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IMPACT OF INTEGRATED ORGANIC AND INORGANIC NUTRIENT SOURCES ON GROWTH PERFORMANCE, YIELD POTENTIAL AND ECONOMIC VIABILITY OF SPINACH (*SPINACIA OLERACEA* L.) IN AN INCEPTISOL OF PRAYAGRAJ, UTTAR PRADESH, INDIA

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ABSTRACT

The present study investigated the effect of nutrient management on the growth, yield and economics of spinach (*Spinacia oleracea* L.) cultivation. Organic amendments, particularly farmyard manure (FYM) combined with recommended doses of inorganic fertilizers (RDF) were evaluated for their impact on soil fertility, plant growth and leaf yield. Field experiments were conducted at the Teaching and Research Farm, SHUATS, Prayagraj during the 2021–2022 cropping season under randomized complete block design with nine treatments and three replications. Growth parameters, including plant height and number of leaves per plant and yield attributes were recorded at regular intervals. Results revealed that the combined application of 100% RDF + 100% FYM significantly enhanced plant height, number of leaves and leaf yield compared to control. This treatment also showed superior economic returns with a net profit of Rs. 37,805 and a cost-benefit ratio of 1:1.95. The study highlights the importance of nutrient management for improving spinach productivity, soil fertility and sustainable crop production.

Keywords **:** Economic Return, Farmyard Manure, Inorganic Fertilizer, Leaf Yield, Nutrient Management, Spinach, Soil Fertility.

Introduction

Organic composting plays an important role in improving soil fertility and maintaining long-term crop productivity. By recycling organic waste into valuable compost, it enriches the soil with nutrients, improves soil structure, and supports healthy plant growth. At the same time, composting contributes to a circular economy by reducing the amount of organic waste sent to landfills. This process helps lower greenhouse gas emissions and enhances carbon sequestration in soils, making agriculture more environmentally friendly and sustainable (Favoino and Hogg, 2008; Marmo, 2008, Smith *et al*., 2001). Organic composts enrich the soil by increasing its nutrient content and making these nutrients more easily available to plants, thereby supporting healthier growth and better productivity (Boldrin *et al*., 2009).

Traditionally, farmers have relied on organic manures such as compost, chicken manure, and farmyard manure to enhance soil fertility and supply essential nutrients, especially nitrogen, required for optimal plant growth (Zaman *et al*., 2004). Most essential plant nutrients, especially nitrogen, are found in organic manures in smaller quantities compared to chemical fertilizers. However, because organic manures release nutrients more slowly, they may not supply enough nutrition during the plant's critical growth stages, which can sometimes lead to reduced yields (Zaman *et al*., 2004); When used correctly over a long period, they can actually improve the soil's health and make it more fertile (Ahmad *et al*., 2013). Applying organic manure was found to enhance soil nutrients like nitrogen, phosphorus, and potassium, which in turn boosted spinach yield. Combining organic and inorganic fertilizers could further increase plant productivity (Shaheen *et al.,* 2014).

Nitrogen plays a vital role in plant metabolism, as it supports the formation of protoplasm, activates enzymes, and is required for the synthesis of proteins and amino acids. Through these functions, nitrogen enhances cell division and initiates meristematic activity, which together contribute to better plant growth, development, and ultimately higher productivity (Mirdad, 2009; Kuş and Gedik, 2023). Phosphorus is an essential macronutrient that plays a vital role in almost all plant growth and developmental processes. It is a key component of important organic compounds such as nucleic acids, proteins, phospholipids, enzymes, sugar phosphates, and energy-carrying molecules like ATP and ADP. Through its involvement in energy transfer, phosphorus supports active metabolic functions within the plant. Adequate phosphorus nutrition helps plants tolerate harsh winter conditions, improves water-use efficiency, and accelerates crop maturity. It is especially important for cell division and the proper formation of seeds and fruits. Phosphorus also encourages early root establishment, increases leaf size, promotes tillering, flowering, and grain development, and enhances overall yield. Well-developed deep root systems supported by phosphorus enable plants to access nutrients and moisture from deeper soil layers, improve anchorage, and reduce the risk of lodging and water loss (Oladipo *et al*., 2015). Potassium (K) is one of the most important plant nutrients closely linked with crop quality. It plays a vital role in overall plant growth, improving stress tolerance, seed quality, and general plant health. Adequate potassium nutrition helps crops achieve their full quality potential. In grain crops, potassium enhances oil and protein content, thereby improving their nutritional value. Cereals supplied with sufficient potassium produce stronger stalks and well-filled, healthy grains. Moreover, potassium improves resistance to mechanical damage during harvesting, transportation, and storage, which helps reduce losses and extends the shelf life of agricultural produce (Agbede, 2019).

Diets rich in fruits and vegetables have been shown to help prevent many common chronic diseases including cancer obesity and cardiovascular disorders. Leafy green vegetables in particular are valued for their significant health benefits which are attributed to both their essential nutrients and bioactive compounds (Bremner, 1996).

Spinach (*Spinacia oleracea* L.) is a highly nutritious leafy green vegetable belonging to the Chenopodiaceae family and is widely known for its fast growth cycle (Naseem *et al*., 2023). It is rich in essential nutrients and contains high amounts of vitamins A, B and C (Tai *et al*., 2020). The FAO and WHO recommend that an adult should consume about 250 g of vegetables daily; however, current vegetable production levels are inadequate to meet this nutritional requirement (DAE, 1995). Spinach is one of the most important leafy vegetables grown worldwide including across the Indian subcontinent. It is highly nutritious being rich in minerals, vitamins, carbohydrates, dietary fibre, proteins and water (Toledo *et al*., 2003). Fresh spinach provides about 23 calories of energy per 100 g and contains nearly 91% water. It is also a good source of nutrients supplying approximately 2.9 g protein, 3.6 g carbohydrates, 0.4 g sugars, 2.2 g dietary fibre and 0.4 g fat per 100 g of raw spinach (Tang, 2010) and additionally, spinach is exceptionally rich in vitamins, particularly vitamin A (97,701 IU), along with riboflavin, thiamine and ascorbic acid (70 mg per 100 g). It also contains important minerals such as calcium and iron (380 mg per 100 g), folic acid and trace amounts of nicotinic acid and pyridoxine. Furthermore, it is a good source of antioxidants like carotene, flavones, indoles and isothiocyanates as well as essential amino acids. Due to this impressive nutritional profile, spinach is often referred to as a “mine of minerals” (Thamburaj and Singh, 2015). India is the second-largest producer of fruits and vegetables in the world, after China. According to a report likely based on data from the National Horticulture Board (NHB), India produced approximately 33,116.2 thousand tonnes of spinach during the 2021–2022 period (FAO, 2022).

Materials and Methods

Site description

A field experiment was carried out during the 2021–2022 cropping seasons at the Teaching and Research Farm of the Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh. Sam Higginbottom University of Agriculture, Technology and Sciences is situated about 6 km from the city on the right bank of the Yamuna River, at an elevation of 98 m above mean sea level, between 25°24′30″ N latitude and 81°51′10″ E longitude. The experimental site falls under the Upper Gangetic Plain Agro-Climatic Region and the North Alluvial Plain Agro-Ecological Sub-Region with a gentle slope of about 1%.

Climate condition

The rainfall pattern of the experimental area was bimodal, with peak rainfall occurring from July to September. The soils at the experimental site were classified as alluvial soils belonging to the Inceptisol order. The region receives an average annual rainfall of about 1100 mm, and the mean temperature generally ranges between 25 and 30 °C.

Treatments and experimental design:

Nine treatments were used: control and combination of inorganic fertilizer mixtures by substituting surface soil with organic manure like FYM in the proportions of 0, 50 and 100%. There were three replications of treatment and the experiment were set up as a randomized complete block design. The surface soil was sandy loam and the FYM was produced from decomposition of cattle manure. The composition of FYM (Table 1).

Table 1: Chemical composition of FYM:

The nutrient contents in FYM applied in the experiment was given in table (Lal *et al.,* 2014):

Particulars	FYM
Organic Carbon (%)	5.07
Nitrogen (%)	0.92
Phosphorus (%)	0.239
Potassium (%)	0.361
Iron (%)	0.55
Manganese (%)	0.12
Zinc (%)	0.009
Cupper (%)	0.005

Incorporation of Farm yard manure and Sowing of Spinach

After land preparation through ploughing and harrowing, the experimental field was laid out into plots measuring 2 × 2 m. Farmyard manure used in the study was collected from the University's Dairy Farm and incorporated into the soil at the rate of 25 t ha^{-1} using a hoe. The plots were then left undisturbed for two weeks to allow proper decomposition of the manure before sowing. Spinach seeds of the variety Harit Shobha were sown in December. Two weeks after sowing, thinning was carried out to maintain one healthy plant per stand, followed by manual weeding using a hoe to keep the plots weed-free.

Detailed of Observations record

Growth and Yield parameters

Plant height (cm)

Height of plant in general indicates the growth of a crop. The height of the plant was recorded by measuring the length of plant from its base near ground level up to the base of the last emergence at an interval of 15 days.

Number of leaves per plant

Number of fully opened green leaves plant was counted at an interval 15 days from 30 days onwards. The average of five plants was then calculated to work out the mean value.

Leaf yield (q ha^{-1})

At each cutting 1 sq. m. area was demarcated in each treatment and yields was recorded by taking fresh weight. The total yields are computed by adding the weights recorded at all cuttings were expressed as q ha^{-1}.

Economics of Treatment

Input and output costs were calculated based on prevailing market prices, and key economic parameters such as net profit and cost–benefit ratio were worked out.

Cost of cultivation (₹ ha^{-1})

The cost of cultivation of each treatment was calculated separately taken into consideration all the cultural practices followed in the cultivation of spinach.

Net Profit (₹ ha^{-1})

The net profit of each treatment was calculated separately by using the following formula.

Net return (₹ ha^{-1}) = Gross return - Total cost of cultivation.

Cost Benefit Ratio (C: B)

Cost Benefit ratio was calculated by dividing gross return by cost of cultivation.

$$\text{Cost Benefit Ratio (C: B)} = \frac{\text{Gross returns}}{\text{Total cost of cultivation}}$$

Statistical analysis

The data recorded during the course of the investigation were statistically analysed using the randomized block design, following Fisher's (1960) analysis of variance (ANOVA) technique. After completing the analysis of variance, treatment means were compared using the least significant difference (LSD) test at the 5% level of significance to determine meaningful differences among treatments.

Results and Discussion

The findings of the present study as well as relevant discussion are summarized under following headings:

Effect on Plant height (cm)

Application of combination of 100 percent of RDF + 100 percent of FYM (T_9), resulted in significantly higher plant height (13.20, 24.67 and 27.90 cm) followed by 100 percent of RDF + 50 percent of FYM (12.80, 23.73 and 27.70 cm) and 50 percent of RDF + 100 percent of FYM (12.47, 22.37 and 26.60 cm) at 30, 45 and 60 days after sowing, respectively. The minimum plant height was recorded in T_1 (10.23, 18.20 and 22.27 cm) and which was on par with T_2 (10.37, 18.87 and 23.63 cm) and T_4 (10.80, 19.53 and 23.73 cm) at 30, 45 and 60 days after sowing. The application of inorganic fertilizer along with organic manures had better effect on plant growth. The decomposition of organic manures is slow and the nutrient supply for plants was found for long time. The results were in agreement with the research findings of Dangi *et al.* (2025), Gowda *et al.* (2022), Kurakula *et al.* (2021) and Khadse *et al.* (2021) in spinach. (Table: 2 and Fig.: 1)

Effect on Number of leaves plant^{-1}

The data on number of leaves varied at different intervals are presented in table 2. Combination of 100 percent of RDF + 100 percent of FYM resulted highest number if leaves per plant (8.80, 13.83 and 11.80) followed by 100 percent of RDF + 50 percent of FYM (8.20, 13.20 and 11.53) and 50 percent of RDF + 100 percent of FYM (8.13, 13.27 and 11.07) at 30, 45 and 60 days after sowing, respectively. The lowest number leaves per plant recorded in T_1 (5.23, 10.17 and 8.70) followed by T_2 (5.80, 10.80 and 8.83) and T_4 (6.43, 11.50 and 9.77) at 30, 45 and 60 days after sowing. The results were in agreement with the research findings of Dangi *et al.* (2025), Gowda *et al.* (2022), Kurakula *et al.* (2021) and Khadse *et al.* (2021) in spinach. (Table: 2 and Fig.: 1)

Effect on Leaf Yield (q ha^{-1})

The leaf yield of spinach was significantly influenced by different combination of treatments (table 2). Treatment T_9, comprising application of 100 percent of RDF + 100 percent of FYM recorded maximum leaf yield 69.46 and 81.68 q ha^{-1} followed by T_6 (63.21 and 76.36 q ha^{-1}) and T_8 (59.33 and 71.05 q ha^{-1}) at 45 and 60 days after sowing cutting. The minimum leaf yield was in T_1 (32.15 and 47.87 q ha^{-1}) followed by T_4 (41.74 and 54.21 q ha^{-1}) and T_2 (45.22 and 58.40 q ha^{-1}). (Table: 2 and Fig.: 1)

The growth and yield of leaves have been affected by the nutrient sources in the inorganic fertilizer and organic manure. The amount of nutrient content in the soil, and other factors like number of leaves, leaf area and weight of leaves etc., have the positive effect on the yield of leaves. The microbial content within FYM will be high which help in the decomposition and mineralization. The mixture of all the nutrients has increased the plant growth regulators. The overall effect of organic and inorganic nutrients made a significant influence on yield of spinach. The results were in agreement with the research findings of Dangi *et al.* (2025), Gowda *et al.* (2022), Kurakula *et al.* (2021) and Khadse *et al.* (2021) in spinach.

Economics

Higher money value and less cost of cultivation are desirable traits for getting higher returns. Hence economics of the treatment was work out. Results revealed from the (table 3) that the significantly maximum net return of Rs: 37,805 and cost benefit ratio 1:1.95 in the treatment T_9 (100% RDF + 100% FYM) followed by T_6 (50% RDF + 100% FYM) net return of Rs: 35,149 and cost benefit ration 1:1.94. The lowest net return of Rs: 20,492 and cost benefit ratio 1:1.82 in the treatment T_1 followed by T_2 (25,492; 1:1.85). The results were in agreement with the research findings of Dangi *et al.* (2025) and Kurakula *et al.* (2021). (Table: 3).

Table 2 : Impact of Integrated Organic and Inorganic Nutrient Sources on Growth Performance and Yield Potential of Spinach.

S. No.	Treatment Combination	Plant height (cm)			Number of leaves plant^{-1}			Leaf Yield (q ha^{-1})	
		30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	45 DAS	60 DAS
T_1	Absolute Control	10.23	18.20	22.27	5.23	10.17	8.70	32.15	47.87
T_2	RDF @ 0 % + FYM @ 50%	10.37	18.87	23.63	5.80	10.80	8.83	45.22	58.40
T_3	RDF @ 0 % + FYM @ 100%	10.97	20.23	24.83	7.13	12.13	10.20	64.63	70.35
T_4	RDF @ 50 % + FYM @ 0%	10.80	19.53	23.73	6.43	11.50	9.77	41.74	54.21
T_5	RDF @ 50 % + FYM @ 50%	11.23	20.93	25.43	7.43	12.43	10.27	55.65	65.46
T_6	RDF @ 50 % + FYM @ 100%	12.47	22.37	26.60	8.13	13.27	11.07	63.21	76.36
T_7	RDF @ 100 % + FYM @ 0%	11.57	21.57	26.10	7.70	12.77	10.47	49.85	60.21

T_8	RDF @ 100 % + FYM @ 50%	12.80	23.73	27.70	8.20	13.20	11.53	59.33	71.05
T_9	RDF @ 100 % + FYM @ 100%	13.20	24.67	27.90	8.80	13.83	11.80	69.46	81.68
F-test		S	S	S	S	S	S	S	S
S. Em. (+)		0.135	0.198	0.354	0.048	0.353	0.229	0.788	1.224
C.D. @ 5%		0.405	0.594	1.061	0.145	1.059	0.686	2.363	3.671

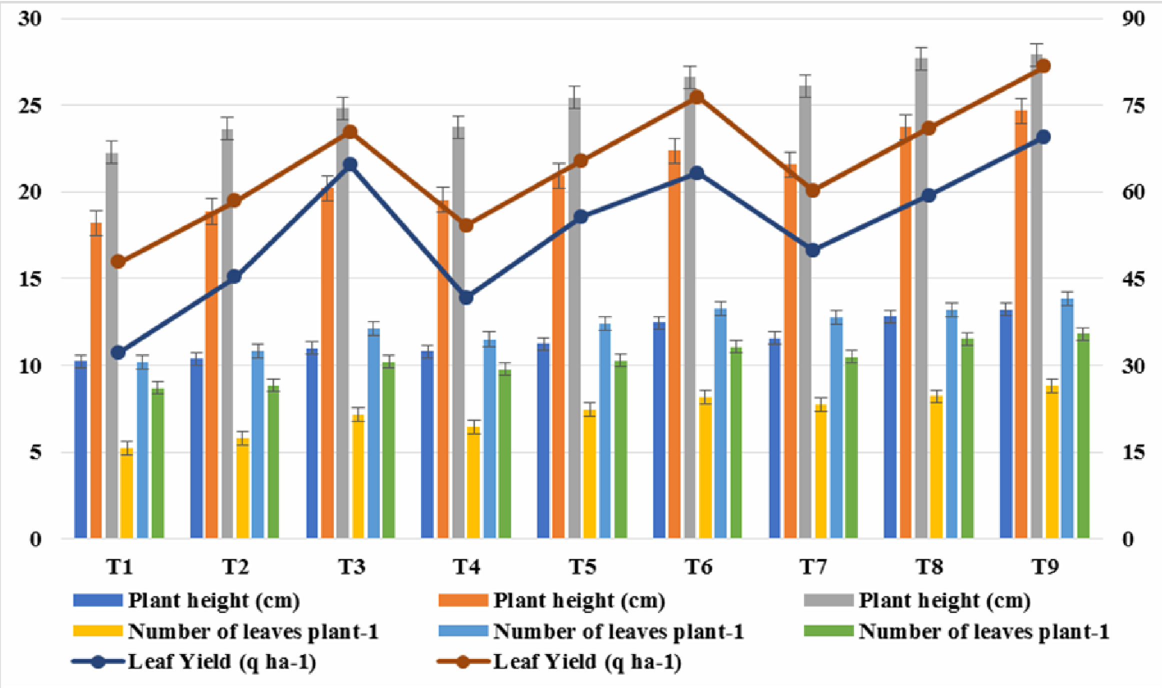

Fig. 1: Impact of Integrated Organic and Inorganic Nutrient Sources on Growth Performance and Yield Potential of Spinach.

Table 3: Impact of Integrated Organic and Inorganic Nutrient Sources on Economic Viability of Spinach.

S. No.	Treatment Combination	Gross return (₹ ha^{-1})	Total cost of cultivation (₹ ha^{-1})	Net profit (₹ ha^{-1})	C:B ratio
T_1	Absolute Control	45,482.00	24,990	20,492	1:1.82
T_2	RDF @ 0 % + FYM @ 50%	55,482.00	29,990	25,492	1:1.85
T_3	RDF @ 0 % + FYM @ 100%	66,831.00	34,990	31,841	1:1.91
T_4	RDF @ 50 % + FYM @ 0%	51,498.00	27,393	24,105	1:1.88
T_5	RDF @ 50 % + FYM @ 50%	62,195.00	32,393	29,802	1:1.92
T_6	RDF @ 50 % + FYM @ 100%	72,542.00	37,393	35,149	1:1.94
T_7	RDF @ 100 % + FYM @ 0%	57,206.00	29,795	27,411	1:1.92
T_8	RDF @ 100 % + FYM @ 50%	67,502.00	34,795	32,707	1:1.94
T_9	RDF @ 100 % + FYM @ 100%	77,600.00	39,795	37,805	1:1.95

Conclusion

The findings of the present study clearly indicate that nutrient management plays a vital role in improving the growth, yield and economic returns of spinach. Among all the treatment combinations, the application of 100% recommended dose of fertilizers (RDF) in conjunction with 100% farmyard manure (FYM) proved to be the most effective, resulting in superior plant height, higher number of leaves, maximum leaf yield and the highest net profit and cost–benefit ratio. The combined use of organic and inorganic nutrient sources ensured a balanced and sustained supply of essential nutrients, enhanced microbial activity and improved overall soil health, which collectively contributed to better crop performance. Treatments involving only organic or only inorganic sources were comparatively less effective. Therefore, integrating FYM with chemical fertilizers can be recommended as a sustainable and economically viable nutrient management strategy for spinach cultivation, ensuring higher productivity while maintaining long-term soil fertility and environmental sustainability.

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