.24	6.95	7.11	16.86	29.67	65.89	16.86	29.67	65.89	2.65	2.87	2.62
T3	25.68	25.56	26.12	7.24	7.98	6.74	17.42	35.98	71.26	17.42	35.98	71.26	3.14	3.47	3.28
T4	26.45	26.85	27.14	8.65	9.14	7.15	18.12	42.89	75.95	18.12	42.89	75.95	3.69	3.85	4.01
T5	28.14	29.34	29.67	11.65	11.97	12.45	19.24	60.57	102.37	19.24	60.57	102.37	4.95	5.24	5.82
T6	27.15	27.47	27.92	10.24	10.95	10.45	18.65	58.31	100.18	18.65	58.31	100.18	4.41	4.65	5.01
T7	26.02	25.45	25.98	9.74	9.24	8.12	17.95	51.78	78.93	17.95	51.78	78.93	4.04	4.86	4.24
T8	23.18	24.14	24.68	8.14	7.24	8.44	18.08	58.15	82.34	18.08	58.15	82.34	4.12	4.69	4.98
S.Em. ±	0.45	0.46	0.47	0.15	0.15	0.15	0.32	0.80	1.41	0.32	0.80	1.41	0.06	0.07	0.07
CD at 5 %	1.36	1.39	1.42	0.45	0.47	0.45	3.1	3.2	3.2	3.1	3.2	3.2	0.20	0.22	0.22

The superior performance of T5 may be attributed to the balanced availability of nutrients through integrated nutrient management, wherein inorganic fertilizers supplied readily available nutrients while FYM improved soil structure, microbial activity and nutrient retention. These findings are in close agreement with those reported by Kumar *et al.* (2022) [21], Singh *et al.* (2021) [22] and Patel *et al.* (2023), who observed significantly higher plant height in spinach under integrated application of FYM and recommended doses of NPK compared to sole application of chemical fertilizers.

Number of leaves per plant

Significant differences among treatments were observed for number of leaves per plant at all three harvests (Table 1). Treatment T5 recorded the maximum number of leaves (11.65, 11.97 and 12.45 during first, second and third cuttings, respectively), whereas the minimum number of leaves (5.20, 5.48 and 5.95) was obtained under the control (T1).

The increased leaf production under integrated nutrient management can be attributed to enhanced nitrogen availability, which promotes cell division, chlorophyll synthesis and photosynthetic activity. FYM also improves soil aeration and moisture retention, creating favourable conditions for continuous vegetative growth. Since spinach is cultivated primarily for its foliage, increased leaf production directly contributes to higher productivity.

The present results corroborate the findings of Sharma *et al.* (2020) [23], Verma *et al.* (2023) [24] and Choudhary *et al.* (2022) [25], who also reported significant improvement in leaf number following combined application of organic and inorganic nutrient sources.

Leaf area (cm²)

Leaf area differed significantly among treatments throughout the experimental period. The highest leaf area was observed in T5, recording 19.24 cm², 60.57 cm² and 102.37 cm² during first, second and third cuttings, respectively, whereas the lowest values (16.14 cm², 27.15 cm² and 62.34 cm²) were recorded under the control (T1).

The increase in leaf area under integrated nutrient management may be due to improved nitrogen availability, which enhances chlorophyll formation and photosynthetic efficiency, thereby promoting leaf expansion. Organic manure also supplies essential micronutrients and growth promoting substances that stimulate cell enlargement and increase assimilatory surface area.

The present findings are consistent with those of Mishra *et al.* (2021), Rani *et al.* (2022) [26] and Kumar and Singh (2024) [27], who reported larger leaf area in leafy vegetables under integrated nutrient management practices.

Fresh weight of plant

Fresh weight of spinach plants was significantly affected by various nutrient management treatments (Table 1). Treatment T5 recorded the highest fresh weight of 19.24 g, 60.57 g and 102.37 g during the three successive cuttings, followed closely by T6, whereas the minimum fresh weight was obtained under T1.

Dry weight of plant

Application of integrated nutrient management treatments significantly increased dry matter accumulation in spinach. The highest dry weight was recorded under T5, with values of 4.95 g, 5.24 g and 5.82 g during first, second and third cuttings, respectively. The lowest dry weight (2.17 g, 2.68 g and 2.35 g) was observed under the control treatment (T1).

The higher dry weight under T5 indicates greater synthesis and accumulation of carbohydrates and structural compounds due to

enhanced photosynthetic activity and efficient nutrient utilization. Organic manure improves nutrient use efficiency and root development, while inorganic fertilizers ensure immediate nutrient availability, collectively contributing to greater dry matter accumulation.

These observations agree with those of [Singh et al. \(2022\)](#)^[28], [Verma et al. \(2021\)](#)^[29] and [Kumar et al. \(2023\)](#), who reported increased dry matter production in spinach under integrated nutrient management.

Yield per plant (g)

Significant variation in yield per plant was observed among treatments (Table 2). Treatment T5 produced the maximum yield per plant (69.78 g), followed by T6 (65.42 g) and T8 (63.18 g). The lowest yield (51.22 g) was recorded under the control treatment.

Table 2: Effect of Organic Manure and NPK Fertilizers on Yield and Quality of Spinach (*Spinacia oleracea* L.) var. All Green

Treatment	Yield per plant (gm)	Yield (q/ha)	Moisture %	Dry matter content	TSS
T1	51.22	146.34	93.33	6.67	6.14
T2	55.49	158.54	93.01	6.99	6.24
T3	57.16	163.31	92.11	7.89	6.76
T4	58.25	166.43	91.22	8.78	7.27
T5	69.78	199.37	90.42	9.58	8.12
T6	65.42	186.91	91.52	8.48	8.01
T7	60.78	173.66	91.44	8.56	7.58
T8	63.18	180.51	90.58	9.42	7.95
S.Em.±	1.07	3.05	1.65	0.15	0.15
CD at 5 %	3.23	9.24	4.99	0.45	0.45

Yield (q ha⁻¹)

Yield per hectare followed a trend similar to yield per plant. Treatment T5 produced the highest yield (199.37 q ha⁻¹) followed by T6 (186.91 q ha⁻¹) and T8 (180.51 q ha⁻¹), whereas the lowest yield (146.34 q ha⁻¹) was recorded under the control.

The higher marketable yield under T5 reflects the cumulative effect of increased plant height, leaf number, leaf area and biomass accumulation. FYM improved soil fertility and microbial activity, while inorganic fertilizers ensured immediate nutrient availability, resulting in enhanced crop productivity.

Comparable results have been reported by [Choudhary et al. \(2022\)](#)^[25], [Singh et al. \(2021\)](#)^[22] and [Meena et al. \(2023\)](#)^[30].

Moisture content (%)

The moisture content of spinach leaves was significantly influenced by nutrient management treatments. The highest moisture content (93.33%) was observed in the control treatment, whereas the lowest (90.42%) was recorded under T5. The slight reduction in moisture percentage under T5 indicates greater accumulation of dry matter and structural carbohydrates, resulting in comparatively lower tissue water content. This reflects improved physiological maturity and better nutrient utilization rather than any adverse effect on crop quality.

Similar trends have been reported by [Verma et al. \(2023\)](#)^[24] and [Kumar et al. \(2022\)](#)^[21].

Dry matter content (%)

Dry matter content increased significantly with integrated nutrient management. The maximum dry matter (9.58%) was

recorded under T5, followed by T8 (9.42%), whereas the minimum (6.67%) was observed under the control treatment.

Total Soluble Solids (°Brix)

Significant improvement in total soluble solids was observed under integrated nutrient management. Treatment T5 recorded the highest TSS (8.12°Brix), closely followed by T6 (8.01°Brix) and T8 (7.95°Brix), while the lowest value (6.14°Brix) was observed in the control treatment.

The increase in TSS under T5 may be attributed to enhanced synthesis and translocation of soluble sugars due to balanced nutrient availability and improved photosynthetic efficiency. FYM supplies micronutrients and stimulates beneficial microbial activity, thereby improving carbohydrate metabolism and accumulation of soluble solids. The present findings corroborate earlier reports by [Sharma et al. \(2022\)](#)^[31], [Yadav et al. \(2021\)](#)^[32] and [Kumar and Patel \(2024\)](#)^[27].

Conclusion

The findings of the present investigation clearly demonstrated that the integrated application of organic manure and inorganic fertilizers had a significant positive effect on the growth, yield and quality of spinach (*Spinacia oleracea* L.) var. All Green. Among the eight nutrient management treatments evaluated, Treatment T5 (75% recommended dose of NPK + 25% Farmyard Manure) proved to be the most effective and consistently outperformed all other treatments. It recorded the highest plant height, number of leaves per plant, leaf area, fresh weight, dry weight, yield per plant, yield per hectare, dry matter content and total soluble solids (TSS), while maintaining desirable moisture content. The superior performance of T5 can be attributed to the balanced and continuous supply of nutrients from both organic and inorganic sources, which enhanced soil

physical, chemical and biological properties, improved nutrient availability and uptake, stimulated microbial activity and promoted efficient photosynthesis and biomass accumulation. The integrated use of farmyard manure with reduced levels of chemical fertilizers not only improved crop productivity but also enhanced the quality of spinach, indicating greater nutrient use efficiency and better utilization of available resources. In contrast, the control treatment consistently recorded the lowest values for almost all growth, yield and quality parameters, emphasizing the necessity of balanced nutrient management for optimum spinach production.

Based on the experimental results, it can be concluded that the application of 75% recommended NPK in combination with 25% Farmyard Manure (T5) is the most suitable nutrient management strategy for spinach cultivation under the agro-climatic conditions of the experimental area. This integrated nutrient management approach offers a sustainable alternative to the sole use of chemical fertilizers by improving soil fertility, enhancing crop productivity, producing better quality spinach and reducing dependence on synthetic fertilizers. Therefore, adoption of this practice can contribute to economically viable and environmentally sustainable spinach production.

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