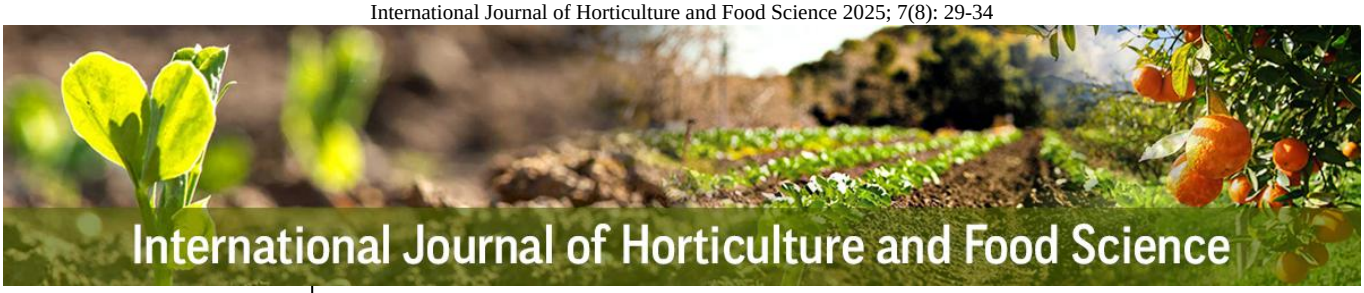

E-ISSN: 2663-1067
P-ISSN: 2663-1075
NAAS Rating (2025): 4.74
www.hortijournal.com
IJHFS 2025; 7(8): 29-34
Received: 05-06-2025
Accepted: 09-07-2025

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Effect of organic and inorganic source of nutrient and their combination on growth, yield and quality of Palak (*Beta vulgaris* var. *bengalensis*)

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DOI: https://www.doi.org/10.33545/26631067.2025.v7.i8a.363

Abstract
A field experiment entitled "Effect of Organic and Inorganic Source of Nutrient and their Combination on Growth, Yield and Quality of Palak (*Beta vulgaris var. bengalensis*)" was conducted during *rabi*, 2024-25 at Instructional Farm, School of Agricultural Sciences, Dabok, Udaipur to find out the effect of integrated nutrient management on growth, yield and quality of palak, to explore whether application of organic nutrients can fulfil the recommended dose of fertilizers and to work out an economically viable treatment. The experiment consisted of 10 treatment combinations including four with 100% RDF along with vermicompost, FYM and PSB in combination or alone, five with 50% RDF along with vermicompost, FYM and PSB in combination or alone and control which were evaluated under randomized block design with 3 replications. The findings showed that the highest values for growth and yield attributes *viz.*, plant height, number of leaves plant^{-1}, leaf length and width were recorded with application of 50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB. The maximum total leaf yield plot^{-1} and ha^{-1} (11.16 kg and 29.07 q ha^{-1}) was also recorded with application of 50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB which was statistically at par with 50% RDF through inorganic fertilizer + 25% RDF through FYM + 25% RDF through Vermicompost + PSB. The palak crop accumulated highest dry matter content and chlorophyll content with the application of 50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB. The aforesaid treatment also fetched highest net return (₹196062 ha^{-1}) contrary highest B-C ratio (3.0) was recorded under treatment 100% RDF through inorganic fertilizer.

Keywords: Palak, vermicompost, FYM, PSB, growth, yield, quality and economics

1. Introduction
Palak (*Beta vulgaris var. bengalensis)* is one of the most important leafy vegetables consumed all over the country and belongs to the family Chenopodiaceae, which also includes beetroot, spinach, swiss chard, parsley and celery. The chromosomal count in Palak is 2n=18. Other names for it include Indian spinach, spinach beet, garden beet, palong, sag, teegabatchali, busabyeley, dumpsbucchale, and pasalai. It thrives in tropical and subtropical regions. The states that are most famous for producing palak include Uttar Pradesh, West Bengal, Rajasthan, Haryana, Punjab, Delhi, Madhya Pradesh, and Bihar. The leaves of Beta vulgaris var. bengalensis were originally used in Bengal, thus the name. Given that Indian spinach was identified in China as early as 647 A.D., it is most likely indigenous to Indo-Chinese regions (Nath, 1976) [21]. According to Narayan *et al.* (2018) [19], 100 g of leaves have the following nutrients: 86.6% moisture, 3.4 g protein, 0.8 g fat, 6.6 g carbohydrate, 5862 IU vitamin A, 0.26 mg thiamine, 0.56 mg riboflavin, 3.3 mg niacin, 70 mg ascorbic acid, 380 mg calcium, 30 mg phosphorus and 16 mg iron. Palak leaves include several therapeutic qualities. Palak leaves are high in natural antioxidants such flavonoids, polyphenols, vitamins, and folic acid (Jabeen *et al.*, 2017) [11]. The leaves are used to treat inflammation, paralysis, headaches, and earaches, as well as spleen and liver problems. It aids in the prevention of constipation and the neutralization of acids formed during the digestion of fatty foods.
Organic farming has always been controversial, with some claiming it is less effective than

traditional methods of producing food. Critics argue that it results in lower yields and higher prices, casting doubt on its ability to meet the world's food needs. In spite of this, the organic food and beverage industry is growing quickly on a worldwide scale. Despite having less plant nutrients than artificial fertilizers, organic manures are crucial for increasing soil fertility and crop yield because they also include micronutrients and growth-promoting substances like hormones and enzymes (Premsekhar and Rajshree, 2009) [23].

Farmyard manure is important for plant nutrition since it directly increases crop yields by speeding up the respiratory process, increasing cell permeability, and hormonal growth activity, or a combination of these activities. FYM provides plants with nitrogen, phosphorus, potassium, and micronutrients like Fe, S, Mo, and Zn while also improving soil physicochemical properties like aggregation, aeration, permeability, water holding capacity, slow nutrient release, increased cation exchange capacity, and stimulation of soil flora and fauna (Tadesse *et al.*, 2013) [32]. FYM contains N, P, and K values of 0.54, 0.29 and 0.40 per cent, according to the chemical analysis (Veeresha and Gopakkali, 2014) [33]. Vermicompost is another popular organic manure that contains macro and micronutrients, plant growth boosters, humus-forming bacteria, and nitrogen fixers (Bano *et al.*, 1987) [1]. Vermicompost has higher levels of organic matter, nitrogen, phosphorus, sulphur, calcium and magnesium (Zahid, 2001) [35]. In addition to preserving and enhancing top soil fertility, it also contributes to a 40% boost in yield while using 20% to 60% less fertilizer inputs (Sunassee, 2001) [30]. Microorganisms are an essential component of the soil P cycle because they participate in a variety of actions that affect the transformation of soil P (Chen *et al.*, 2006) [5]. In a sustainable agricultural system, microbial inoculants also referred to as biofertilizers are inexpensive, environmentally safe, and renewable sources of plant nutrients that are used in addition to chemical fertilizers. Phosphatic fertilizer efficiency is increased when PSB is added to the crop's rhizosphere (Gaur, 1990) [8]. Therefore, using PSB in combination with efficient nutrient management techniques will help to preserve soil fertility while boosting production and quality (Singh and Singh, 2014) [28]. The prolonged usage of chemical fertilizers has resulted in a large increase in crop yields over time. But the nutrients present in the bulk chemical forms are not entirely utilized by plants because the majority of them invert to an insoluble form in soil. Crop plants typically absorb just half of the chemical fertilizers that are applied (Loomis and Connor, 1992) [16]. Thus, employing effective nutrient management strategies in conjunction with organic manures and biofertilizers like PSB will assist to increase the production and quality of crops while also maintaining soil fertility (Singh and Singh, 2014) [28].

Materials and Methods

In the *rabi* of 2024-25, the field experiment was carried out at the School of Agricultural Sciences' Instructional Farm in Dabok, Udaipur. There was 6.4 mm of rain overall throughout the crop growing season. Clay loam soil with a slightly alkaline response (pH 7.3), low organic carbon (0.58%), low nitrogen (254.4 kg ha^{-1}) and medium accessible phosphorus (21.5 kg ha^{-1}), but high potassium (353.2 kg ha^{-1}) was the soil type used in the experiment. Ten treatment combinations including four with 100% RDF along with vermicompost, FYM and PSB in combination or alone, five with 50% RDF along with vermicompost, FYM and PSB in combination or alone and control which were evaluated under randomized block design with 3 replications. On November 16, 2024, palak crop was planted. To maximize plant stands, 30 kg ha^{-1} of seeds were utilized, with 30 cm between rows. The fertilizer dosage that was advised was maintained at 120:60:60 (N:P:K). During the whole growth season, two irrigations were given. In accordance with treatments, fertilizers were administered.

Results and Discussion

Effect of treatments

Growth attributes

Plant growth attributes are considered important to predict the productivity of the crop. The results (Table 1) revealed that significant effect of organic and inorganic sources of nutrient and their combination was recorded on different growth parameter as *viz.*, plant height, number of leaves $plant^{-1}$ and leaf length over control which indicated that varying doses of treatments were effective in increasing the growth parameter of palak. The highest plant height at 30 and 45 DAS (25.78 and 35.42 cm, respectively), number of leaves $plant^{-1}$ at 30 and 45 DAS (8.42 and 11.95, respectively) and leaf length at 30 and 45 DAS (14.75 and 20.83, respectively) were recorded superior with the application of T_8 (50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB) which was statistically at par with T_6 (50% RDF through inorganic fertilizer + 50% RDF through Vermicompost) and T_{10} (50% RDF through inorganic fertilizer + 25% RDF through FYM + 25% RDF through Vermicompost + PSB). FYM, vermicompost and PSB boosted plant growth by promoting rapid cell division and elongation in the meristematic zone, leading to increased plant height. This growth likely resulted from improved soil physio-chemical and biological properties—such as better water-holding capacity, microbial activity, soil aeration, and organic acid release—that enhance nutrient and water availability (Naidu *et al.*, 2002) [18]. Phosphorus stimulates cell division and enlargement (Reyes *et al.*, 2002) [24], so PSB's role in mobilizing soil phosphorus alongside inorganic fertilizers supports this growth. PSB also raises growth hormones like auxin and gibberellic acid, further enhancing development. Organic manure improves physiological processes like transpiration, stomatal conductance, and photosynthesis, which likely boosted nutrient absorption, carbohydrate metabolism, and tissue formation, driving vegetative growth. The findings of the present study are in the similar consent with the findings of Baria *et al.* (2023) [2] in beetroot and Jabeen *et al.* (2017) [11], Khadse *et al.* (2021) [14] and Choudhary *et al.* (2024) [6] in spinach beet.

Yield attributes and yield

It was observed (Table 1 and 2) that organic and inorganic sources of nutrient and their combination had a significant effect on yield attributes and yield during experiment. The maximum leaf width at 30 and 45 DAS (7.68 and 8.81 cm, respectively), total leaf yield $plot^{-1}$ (11.16 kg) and total leaf yield (29.07 q ha^{-1}) was recorded with the application of treatment T_8 (50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB) which was statistically at par with T_{10} (50% RDF through inorganic fertilizer + 25% RDF through FYM + 25% RDF through

Vermicompost + PSB). The minimum values for yield attributes and yield was recorded with treatment T_1 (Control). Better yield and production in palak come from a balanced supply of nutrients, especially phosphorus, potassium, and others supplied by organic manures. Alongside nitrogen from inorganic fertilizers, humic substances in manure boost cell division, photosynthesis, and water regulation, enhancing plant growth traits like height, leaf size, and chlorophyll content. This improved growth increases photosynthesis and nutrient flow to fruits. Organic manures improve soil's physical, chemical, and biological properties, promoting root growth and nutrient uptake (Devi *et al.*, 2018; Kumar *et al.*, 2018) [7 15]. Soil microflora uses organic sources to convert nutrients into forms plants can absorb, while phosphate-solubilizing bacteria (PSB) produce growth hormones and convert insoluble fertilizers into soluble forms, further boosting taro yield (Kenneth *et al.*, 2019; Gupta *et al.*, 2011) [13, 10]. Similar close results were reported by Baria *et al*. (2023) [2] and Singh *et al.* (2023) [29] in beetroot and Vishwakarma *et al*. (2023) [34] and Sunitha *et al.* (2025) [31] in palak and Olowoake (2014) [22] in amaranthus.

Quality parameters

It was observed (Table 2) that organic and inorganic sources of nutrient and their combination had a significant effect on quality attributes of palak. Maximum dry matter content (12.85%) and chlorophyll content (13.09 mg g^{-1}) was recorded with the application of treatment T_8 (50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB) which was statistically at par with T_6 (50% RDF through inorganic fertilizer + 50% RDF through Vermicompost) and T_{10} (50% RDF through inorganic fertilizer + 25% RDF through FYM + 25% RDF through Vermicompost + PSB). The minimum values for quality attributes was recorded with treatment T_1 (Control). This might be as a result of the application of inorganic fertilizers and organic manures, which may offer the nutrition required for the development of protein. It's possible that the organic sources of plant nutrients, such as FYM or vermicompost, improved the physicochemical and biological properties of the soil to improve nitrogen fixation and root absorption. This, in turn, increased the amount of chlorophyll and dry matter accumulation in palak. Because vermicompost encourages root growth and proliferation and eventually removes biotic stress on soil microbes, it may be advantageous for dry matter. Plants may satisfy their nutritional demands for longer thanks to vermicompost, an organic manure that releases nutrients gradually and includes chelated versions of the majority of macro and micronutrients. The larger starch content may be the consequence of enhanced photosynthetic production and translocation, since the higher tuber yield leads to the synthesis of stored starch. Sable *et al.* (2007) [25] also found that applying vermicompost and neem cake to tomatoes resulted in noticeably longer T.S.S. and shelf life. The associated growth characteristics also affect the accumulation of dry matter; in particular, the palak plant's leaf length/width (leaf area) has a significant effect in both biomass production and solar radiation absorption, which in turn affects dry matter accumulation. It is evident from the leaf length and width characters in the study, as application of 50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB have shown higher leaf length and width, resulted in higher yield due to more dry matter accumulation. Mbithi *et al*. (2015) [17] and Baria *et al*. (2023) [2] in beetroot, Nargave *et al.* (2018) [20] in radish and Gowda *et al.* (2022) [9] in palak and Sen *et al*. (2006) [26] observed similar findings in taro.

Soil properties and microbial population after harvest

The maintenance of soil fertility is a pivot for the successful and sustainable production of any crop. For maintaining soil fertility application of organic input is desirable. The effect of organic and inorganic sources of nutrient and their combination on soil properties was found significant during experiment (Table 4.7, 4.8 and 4.9). The significantly maximum organic carbon of soil (0.51 per cent) was recorded with T_4 (100% RDF through Vermicompost) whereas maximum available nitrogen in soil (144.62 kg ha^{-1}), available phosphorous in soil (33.38 kg ha^{-1}), soil bacteria (53.37 x 10^6 cfu g^{-1}) and fungi (22.12 x 10^4 cfu g^{-1}) population was observed under T_8 (50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB) which was at par with T_6 (50% RDF through inorganic fertilizer + 50% RDF through Vermicompost) and T_{10} (50% RDF through inorganic fertilizer + 25% RDF through FYM + 25% RDF through Vermicompost + PSB). The significant increase in the soil available nutrient content could be attributed due to direct incorporation of organic matter in soil. Further, addition of organic manures might have also stimulated the growth and activity of microorganisms which directly contributed to increased level of soil available nutrient content. Incorporation of organic manures in soil and also increase the carbon sequestration in the soil which might have resulted in increased yield of roots thereby adding a good amount of organic biomass to soil. The increase in available nitrogen, phosphorous and potassium content of soil under organic and inorganic sources of nutrient and their combination application might be ascribed to greater multiplication of soil microbes which could convert organically bound nitrogen to inorganic form (Bellakki and Badanur, 1997) [3]. These findings are in conformity with those of Kumar *et al.* (2021) [15] in beetroot reported that vermicompost and FYM improved soil microbial activity and organic carbon content, fostering long-term soil fertility. These organic inputs, when combined with reduced doses of chemical fertilizers, helped maintain soil health and nutrient balance. Singh *et al.* (2022) [27] in beetroot also reported that continuous use of organic manures increases organic carbon and microbial biomass, ensuring sustainable productivity.

Economics

The results (Table 4) revealed that the application of organic and inorganic sources of nutrient and their combination in palak significantly influenced net return and B-C ratio. The maximum net return (₹196062 ha^{-1}) was recorded under T_8 (50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB) which was at par with T_{10} (50% RDF through inorganic fertilizer + 25% RDF through FYM + 25% RDF through Vermicompost + PSB) whereas, maximum B-C ratio (2.5) was recorded under T_2 (100% RDF through inorganic fertilizer). The increased net return could be explained on the basis of increased yield under T_8 (50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB) which was higher than rest of the treatments. The present results are consistent with the

findings of Jawadagi *et al.* (2020) [12] in beetroot, Chaudhary and Rawat (2022) [4] in taro and Chaudhary *et al.* (2024) in palak as they reported maximum net return with treatments having application of organic manures.

Table 1: Effect of treatments on plant height, number of leaves plant^{-1}, leaf length and leaf width of palak

Treatments	Plant height (cm)		Number of leaves plant^{-1}		Leaf length (cm)		Leaf width (cm)	
	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS
Control	16.27	21.52	4.74	6.59	10.35	12.73	4.74	5.07
100% RDF through inorganic fertilizer	24.95	33.16	7.07	9.35	13.65	17.64	6.40	7.40
100% RDF through FYM	19.87	27.65	5.58	9.85	12.45	16.66	5.58	5.91
100% RDF through Vermicompost	21.68	31.53	7.02	9.92	13.35	16.24	5.91	6.69
50% RDF through inorganic fertilizer + 50% RDF through FYM	22.22	31.65	6.22	9.49	14.15	14.88	5.30	6.33
50% RDF through inorganic fertilizer + 50% RDF through Vermicompost	23.81	33.02	7.09	10.51	14.50	19.91	6.88	7.63
50% RDF through inorganic fertilizer + 50% RDF through FYM + PSB	23.72	33.32	6.31	9.25	14.45	18.05	5.88	7.25
50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB	25.78	35.42	8.42	11.95	14.75	20.83	7.68	8.81
100% RDF through FYM + PSB	19.97	30.42	6.85	8.38	13.15	15.47	5.71	6.85
50% RDF through inorganic fertilizer + 25% RDF through FYM + 25% RDF through Vermicompost + PSB	24.18	34.67	6.64	9.29	14.19	17.87	6.64	7.39
S.Em. ±	0.52	0.73	0.48	0.67	0.26	1.09	1.09	0.49
C.D. (P=0.05)	1.55	2.17	1.43	2.01	0.79	3.26	3.26	1.45

Table 2: Effect of treatments on total leaf yield, dry matter content and chlorophyll content in palak

Treatments	Total leaf yield plot^{-1} (kg)	Total leaf yield (q ha^{-1})	Dry matter content (%)	Chlorophyll content at 30 DAS (mg g^{-1})
Control	6.60	17.20	9.75	7.87
100% RDF through inorganic fertilizer	9.06	22.83	11.85	10.07
100% RDF through FYM	7.84	20.41	11.25	9.48
100% RDF through Vermicompost	9.35	23.48	11.95	10.86
50% RDF through inorganic fertilizer + 50% RDF through FYM	8.23	21.43	12.15	9.38
50% RDF through inorganic fertilizer + 50% RDF through Vermicompost	9.66	25.69	12.35	11.58
50% RDF through inorganic fertilizer + 50% RDF through FYM + PSB	9.09	23.67	12.25	10.56
50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB	11.02	29.07	12.85	13.09
100% RDF through FYM + PSB	8.88	23.19	11.65	10.61
50% RDF through inorganic fertilizer + 25% RDF through FYM + 25% RDF through Vermicompost + PSB	10.24	26.67	12.65	12.53
S.Em. ±	0.41	1.08	0.25	0.51
C.D. (P=0.05)	1.24	3.23	0.74	1.53

Table 3: Effect of treatments on soil properties and microbial population after harvest

Treatments	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Bacteria population in soil (10^6cfu g^{-1})	Fungi population in soil (10^4cfu g^{-1})	Actinomycetes population in soil (10^4cfu g^{-1})
Control	0.41	131.40	23.12	172.20	46.99	17.43	21.85
100% RDF through inorganic fertilizer	0.45	141.20	28.93	176.50	48.66	18.24	22.51
100% RDF through FYM	0.50	138.97	28.10	178.61	49.95	19.55	24.43
100% RDF through Vermicompost	0.51	137.93	27.84	176.68	49.50	20.86	23.86
50% RDF through inorganic fertilizer + 50% RDF through FYM	0.47	135.29	27.92	176.79	49.67	18.98	23.75
50% RDF through inorganic fertilizer + 50% RDF through Vermicompost	0.48	141.20	29.50	178.35	52.25	21.32	23.03
50% RDF through inorganic fertilizer + 50% RDF through FYM + PSB	0.45	139.70	27.95	178.50	50.20	19.34	23.63
50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB	0.49	144.62	33.38	178.42	53.37	22.12	24.61
100% RDF through FYM + PSB	0.46	140.88	28.09	179.63	50.75	19.87	24.32
50% RDF through inorganic fertilizer + 25% RDF through FYM + 25% RDF through Vermicompost + PSB	0.50	143.03	32.02	180.15	51.79	21.73	22.97
S.Em. ±	0.008	1.88	1.12	1.53	0.57	0.44	0.89
C.D. (P=0.05)	0.02	5.59	3.33	NS	1.70	1.32	NS

Table 4: Effect of treatments on net return and B-C of palak

Treatments	Net return (₹ ha^{-1})	B-C ratio
Control	113962	1.96
100% RDF through inorganic fertilizer	163098	2.50
100% RDF through FYM	86080	0.73
100% RDF through Vermicompost	110757	0.89
50% RDF through inorganic fertilizer + 50% RDF through FYM	122723	1.34
50% RDF through inorganic fertilizer + 50% RDF through Vermicompost	162344	1.72
50% RDF through inorganic fertilizer + 50% RDF through FYM + PSB	145069	1.58
50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB	196062	2.07
100% RDF through FYM + PSB	113808	0.96
50% RDF through inorganic fertilizer + 25% RDF through FYM + 25% RDF through Vermicompost + PSB	173517	1.86
S.Em. ±	10874	0.12
C.D. (P=0.05)	32309	0.34

Conclusion

Based on the results of this investigation, it can be said that in Rajasthan's current agroclimatic zone IVa, application of T_8 (50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB) significantly growth, yield attributes, yield, quality, soil properties as well as net returns of palak. The maximum yield (29.07 t ha^{-1}) and net return (₹196062 ha^{-1}) were obtained with T_8 (50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB). Therefore, application of 50% RDF through inorganic fertilizer + 50% RDF through Vermicompost + PSB may be recommended for palak to obtain higher yield and net returns. However, these are one-year results and need further experimentation for final recommendation.

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