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RESEARCH PAPER

Response of spinach (*Beta vulgaris* var. *bengalensis)* to integrated nutrient management practices under protected condition

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Abstract: An experiment was conducted at Hi-tech Horticulture Unit, MARS, Saidapur Farm, UAS, Dharwad during summer, 2021 to assess the effect of integrated nutrient management practices on growth and yield of spinach under protected condition**.** The treatments comprised of graded levels of recommended dose of fertilizers (100 %, 75 % and 50 % RDF) and graded levels of recommended dose of nitrogen (100 %, 50 % and 25 % RDN) applied through farm yard manure (FYM), vermicompost, neemcake (NC) and biofertilizers (*Azotobacter* and PSB). The results revealed that application of 50 % RDF + 50 % RDN applied through FYM and NC (2:1) + *Azotobacter* and PSB was found better for higher plant height, number of leaves and total yield (21.42 t/ha) and 75 % RDF + 25 % RDN through vermicompost and neem cake (2:1) + *Azotobacter* + PSB gave highest leaf area (152.27 cm^2).

Key words: Biofertiliser, Neem cake, Nitrogen, Spinach

Introduction

Spinach, also called as spinach beet or palak (*Beta vulgaris* var. *bengalensis*) belonging to Chenapodiaceae family with chromosome number 2n=2x=18 is a leafy vegetable of Indo-China origin. It has laxative property, rich in vitamin A and iron content. Spinach is commonly grown in all soil types and is one of the most popular leafy vegetables with good nutritive value. Spinach is also called as palak. Palak responds well to nutrient and fertilizer application. Extensive use of the chemical fertilizers will help in higher production of palak but also show detrimental effect on soil-living organisms which are useful and hence even decrease soil health, ecology and also natural resources over years. The price of chemical fertilizers is high and hence farmers also adopting use of alternate resources of nutrients to reduce depending on use of chemical fertilizers and start better conservation and utilization of natural resources. The use of bio fertilizers, organic manure *etc*., are the other sources of plant nutrients which apart from acting as manure also improves overall productivity of soil. Nurturing the soil will help in getting healthy diet for consumption.

The concept of Integrated Nutrient Management (INM) is defined as adjustment or maintenance of soil fertility and supply of nutrient 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 (Sharma *et al*., 2016). The combined use of chemical fertilizers, organic manures and bio-fertilizers will help in improving the quality traits of vegetables for better health. Use of organic manures like FYM, vermicompost and neem cake along with bio fertilizers with reduced levels of chemical fertilizers plays a vital role in achieving above said aspects. The cultivation of palak under protected condition help in off-season cultivation, due to congenial environment created inside the structure. Productivity of palak leaves will increase by 8-10 times than open field, with good marketable quality. Use of biofertilizers and organic fertilizers in crop cultivation will help in safeguarding the soil health, improvement in quality of the product, increase in crop yield, restores natural soil fertility and provides protection against drought and some soil borne diseases.

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, folic acid content in spinach (Alderfasi *et al.*, 2010).

Material and methods

A field experiment to assess the effect of integrated nutrient management on growth and yield of spinach was carried out in Hi-Tech Horticulture unit, Main Agricultural Research Station, Saidapur Farm, University of Agricultural Sciences, Dharwad in the summer season of 2021. The experiment comprised of 14 treatments (Table 1) and 2 replications which was laid out in a randomized block design. The spinach variety All-green was taken for present investigation. The 35 days old healthy seedlings of palak were transplanted on 1st April, 2021 at a spacing 45 x 30 cm in paired row system on a raised bed of 1 m width with 50 cm path between two beds prepared. Harvesting of green leaves was done weekly once or twice based on leaf yield and made into bunches. The treatments comprised of recommended dose of fertilizers at 80:60:60 kg/ha at graded levels along with graded levels of recommended dose of nitrogen (100 %, 50 % and 25 % RDN) applied through farm yard manure (FYM), vermicompost, neemcake (NC) and biofertilizers

Table 1. Treatment details

T_1	100 % RDF and FYM (Control)
T_2	75 % RDF + 25 % RDN through FYM and neem cake (2:1)
T_3	T_2 + *Azotobacter* + PSB
T_4	75 % RDF + 25 % RDN through vermicompost and neem cake (2:1)
T_5	T_4 + *Azotobacter* + PSB
T_6	50 % RDF + 50 % RDN through FYM and neem cake (2:1)
T_7	T_6 + *Azotobacter* + PSB
T_8	50 % RDF + 50 % RDN through vermicompost and neem cake (2:1)
T_9	T_8 + *Azotobacter* + PSB
T_{10}	75 % RDF + 25 % RDN through FYM, vermicompost and neem cake (2:2:1)
T_{11}	T_{10}+ *Azotobacter* + PSB
T_{12}	50 % RDF + 50 % RDN through FYM, vermicompost and neem cake (2:2:1)
T_{13}	T_{12} + *Azotobacter* + PSB
T_{14}	100 % RDN through FYM, vermicompost and neem cake (2:2:1) + *Azotobacter* + PSB

(*Azotobacter* and PSB). The 100 % RDN through organic manures needed 16000 kg/ha FYM (0.5 % N), 5333 kg/ha vermicompost (1.5 % N) and 2000 kg/ha neem cake (4 % N) when applied singly. It has been calculated according to ratios in treatment for the required plot size.

Results and discussion

Effect on plant height

Application of combination of 50 per cent of RDF, *Azotobacter* and PSB + 50 per cent of RDN through FYM and neem cake in the ratio of 2:1 (T_7), resulted in significantly higher plant height (41.23 cm) followed by T8 (36.84 cm). The minimum plant height was recorded in T_{12} (27.16 cm), which was on par with T_{14} (27.4 cm) and T_{13} (29.86 cm) at 45 days after transplanting. At 60 days after transplanting the Treatment T_7, receiving combination of 50 per cent RDF, *Azotobacter* and PSB + 50 per cent RDN through FYM and neem cake (2:1) resulted in plant height of 45.10 cm followed by T_{11}(43.45 cm). The minimum plant height was recorded in T_{14} (31.17 cm) and which is on par with T_{12} (32.01 cm) (Table 2). The application of inorganic manures along with organic manures and biofertilizers 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 biofertilizers helps in improving the uptake of nutrients by increasing the efficiency of nutrient availability to plants. The results were in agreement with the research findings of Revati *et al.* (2011) and Khadse *et al.* (2021) in spinach.

Effect on Number of leaves and leaf area

The data on number of leaves varied at different intervals are presented in table 3. At 45 days after transplanting combination of 50 per cent RDF + *Azotobacter* and PSB + 50 per cent RDN through FYM and neem cake (2:1) (T_7) resulted highest number of leaves (33.30) which was on par with T_6 (32.80) and T_5 (32.40). Minimum number of leaves were reported in T_4 (26.90) followed by T_{14} (28.20) and T_{10} (28.90). At 60 days

Table 2. Plant height as influenced by integrated nutrient management in spinach

Treatments	Plant height (cm) (DAT)	
	45	60
T_1- 100 % RDF and FYM (Control)	31.42	34.17
T_2- 75 % RDF + 25 % RDN through FYM and NC (2:1)	30.15	35.45
T_3- T_2 + AZT + PSB	32.29	36.77
T_4- 75 % RDF + 25 % RDN through VC and NC (2:1)	33.41	40.66
T_5- T_4 + AZT + PSB	32.87	39.29
T_6- 50 % RDF + 50 % RDN through FYM and NC (2:1)	32.13	36.17
T_7- T_6 + AZT + PSB	41.23	45.10
T_8- 50 % RDF + 50 % RDN through VC and NC (2:1)	36.84	41.95
T_9- T_8 + AZT + PSB	35.91	41.19
T_{10}- 75 % RDF + 25 % RDN through FYM, VC and NC (2:2:1)	35.81	41.87
T_{11}- T_{10} + AZT + PSB	36.72	43.45
T_{12}- 50 % RDF + 50 % RDN through FYM, VC and NC (2:2:1)	27.16	32.01
T_{13}- T_{12} + AZT + PSB	29.86	34.80
T_{14}- 100 % RDN through FYM, VC and NC (2:2:1) + *Azotobacter* + PSB	27.4	31.17
Mean	33.09	38.14
S. Em. ±	0.885	0.343
C.D. @ 5 %	2.703	1.047

DAT: Days after transplanting AZT: Azotobacter VC: Vermi compost FYM: Farm yard manure NC: Neem cake
PSB: P- solubilizing bacteria RDF: Rec. fertilizer (80:60:60 N: P: K kg/ha) RDN: Rec. Nitrogen

Table 3. Number of leaves and leaf area as influenced by integrated nutrient management in spinach

Treatments	Number of leaves at different stages (DAT)		Leaf area (cm^2)
	45	60	
T_1- 100 % RDF and FYM (Control)	29.60	28.10	132.95
T_2- 75 % RDF + 25 % RDN through FYM and NC (2:1)	30.90	29.40	143.23
T_3- T_2 + AZT + PSB	31.80	36.40	155.04
T_4- 75 % RDF + 25 % RDN through VC and NC (2:1)	26.90	27.70	154.40
T_5- T_4 + AZT + PSB	32.40	30.90	157.28
T_6- 50 % RDF + 50 % RDN through FYM and NC (2:1)	32.80	28.40	146.24
T_7- T_6 + AZT + PSB	33.30	34.90	152.27
T_8- 50 % RDF + 50 % RDN through VC and NC (2:1)	32.10	30.90	143.44
T_9- T_8 + AZT + PSB	31.00	32.70	149.02
T_{10}- 75 % RDF + 25 % RDN through FYM, VC and NC (2:2:1)	28.90	32.80	124.16
T_{11}- T_{10} + AZT + PSB	32.50	33.80	124.17
T_{12}- 50 % RDF + 50 % RDN through FYM, VC and NC (2:2:1)	30.80	33.70	117.75
T_{13}- T_{12} + AZT + PSB	31.50	35.00	117.30
T_{14}- 100 % RDN through FYM, VC and NC (2:2:1) + *Azotobacter* + PSB	28.20	31.00	107.33
Mean	30.91	31.82	137.47
S. Em.±	0.327	0.234	2.006
C..D @ 5 %	0.999	0.714	6.127

Table 4. Spinach leaf yield as influenced by integrated nutrient management

Treatments	Green leaf yield		
	(kg/ plant)	(kg/ sq. m)	(t/ha)
T_1- 100 % RDF and FYM (Control)	0.369	1.62	16.23
T_2- 75 % RDF + 25 % RDN through FYM and NC (2:1)	0.353	1.55	15.53
T_3- T_2 + AZT + PSB	0.367	1.62	16.16
T_4- 75 % RDF + 25 % RDN through VC and NC (2:1)	0.441	1.94	19.39
T_5- T_4 + AZT + PSB	0.431	1.90	18.97
T_6- 50 % RDF + 50 % RDN through FYM and NC (2:1)	0.465	2.05	20.48
T_7- T_6 + AZT + PSB	0.487	2.14	21.42
T_8- 50 % RDF + 50 % RDN through VC and NC (2:1)	0.409	1.80	18.00
T_9- T_8 + AZT + PSB	0.383	1.68	16.84
T_{10}- 75 % RDF + 25 % RDN through FYM, VC and NC (2:2:1)	0.391	1.72	17.21
T_{11}- T_{10} + AZT + PSB	0.372	1.64	16.38
T_{12}- 50 % RDF + 50 % RDN through FYM, VC and NC (2:2:1)	0.387	1.70	17.03
T_{13}- T_{12} + AZT + PSB	0.357	1.57	15.69
T_{14}- 100 % RDN through FYM, VC and NC (2:2:1) + *Azotobacter* + PSB	0.311	1.37	13.67
Mean	0.394	1.74	17.36
S. Em ±	0.003	0.013	0.126
C.D. @ 5 %	0.009	0.038	0.384

DAT: Days after transplanting AZT: Azotobacter VC: Vermi compost FYM: Farm yard manure NC: Neem cake
PSB: P- solubilizing bacteria RDF: Rec. fertilizer (80:60:60 N: P: K kg/ha) RDN: Rec. Nitrogen

after transplanting highest number of leaves found at Treatment T_3, receiving 75 per cent RDF added with 25 per cent RDN through FYM and neem cake in the ratio 2:2:1 (36.40) followed by T_{13} (35.00). The minimum were values recorded in T_4 (27.70) followed by T_1 (28.10). The organic, inorganic manures and biofertilizers in combination resulted in maximum number of leaves as compared to control. The works carried out earlier stated that the application of biofertilizers which improves secretion of growth promoting substances, might have led to improvement in nutrient uptake which directly influenced number of leaves. The results were in agreement with Koppad *et al*. (2019) in red cabbage and Khadse *et al.* (2021) in spinach.

Significantly highest leaf area was recorded in treatment T_5, receiving 75 per cent RDF + 25 per cent RDN through vermicompost and neem cake (2:1) + *Azotobacter* and PSB (157.28 cm^2) which was on par with T (155.04 cm^2) and T_4 (154.40 cm^2). The lowest values were found at T_{14} (107.33 cm^2) followed by T_{13} (117.30 cm) (Table 3). The increased leaf area might be due to added organics in integrated nutrient management which would have improved the physical, chemical and biological properties of soil which also helped the plant to better nutrient absorption and utilization by the plant. This might be due to the increased uptake of available major nutrients of the plant which results in the translocation of nutrients to the plant

part (Thampi and Vethamoni, 2019). The translocated minerals help in increasing cell division and cell elongation, which improves leaf size, thereby increasing leaf area. Khadse *et al.* (2021) also reported higher leaf area with integrated application of nutrients in spinach.

Effect on green leaf yield

The yield of spinach leaf was significantly influenced by integrated nutrient management treatments (Table 4). Treatment T_7, comprising application of 50 per cent RDF + 50 per cent RDN through FYM and neem cake in the ratio of 2:1 + *Azotobacter* and PSB recorded maximum leaf yield of 0.487 grams per plant followed by T_6 (0.465 g/plant). The lowest leaf yield was in T_{14} (0.311 g/plant) followed by T_2 (0.353 g/plant). The yield per square meter shown highest in T_7 (2.14 kg/sq.m) followed by T_6 (2.05 kg/sq.m). The lowest values found T_{14} (1.37 kg/sq.m) followed by T_2 (1.55 kg/sq.m). The maximum leaf yield per hectare was recorded in T_7 (21.42 t/ha) followed by T_6 (20.48 t/ha). The lowest was found at T_{14} (13.67 t/ha) followed T_2 (15.53 t/ha). The growth and yield of leaves have been affected by the nutrient sources in the inorganic and organic forms along with biofertilizers. 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 neem cake added release nutrient in slower rate for getting nutrients for a long period. The addition of neem cake also reduced attack of pest or diseases as it acts as both manure and insecticide also. The effect of *Azotobacter* have also made an impact on the yield of leaves of spinach. The mixture of all the nutrients have increased the plant growth regulators. The overall effect of organic and inorganic nutrients along with biofertilizers made a significant influence on yield of spinach. Manju *et al.* (2017) and Khadse *et al.* (2021) also reported higher spinach leaf yield with integrated nutrient management practices.

Conclusion

Based on the results it was concluded that application of different combination of nutrient sources was found to improve the growth and yield of spinach. Integrated application of 50 % RDF + 50 % RDN through FYM and neem cake (2:1) + *Azotobacter* + PSB was found optimum for better plant height, higher number of leaves and higher yield of spinach.

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