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Influence of inorganic nutrients and biofertilizers on growth parameters of Palak

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ABSTRACT

Now-a-days, the producers are taking more interest in the nutritional harvest i.e., quality of the produce in terms of its food value rather than its quantity per hectare. Ignorance of organic manures and random use of chemical fertilizers, soil becomes vulnerable that leads to nutrient imbalance and threat to ecological sustainability. A Field experiment was conducted during the rabi season at the College of Horticulture, Rajendranagar, Hyderabad. Palak, a nutrient-rich leafy green vegetable, is an essential crop for human consumption, providing vital vitamins, minerals, and antioxidants. To meet the increasing demand for Palak, farmers rely on fertilizers to enhance growth and productivity. Inorganic nutrients such as Nitrogen, Phosphorus, and Potassium are widely used, but their excessive application can harm the environment and human health. Biofertilizer offers a sustainable alternative to promoting plant growth while maintaining soil health. Therefore, research with the ten integrated treatments consisting of inorganic nutrients (75%, 50% and 25% NPK kg ha^{-1}), Bio-fertilizers (Azotobacter, Phosphorus Solubilizing Bacteria (PSB), Potassium Solubilizing Bacteria (PSB), Arka Microbial Consortium (AMC) along with Arka vegetable special (micronutrient spray) @ 5 gm litre^{-1} was done for 3 times at 15 days interval with three replications. Results revealed that maximum growth was influenced by the application of a 50% Recommended Dose of Fertilizers (NPK kg ha^{-1}), 50% Biofertilizers (Arka Microbial Consortium + Potassium Solubilizing Bacteria), along with Arka Vegetable Special (micronutrient spray). This study investigates the influence of inorganic nutrients and Biofertilizers on growth parameters like Leaf area, Leaf area Index, Specific leaf area, Specific leaf weight, and Leaf area duration of Palak, aiming to identify an optimal fertilization strategy that balances productivity and environmental sustainability.

Keywords: *Palak, Inorganic nutrients, Biofertilizers, Productivity, Sustainability, Nitrogen, Phosphorous, Potassium, Arka Vegetable Special and Arka Microbial Consortium.*

Introduction

Spinach beet (*Beta vulgaris* var. *bengalensis*) is one of the most important green leafy vegetables consumed all over the country. It plays an important role in the human diet by providing nutritious compounds like vitamins, minerals, fiber, proteins, antioxidants, folic acid, etc., which are essential constituents of a balanced diet. To enhance its growth and productivity, farmers often rely on fertilizers. Continuous application of fertilizers and chemicals deteriorates the soil and causes soil problems.

These days, farmers use large amounts of nitrogen application in the form of urea for effective growth and yield, which becomes vulnerable to soil that leads to nutrient imbalance and a threat to ecological sustainability. Excessive use of chemical fertilizers creates a multiple nutrient deficiency, deteriorating soil structure and texture, along with undesirable crop yield [1]. The effect of both organic and inorganic sources of nutrients associated with microbial population through inoculation with biofertilizer helping in mobilizing phosphorus and nitrogen fixation into soluble form in the soil, there by higher release of both nutrient forms, this is in turn promoted in growth, increased the rate of absorption, increased the photosynthesis productivity and better accumulation of macronutrients and Fe content and ascorbic acid and folic acid content in spinach [2]. The concept of Integrated Nutrient Management (INM) is defined as the adjustment or maintenance of soil fertility and the supply of nutrients to plants up to an optimum level for sustaining the desired crop productivity through optimized utilization of all possible resources of plant nutrients in an integrated manner [3].

Therefore, it has become essential to use untraditional fertilizers as supplements or substitutes for chemical fertilizers. In the production of Palak, with the help of the INM system approach, which is economically cheap, technically sound, practically feasible, and paying way for sustainable cultivation, [4]. Biofertilizers are less expensive, eco-friendly, and sustainable, likely to assume greater significance as a complement or supplement to inorganic fertilizers. Azotobacteria an aerobic, free-living gram-negative bacterium that fixes nitrogen from the atmosphere. The phosphate-solubilising bacteria increase the availability of phosphorus in the soil through the secretion of phosphatase enzyme, which leads to the transfer of organic phosphorus to an available form. Consequently, it increases phosphorus absorption and accumulation in plants [5].

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Biofertilizers utilize the symbiotic relationships between plants and beneficial microorganisms to enhance soil fertility and plant growth. Use of biofertilizers and organic fertilizers in crop cultivation will help in safeguarding the soil health, improving in quality of the product, increasing crop yield, restoring natural soil fertility, and providing protection against drought and some soil-borne diseases [6]. Phosphate-Solubilizing Biofertilizers contain phosphate-solubilizing bacteria and fungi, such as Bacillus and Penicillium species, which solubilize insoluble phosphates in the soil, enhancing phosphorus uptake and promoting root development [7]. Potassium-Enhancing Biofertilizers: These formulations harbour microorganisms, including potassium-solubilizing bacteria, that improve potassium availability in the soil. By enhancing potassium uptake, they foster better plant growth and stress tolerance [8]. Arka Microbial Consortium is a carrier-based product that contains N-fixing, P & Zn-solubilizing, and Plant Promoting Microbes in a single formulation. The novelty of this technology is that farmers need not apply nitrogen-fixing, phosphorus-solubilizing, and growth-promoting bacterial inoculants individually [9]. Hence, keeping the same approach in view a study has been done with the supplementation of FYM, Azotobacter, PSB, KSB, and AMC, along with the reduced level of inorganic nutrients like urea, SSP, and MOP is applied with the objective to study the influence of reduced inorganic nutrients and biofertilizers on the growth of Spinach beet. By exploring the effects of these fertilizers on palak growth, this research contributes to the development of eco-friendly agricultural practices, ensuring a sustainable food supply while minimizing environmental impact.

Material and Methods

The experiment was carried out at PG research from the College of Horticulture, Rajendranagar, Hyderabad, Telangana, during the *rabi season*. The experimental site is situated at an altitude of 542.3 m above the mean sea level at 17º 191 North latitude and 79º 231 East longitude. The experiment was laid out in a randomized block design (RBD) with three replications and ten treatments. Treatments consisted of T_1 - 100% RDF @ 100:25:50 kg ha^{-1} T_2 -75% RDF + Biofertilizers [Azotobacter + Phosphorus Solubilizing Bacteria (PSB) + Potassium Solubilizing Bacteria (KSB)] (Each @ 1.25 kg ha^{-1}) T_3 - 50% RDF + Biofertilizers [Azotobacter + Phosphorus Solubilizing Bacteria (PSB) + Potassium Solubilizing Bacteria (KSB)] (Each @ 2.5 kg ha^{-1}) T_4 -25% RDF + Biofertilizers [Azotobacter + Phosphorus Solubilizing Bacteria (PSB) + Potassium Solubilizing Bacteria (KSB)] (Each @ 3.75 kg ha^{-1}) T_5 -75% RDF + Arka Microbial Consortium (AMC) @ 2.5 kg ha^{-1} + Potassium Solubilizing Bacteria (KSB) @ 1.25 kg ha^{-1} T_6 - 50% RDF + Arka Microbial Consortium (AMC) @ 5 kg ha^{-1} + Potassium Solubilizing Bacteria (KSB) @ 2.5 kg ha^{-1} T_7 - 25% RDF + Arka Microbial Consortium (AMC) @ 7.5 kg ha^{-1} + Potassium Solubilizing Bacteria (KSB) @ 3.75 kg ha^{-1} T_8 - T_5 + Arka vegetable special @ 5 gm liter^{-1} T_9 - T_6 + Arka vegetable special @ 5 gm liter^{-1} T_{10} - T_7 + Arka vegetable special @ 5 gm liter^{-1} The field was thoroughly prepared and experimental plots of 2 m x 2 m size were made. Biofertilizers mixed with organic manure were applied as per the rates indicated under the treatments after preparation of the layout i.e., FYM, Azotobacter, PSB, KSB, and AMC followed by irrigation and fertilizers, full doses of P_2O_5, K_2O were applied respectively through single super phosphate and murate of potash before sowing. While application of nitrogen was made through urea in three equal splits i.e., 50% at the time of sowing and the remaining 50% at 30, and 45 days after sowing. 3-4 seeds per hill were sown at a spacing of 30×10 cm. Thinning was done 15 days after sowing and all other cultural and plant protection measures were done as per the recommended package of practices for the healthy crop.

The observations were recorded for five plants in each treatment and replications were randomly selected and tagged for each replication in each treatment for recording the observations.

Growth Parameters

1. Leaf area (cm^2)

Leaf area was recorded with leaf area meter model number CI 202 portable area meter at 15,30 and 45 days after sowing from five plants per treatment per replication and their mean was worked out.

2. Leaf area Index (LAI)

The leaf area index was calculated by the formula [10].

$$LAI = \frac{\text{Leaf area per plant (cm}^2)}{\text{Area occupied by each plant (cm}^2)}$$

3.Specific leaf area (SLA) (cm^{2}g^{-1})

The specific leaf area was calculated by the formula given below

$$SLA = \frac{\text{Leaf area (cm}^2)}{\text{Leaf weight (g)}}$$

4. Specific leaf weight (SLW) (g cm^{-1})

The specific leaf weight was calculated by the formula given below

$$SLW = \frac{\text{Leaf weight (g)}}{\text{Leaf area (cm}^2)}$$

5. Leaf Area Duration (LAD) (cm^{2}d^{-1})

Leaf area duration is the integral of the leaf area index over the growth period and was worked out as per the formula [11].

$$LAD = \frac{LAI_1 + LAI_2}{2} \times (t_2 - t_1)$$

Whereas, LAI_1 = Leaf area index at time t_1

LAI_2 = Leaf area index at time t_2

Results and Discussions

1. Leaf area (cm^2)

The data pertaining to leaf area were recorded at 15, 30, and 45 DAS which are presented in Table 1.

The highest leaf area was found significantly maximum in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) at 15, 30 and 45 DAS as (120.83 cm^2), (353.56 cm^2) and (401.88 cm^2). The minimum leaf area was observed in treatment T_4 (25% RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (88.32 cm^2), (302.84 cm^2) and (354.11 cm^2).

Table 1. Influence of inorganic nutrients and Biofertilizers on Leaf area (cm^2) in Palak

Treatments	Leaf area (cm^2)		
	15 DAS	30 DAS	45 DAS
T_1 – 100 % RDF @ 100:25:50 kg ha^{-1}	95.88	317.59	369.66
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg ha^{-1})	101.33	324.14	376.33
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg ha^{-1})	99.44	320.84	374.88
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg ha^{-1})	88.32	302.84	354.11
T_5 – 75 % RDF + AMC @ 2.5 kg ha^{-1} + KSB @ 1.25 kg ha^{-1}	110.37	338.66	389.18
T_6 – 50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}	117.53	347.24	396.44
T_7 – 25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}	90.95	306.37	359.34
T_8 – T_5 + Arka vegetable special @ 5 g $liter^{-1}$	114.53	344.88	393.18
T_9 – T_6 + Arka vegetable special @ 5 g $liter^{-1}$	120.83	353.56	401.88
T_{10} – T_7 + Arka vegetable special @ 5 g $liter^{-1}$	92.59	308.37	360.77
S.E (m) ±	**0.72**	**0.82**	**1.09**
CD at 5 %	**2.16**	**2.45**	**3.23**

The increase in leaf area might be due to the application of an integrated nutrient combination which enhances the availability of nutrients in the soil, reflected in the increase of leaf area. These results are in accordance with Kasurimethi [12].

2. Leaf area index

Leaf area index of various treatments of spinach beet is given in Table 2. at 15, 30, and 45 days after sowing.

The highest leaf area index (0.402, 1.178, and 1.339) was found significantly in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}). The minimum leaf length (0.294, 1.007, and 1.180) was observed in T_4 (25% RDF + Azotobacter + PSB + KSB) (Each @ 3.75 kg ha^{-1}).

Table 2. Influence of inorganic nutrients and Biofertilizers on Leaf area Index in Palak

Treatments	Leaf area index		
	15 DAS	30 DAS	45 DAS
T_1 – 100 % RDF @ 100:25:50 kg ha^{-1}	0.319	1.058	1.232
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg ha^{-1})	0.337	1.080	1.254
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg ha^{-1})	0.331	1.069	1.249
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg ha^{-1})	0.294	1.007	1.180
T_5 – 75 % RDF + AMC @ 2.5 kg ha^{-1} + KSB @ 1.25 kg ha^{-1}	0.367	1.128	1.297
T_6 – 50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}	0.391	1.157	1.321
T_7 – 25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}	0.303	1.021	1.197
T_8 – T_5 + Arka vegetable special @ 5 g $liter^{-1}$	0.381	1.149	1.310
T_9 – T_6 + Arka vegetable special @ 5 g $liter^{-1}$	0.402	1.178	1.339
T_{10} – T_7 + Arka vegetable special @ 5 g $liter^{-1}$	0.308	1.027	1.202
S.E (m) ±	**0.003**	**0.006**	**0.005**
CD at 5 %	**0.009**	**0.01**	**0.01**

The increase in leaf area index was due to an increase number of leaves per plant and leaf area. The results are in agreement with the findings in Amaranthus [13].

3. Specific leaf area ($cm^2 g^{-1}$)

Specific leaf area was affected by the inorganic nutrients and biofertilizers, as presented in Table 3.

Significantly maximum values (15.07 cm^2 g^{-1}, 25.57 cm^2 g^{-1}, and 14.64 cm^2 g^{-1}) recorded at 15, 30, and 45 DAS under the treatment T_4 (25% RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}). However, the lowest value was observed in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (8.91 cm^2 g^{-1}, 12.57 cm^2 g^{-1}, and 6.96 cm^2 g^{-1})

Specific leaf area is the ratio of assimilating area to its dry weight. The highest leaf area was observed in the T_9 treatment, which might have led to more assimilation of photosynthates and contributed to the highest specific leaf area. SLA is the maximum open-area crop because of its high photosynthetic surface area [14].

Table 3. Influence of inorganic nutrients and Biofertilizers on Specific Leaf area ($cm^2 g^{-1}$) in Palak

Treatments	Specific Leaf area (cm^2 g^{-1})		
	15 DAS	30 DAS	45 DAS
T_1 – 100 % RDF @ 100:25:50 kg ha^{-1}	13.46	22.30	12.62
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg ha^{-1})	11.97	19.04	10.74
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg ha^{-1})	12.55	20.25	11.57
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg ha^{-1})	15.07	25.57	14.64
T_5 – 75 % RDF + AMC @ 2.5 kg ha^{-1} + KSB @ 1.25 kg ha^{-1}	10.83	16.61	9.50
T_6 – 50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}	9.68	14.31	8.03
T_7 – 25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}	14.41	23.35	13.19
T_8 – T_5 + Arka vegetable special @ 5 g $liter^{-1}$	10.32	15.54	8.82
T_9 – T_6 + Arka vegetable special @ 5 g $liter^{-1}$	8.91	12.57	6.96
T_{10} – T_7 + Arka vegetable special @ 5 g $liter^{-1}$	13.57	21.06	11.87
S.E (m) ±	**0.18**	**0.34**	**0.17**
CD at 5 %	**0.53**	**1.03**	**0.51**

4. Specific leaf weight (g cm^{-2})

The data pertaining to specific leaf weight was found to be non-significant at 15, 30, and 45 DAS presented in Table 4.

The Highest Specific leaf weight was recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) at 15, 30, 45 DAS as (0.112 g cm^{-2}, 0.079 g cm^{-2}, and 0.143 g cm^{-2}). Lowest Specific leaf weight was recorded in T_4 (25% RDF + Azotobacter + PSB + KSB) (Each @ 3.75 kg ha^{-1}) (0.053 g cm^{-2}, 0.039 g cm^{-2} and 0.068 g cm^{-2}).

Specific leaf weight is the reverse condition of the Specific leaf area, which indicates leaf thickness. Therefore, the highest SLW might be due to the presence of high leaf thickness, which leads to an increase in dry leaf weight. The results are confirmed in small grain crops [15].

Table 4. Influence of inorganic nutrients and Biofertilizers on Specific Leaf weight (g cm^{-2}) in Palak

Treatments	Specific Leaf weight (g cm^{-2})		
	15 DAS	30 DAS	45 DAS
T_1 – 100 % RDF @ 100:25:50 kg ha^{-1}	0.074	0.047	0.079
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg ha^{-1})	0.083	0.052	0.093
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg ha^{-1})	0.079	0.049	0.086
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg ha^{-1})	0.053	0.039	0.068
T_5 – 75 % RDF + AMC @ 2.5 kg ha^{-1} + KSB @ 1.25 kg ha^{-1}	0.092	0.060	0.105
T_6 – 50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}	0.103	0.069	0.124
T_7 – 25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}	0.069	0.042	0.075
T_8 – T_5 + Arka vegetable special @ 5 g $liter^{-1}$	0.096	0.064	0.113
T_9 – T_6 + Arka vegetable special @ 5 g $liter^{-1}$	0.112	0.079	0.143
T_{10} – T_7 + Arka vegetable special @ 5 g $liter^{-1}$	0.073	0.044	0.084
S.E (m) ±	**0.002**	**0.001**	**0.003**
CD at 5 %	**0.007**	**0.004**	**0.009**

5. Leaf area Duration (cm^2 d^{-1})

The data on leaf area duration as influenced by various treatments are presented in Table 5

Between 15 to 30 days

Leaf area duration was highest in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) (11.79 cm^2 d^{-1}) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (11.55 cm^2 d^{-1}) whereas, lowest values were recorded in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (9.70 cm^2 d^{-1}).

Between 30 to 45 days

Leaf area duration was highest in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) (18.75 cm^2 d^{-1}) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (18.52 cm^2 d^{-1}) whereas, lowest values were recorded in treatment T4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (16.35 cm^2 d^{-1}) Higher Leaf area duration may be due to the higher leaf area index. The results are confirmation with the findings in Amaranthus [13].

Table 5. Influence of inorganic nutrients and Biofertilizers on Leaf area Duration (cm^{-2} d^{-1}) in Palak

Treatments	Leaf area duration (cm^{-2} d^{-1})	
	15 to 30 DAS	30 to 45 DAS
T_1 – 100 % RDF @ 100:25:50 kg ha^{-1}	10.26	17.10
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg ha^{-1})	10.62	17.47
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg ha^{-1})	10.43	17.25
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg ha^{-1})	9.70	16.35
T_5 – 75 % RDF + AMC @ 2.5 kg ha^{-1} + KSB @ 1.25 kg ha^{-1}	11.15	18.07
T_6 – 50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}	11.55	18.52
T_7 – 25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}	9.92	16.57
T_8 – T_5 + Arka vegetable special @ 5 g $liter^{-1}$	11.40	18.37
T_9 – T_6 + Arka vegetable special @ 5 g $liter^{-1}$	11.79	18.75
T_{10} – T_7 + Arka vegetable special @ 5 g $liter^{-1}$	9.96	16.65
S.E (m) ±	**0.06**	**0.04**
CD at 5 %	**0.19**	**0.14**

Conclusion

This study concludes that the integrated use of inorganic nutrients and biofertilizers i.e. use of inorganic 50% RDF, 50% organic (AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) along with micronutrient spray i.e., Arka vegetable special @ 5 g $liter^{-1}$ at 15, 30, and 45 days after sowing is an effective approach to enhance the growth and productivity of Palak. This combination can lead to improved nutrient uptake, plant growth promotion, and increased yield, making it a sustainable and eco-friendly practice for Palak cultivation. However, the experiment should be extended on a larger scale in the future to investigate Standardization of different combinations of biofertilizers and their dosage to enhance the yield and various storage methods to increase the shelf life of Palak.

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