International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(10): 684-687
Received: 13-08-2024
Accepted: 24-09-2024

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Soil nutrient analysis on inorganic nutrients and biofertilizer application in spinach beet (*Beta vulgaries* var. *Bengalensis*)

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i10Sj.1864

Abstract
In recent years, the consumers are becoming more aware about the use of chemical free vegetables particularly leafy vegetables. Hence, it becomes the need to sustain the production level with minimum or no use of chemicals. Continuous application of chemicals deteriorates the soil and cause soil problems. Ignorance of organic manures and random use of chemical fertilizers, soil becomes vulnerable that leads to nutrient imbalance and threat to ecological sustainability. It is also well understood that the ideal soil condition can be created through combination of organic manures for maximum crop yield. Keeping this facts in view, A Field experiment has been conducted to study the effect of inorganic nutrients and biofertilizers on growth, yield and quality of spinach beet during rabi, at PG research farm, College of Horticulture, Rajendranagar, Hyderabad with the ten integrated treatments consisting of inorganic nutrients (75%, 50% and 25% NPK kg/ha), Biofertilizers such as Azotobacter, Phosphorous Solubulizing Bacteria (PSB), Potassium Solubulizing Bacteria (PSB), Arka Microbial Consortium (AMC) and Arka vegetable special @ 5 gm/litre was done for 3 times at 15 days interval with three replications were arranged in a randomized block design. Results revealed that Maximum macronutrients and micronutrients are recorded high in effective nutrient combination of application of 50% Recommended Dose of Fertilizers (NPK kg/ha), 50% Biofertilizers (Arka Microbial Consortium + Potassium Solubulizing Bacteria) along with Arka vegetable special (micronutrient spray) after harvest of the crop.

Keywords: Soil, inorganic nutrients, biofertilizers, micronutrients and sustainability

Introduction
Spinach beet (*Beta vulgaris* var. *bengalensis*) is a nutrient-demanding crop that requires a balanced supply of macronutrients, micronutrients and beneficial microorganisms for optimal growth and productivity. Conventional farming practices often rely on inorganic nutrients which can lead to soil degradation nutrient imbalances and decreased microbial activity. Biofertilizers comprising beneficial microorganisms offer a sustainable alternative enhancing soil nutrient availability and plant growth. Additionally, micronutrient application can further improve crop productivity and nutrient uptake.

This study examined the effects of Inorganic nutrients, biofertilizers and micronutrient application on spinach beet growth, soil nutrient dynamics and microbial activity. The results showed that biofertilizers and micronutrient application significantly improved spinach beet growth, nutrient uptake and soil fertility while mitigating the negative effects of inorganic nutrients on soil health. The combined application of biofertilizers and micronutrients with inorganic nutrients optimized soil nutrient dynamics increased crop productivity and enhanced microbial activity. This study demonstrates the potential of integrated nutrient management strategies for sustainable spinach beet production highlighting the importance of balancing inorganic nutrients with biofertilizers and micronutrients to promote soil health and reduce environmental degradation.

Materials and Methods

Collection of samples: A composite soil sample (0-15 cm depth) was collected from research plot of student research farm, College of Horticulture, Rajendranagar, Hyderabad. Soil sample was collected from research plot before application of fertilizers. The soil sample was air dried, crushed with hammer and passed through 2 mm sieve and preserve for physical and chemical analysis and are presented in Table 1.

Table 1: Salient soil characteristics of experimental site

Physico-chemical properties	
pH	8.65
Electric conductivity (EC) ds m^{-1}	0.16
Chemical properties	
Available Nitrogen (kg ha^{-1})	142.50
Available Phosphorous (kg ha^{-1})	36.00
Available Potassium (kg ha^{-1})	192.00
Zinc (mg kg^{-1})	0.323
Iron (mg kg^{-1})	1.127
Manganese (mg kg^{-1})	5.739
Copper (mg kg^{-1})	0.392

Soil analysis (Before planting and after harvest)

Soil sample were collected randomly from plough layer depth with the help of soil sampling tube before sowing and after harvesting of crops from each plot and mixed thoroughly, dried to air crushed sieved through 2 mm sieves. The soil sampled prepared was subjected to chemical analysis for evaluating soil fertility status by following procedures are presented in Table 2.

a) Available Nitrogen (kg ha^{-1}): Determination of available nitrogen was done by alkaline permanganate method suggested by Subbiah and Asija (1956) [6], which is based on extraction of inorganic and readily oxidizable nitrogen from inorganic compounds. The nitrogen was extracted with 0.32 per cent KMNO4, ammonia distilled by adding 2.5 per cent NaOH and absorbed in 2 per cent boric acid solution containing indicator. The ammonia absorbed was estimated titrimetrically using standard hydrochloric acid (0.02 HCL) Tandon (1995) [7].

b) Available Phosphorous (kg ha^{-1}): Available phosphorous was determined by Olsen's method Olsen *et al.* (1954) [5] using 0.5N $NaHCO_3$ as an extractant and develop blue colour using ascorbic acid Murphy and Riley (1962) [4]. The intensity of blue colour was recorded on 'Spectronic'- 20 spectrophotometer 108 at 730 nm.

c) Available Potassium (kg ha^{-1}): The available amount of potassium was determined by extraction with Neutral 1N ammonium acetate. The soil (5 g) was taken in 100 ml conical flask then 25 ml of neutral 1N ammonium acetate was added and shaked for 5 min and after that the contents were filtered through filter paper (Whatmann No. 1). The concentration of K was determined by Systronic -128 type flame photometer.

d) Available Micronutrients: The available cationic micronutrients (Fe, Mn, Zn and Cu) were extracted from soil by using DTPA extractant in 1: 2 ratio as per the procedure given by Lindsay and Norvell (1978) [1], and were determined by using atomic absorption spectrophotometer (Model varian spectra AA20) the contents of these micronutrients were expressed in mg kg^{-1} of soil.

Table 2: Reference and method of analysis

Parameters	Reference and method of Analysis
Available nitrogen (kg ha^{-1})	Alkaline permanganate method Subbiah and Asija (1956) [6]
Available phosphorous (kg ha^{-1})	Olsen's method Olsen *et al.* (1954) [5]
Available potassium (kg ha^{-1})	Flame photometer method Metson, (1956) [3]
Available micronutrients (mg kg^{-1})	Lindsay and Norvell (1978) [1]

Results and Discussion

Soil nutrient analysis

Macronutrients: The available N2, P2O5 and K2O were significantly influenced by the application of inorganic nutrients and biofertilizers. The results were presented in Table 3 and Fig.1

a) Soil available nitrogen (kg ha^{-1})

After harvest soil available nitrogen status was significantly influenced by the application of inorganic nutrients and biofertilizers and their combinations to the experiment soils. The highest post-harvest soil available nitrogen (202.60 kg ha^{-1}) was recorded in T_9 treatment (T_6 + Arka vegetable special @ 5 gm $litre^{-1}$). The lowest post- harvest soil available nitrogen (85.60 kg ha^{-1}) was recorded T_4 (25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg ha^{-1}).

b) Soil available phosphorous (kg ha^{-1})

Significantly maximum phosphorous (159 kg ha^{-1}) was recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 gm $litre^{-1}$) under the study while, minimum phosphorous content (62.30 kg ha^{-1}) was recorded in treatment T_4 (25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg ha^{-1}) (Table 3) respectively.

c) Soil available potassium (kg ha^{-1})

Significantly maximum potassium (316.60 Kg ha^{-1}) was recorded in treatment T_9 (T_6 + Arka Vegetable Special @ 5 gm $litre^{-1}$) and minimum potassium content in (106.00 kg ha^{-1}) was recorded in treatment T_1 (100 % RDF @ 100: 25: 50 kg ha^{-1}) results are presented in Table 3.

d) Micronutrients

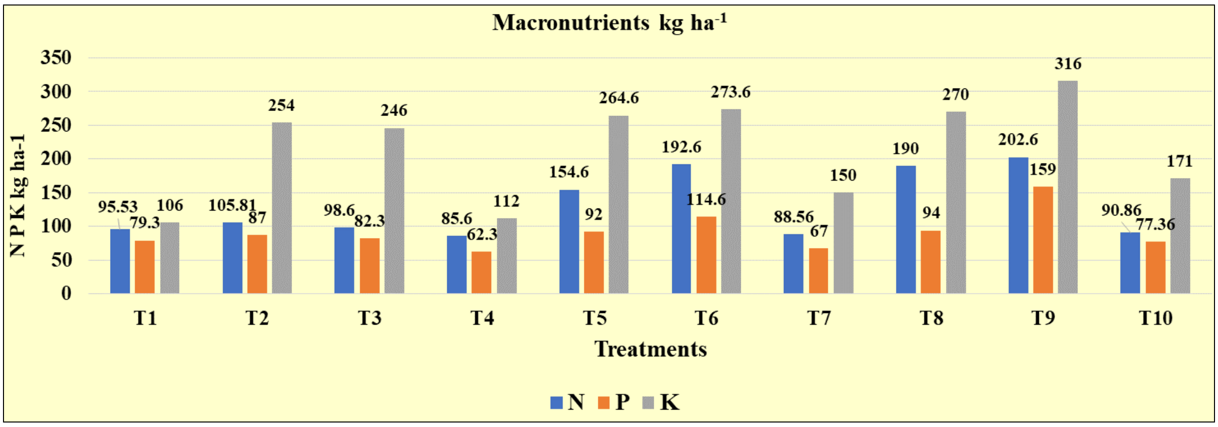
The data on micronutrients (Fe, Mn, Zn and Cu) were analyzed in the post-harvest soil samples and is given in Table 3 and depicted in Fig.2

Highest concentrations of Fe, Mn, Zn and Cu were obtained under treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (9.27, 9.59, 3.08 and 3.66 mg kg^{-1}) Lowest concentrations of Fe, Mn, Zn and Cu were obtained under T_1 (100% RDF @ 100: 25: 50 kg ha^{-1}) compared to rest of treatments (8.23, 9.11, 2.46 and 2.79 mg kg^{-1}).

The data on post-harvest soil analysis revealed meager changes. The post-harvest nutrient levels were more than the intial levels. It appears from the data that application of inorganic, biofertilizers and micronutrients might have been maximized the percentage of these nutrients Mathavan (2000) [2].

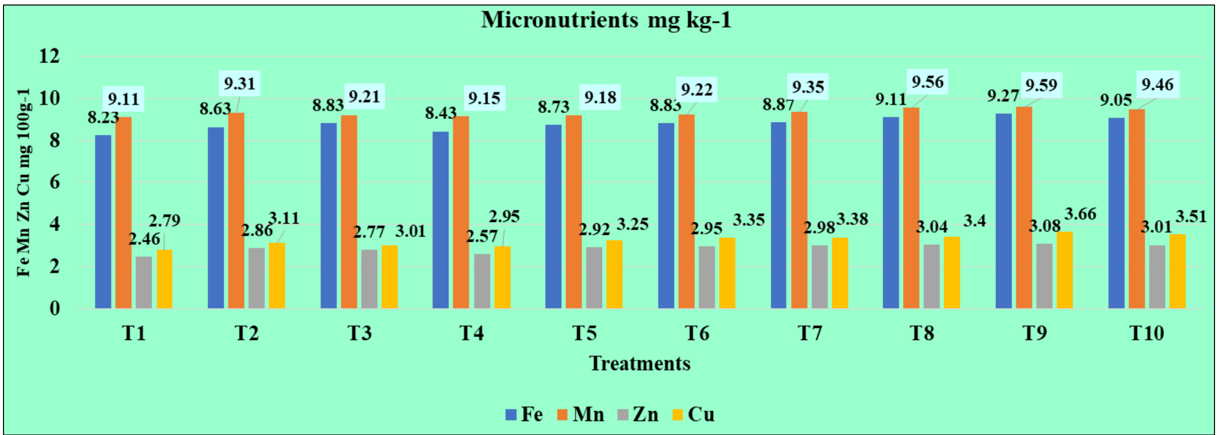
Table 3: Effect of inorganic nutrients and biofertilizers on soil after harvest of the crop

Treatments	Macronutrients (kg ha^{-1})			Micronutrients (mg kg^{-1})			
	N	P	K	Fe	Mn	Zn	Cu
T1 - 100 % RDF @ 100:25:50 kg/ha	95.53	79.30	106.00	8.23	9.11	2.46	2.79
T2 - 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)	105.81	87.00	254.00	8.63	9.31	2.86	3.11
T3 - 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	98.60	82.30	246.00	8.83	9.21	2.77	3.01
T4 - 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	85.60	62.30	112.00	8.43	9.15	2.57	2.95
T5 - 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	154.60	92.00	264.60	8.73	9.18	2.92	3.25
T6 - 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	192.60	114.60	273.60	8.83	9.22	2.95	3.35
T7 - 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	88.56	67.00	150.00	8.87	9.35	2.98	3.38
T8 - T5 + Arka vegetable special @ 5 g/litre	190.00	94.00	270.00	9.11	9.56	3.04	3.40
T9 - T6 + Arka vegetable special @ 5 g/litre	202.60	159.00	316.60	9.27	9.59	3.08	3.66
T10 - T7 + Arka vegetable special @ 5 g/litre	90.86	77.36	171.00	9.05	9.46	3.01	3.51
S.E (m) ±	0.73	0.97	1.33	0.09	0.03	0.03	0.03
CD at 5 %	2.16	2.89	3.97	0.27	0.09	0.09	0.09



T_1 - 100 % RDF @ 100:25:50 kg/ha
T_2 - 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)
T_3 - 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)
T_4 - 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)
T_5 - 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha
T_6 - 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha
T_7 - 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha
T_8 - T_5 + Arka vegetable special @ 5 g/litre
T_9 - T_6 + Arka vegetable special @ 5 g/litre
T_{10} - T_7 + Arka vegetable special @ 5 g/litre

Fig 1: Effect of inorganic nutrients and biofertilizers on macronutrients (kg ha^{-1}) in soil after harvest of the crop.



T_1 - 100 % RDF @ 100:25:50 kg/ha
T_2 - 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)
T_3 - 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)
T_4 - 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)
T_5 - 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha
T_6 - 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha
T_7 - 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha
T_8 - T_5 + Arka vegetable special @ 5 g/litre
T_9 - T_6 + Arka vegetable special @ 5 g/litre
T_{10} - T_7 + Arka vegetable special @ 5 g/litre

Fig 2: Effect of inorganic nutrients and biofertilizers on micronutrients (mg 100 g^{-1}) in soil after harvest of the crop

Conclusion

This study concludes that inorganic nutrients, biofertilizers and micronutrient application on spinach beet growth and soil nutrient dynamics revealed that a balanced approach can optimize soil fertility and crop productivity. The combined application of inorganic nutrients and biofertilizers improved soil nutrient availability, while micronutrient application enhanced spinach beet's growth parameters and nutrient uptake. The integrated approach mitigated the negative effects of inorganic nutrients on soil health, increased crop tolerance to abiotic stresses and optimized soil nutrient dynamics. Overall, the study concludes that a holistic nutrient management strategy, incorporating inorganic nutrients, biofertilizers and micronutrients is essential for sustainable spinach beet production, promoting soil health and reducing environmental degradation.

Acknowledgement

I extend my sincere thanks to COH, Rajendranagar for the opportunity to conduct my research. My gratitude goes to my advisory committee - Dr. M. Hanuman Nayak, Dr. P. Prasanth, A. Mamatha, and Dr. S. Praneeth Kumar - for their invaluable guidance. I am deeply thankful to my parents, S. Solomon Raj and S. Manjula, and my brother, S. Nihal Raj, for their support, as well as to my friends, juniors, and seniors for their encouragement.

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