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Effect of foliar application of Nano nutrients on Growth, Yield and Qualitative attributes in Spinach beet (*Beta vulgaris* var. bengalensis Hort. cv. Arka Anupama)

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ABSTRACT

An experiment was carried out during December 2022 to February 2023 and November 2023 to January 2024 at Agricultural Experimental Farm, Baruipur, University of Calcutta, South 24 Parganas, West Bengal aimed to analyze the growth, qualitative and quantitative attributes of Spinach beet (*Beta vulgaris* var. *bengalensis* Hort. cv. Arka Anupama) utilizing selected macro and micro nano nutrients as foliar spray. The experiment comprised of 17 treatments and 3 replicates with the combinations C_1 (Nano Urea: 3ml, Nano DAP: 5ml and Nano ZnO: 1ml) and C_2(Nano Urea: 5ml, Nano DAP: 10ml, Nano ZnO: 2ml) including control. Obtained results from pooled data indicated that most of the quantitative as well as qualitative traits were superior in treatment T_8 {Nano DAP C_2+ Nano ZnO C_2+(50%N+ 50%P+100% K of RDF as basal fertilizer)}. At 30 DAS the leaf area (77.13sq cm) was highest for control (100% RDF with NPK dose of 50:25:25kg/ha)) whereas the number of leaves (6.88) and chlorophyll (38.06) was highest in T_8 while at 45 days after sowing significant increase in terms of plant height (28.87 cm), number of leaves (7.29), leaf length (21.78 cm) and leaf area (193.30 cm^2) were registered followed by control. Marketable leaf yield (100.90q/ha) was registered high in T_8. Qualitative estimates viz. protein content (3.63g) and ascorbic acid(71.12 mg) was high in T_8 while total carotenoid content (2.62mg per 100g of leaf) was high for treatment T_7 {Nano DAP C_2+Nano ZnO C_1+ (50%N+ 50%P+100% K of RDF as basal fertilizer)}. The least values for growth and yield parameters were observed in T_3 {Nano Urea C_1 +(50% N + 100% P + 100% K of RDF)}. Palak Spinach being a leafy vegetable with wider leaf surface area is a good model crop to study the infiltration of nano molecules and growth rate enhancement. Though our experiment perceives the benefits of foliar nano nutrients, further exploitation with respect to safety limits and efficacy under varied climatic factors needs to be worked out.

Key words: *Nano fertilizers, Growth, Yield, Quality, Spinach beet*

Introduction

Spinach Beet scientifically Known as *Beta vulgaris var bengalensis* also known as Palak, Indian Spinach belongs to the family Chenopodiaceae. This is an annual plant and is popular due to its nutritional value. Spinach Beet is a rich source of vitamins, minerals, and dietary fibre. It plays an important role in the human diet due to the presence of Vitamin A, Vitamin C, Thiamin and Riboflavin content. It is also a rich source of iron and calcium as well as antioxidants such as carotene (Vethamoni and Thampi,

2018). Spinach Beet being a very short-duration leafy vegetable can be incorporated as an intercrop in various crop rotations. Presently farmers are using excess of chemical fertilizers for realizing quick and luxuriant growth to increase the yield, at the cost of quality and poor shelf life besides contaminating the air, soil and surface water which directly or indirectly affects human health. Eco friendly based fertilizer management is essential in mitigation of this harmful fertilizer usage.

To overcome this problem, nano technology based fertilizer seems promising. Reports till now suggests the usage of nano fertilizers in boosting plant nutrition along with healthy food, as compared to traditional fertilizers. Nano fertilizers have gained attention due to their power to increase crop yields, positivity to soil fertility, improving nutrient use efficiency and trimming down pollution. Nano fertilizer technique finds its immense scope in precision agriculture where the nutrients are applied at specific locations preventing the wastage of fertilizers. Several researchers have found that nano fertilizers usage in agriculture increases crop yield, decreases nutrient losses, decreases the chances of diseases by avoiding over-fertilization and improves the soil and environmental health. Foliar application of the nano fertilizers also improved the nutrient uptake and it is readily absorbed by plant systems due to their small size (less than 100nm). Further, the nano fertilizer releases nutrients into the plant gradually and in a controlled way and increases the yield in the plant. The present investigation was aimed to study the effect of selected macro and micro-nano nutrients in spinach beet.

Materials and Methods

An experiment was carried out during December 2022 to February 2023 and November 2023 to January 2024 at Agricultural Experimental Farm, Baruipur, University of Calcutta, South 24 Parganas located at 88.4325°′ East longitude 22.3599°′ North latitude and 9.75m (30 ft) above mean sea level. Soil of the experimental farm was well-drained, medium fertile, loamy to clay loam texture with pH 6.8. The experiment comprised 17 treatments with the combinations C_1 (Nano Urea: 3ml, Nano DAP: 5ml and Nano ZnO: 1ml) and C_2(Nano Urea: 5ml, Nano DAP: 10ml, Nano ZnO: 2ml) along with (50% N + 50% P + 100% K) of RDF or (50% N + 100% P + 100% K) of RDF (NPK ratio of 50:25:25) as basal fertilizer application excluding control.

The treatment details are as follows

T_1	Nano $DAPC_1$+(50% N + 50% P + 100% K) of RDF as Basal fertilizer Application
T_2	Nano $DAPC_2$ +(50% N + 50% P + 100% K) of RDF as Basal fertilizer Application
T_3	Nano Urea C_1 +(50% N + 100% P + 100%) K of RDF as Basal fertilizer Application
T_4	Nano Urea C_2 +(50% N + 100% P + 100% K) of RDF as Basal fertilizer Application
T_5	DAP Nano DAP C_1+ Nano ZnO C_1+(50% N +50% P + 100% K) of RDF as Basal fertilizer Application
T_6	DAP Nano DAP C_1+ Nano ZnO C_2+(50% N + 50% P + 100% K) of RDF as Basal fertilizer Application
T_7	DAP Nano DAP C_2+ Nano ZnO C_1+(50% N + 50% P + 100% K) of RDF as Basal fertilizer Application
T_8	DAP Nano DAP C_2+ Nano ZnO C_2+(50% N + 50% P + 100% K) of RDF as Basal fertilizer Application
T_9	Nano Urea C_1+ Nano ZnO C_1 + (50% N + 100% P + 100% K) of RDF as Basal fertilizer Application
T_{10}	Nano Urea C_1+ Nano ZnO C_2+ (50% N + 100% P + 100% K) of RDF as Basal fertilizer Application
T_{11}	Nano Urea C_2+ Nano ZnO C_1 + (50% N + 100% P + 100% K)of RDF as Basal fertilizer Application
T_{12}	Nano Urea C_2+ Nano ZnO C_2 + (50% N + 100% P + 100% K) of RDF as Basal fertilizer Application
T_{13}	Granular DAP 2% + 50%RDF
T_{14}	Granular Urea 1% + 50%RDF
T_{15}	Granular DAP 2% + 50%RDF + 0.2% $ZnSO_4$
T_{16}	Granular Urea 1% + 50%RDF + 0.2% $ZnSO_4$
T_{17}	Control (RDF)

Note: RDF- Recommended dose of fertilizer

The experiment was laid out in randomized block design (RBD) having three replicates of each treatment. Recommended dosage of synthetic fertilizer (RDF) was incorporated as per treatment combinations, nitrogen was administered in the form of urea, phosphorus in the form of diammonium phosphate (DAP) and potassium in the form of muriate of potash (MOP). The variety Arka Anupama, obtained from ICAR Indian Institute of Horticultural Research, Bengaluru, India was taken as a test variety. Plot size of one sqm area was designated for each treatment. The seeds were sown at a distance of 10cm between plant to plant and 20 cm between row to row. The nano fertilizer was sprayed at 15 DAS (Days after sowing). Observations were recorded from five tagged healthy plants per treatment per replication on growth and yield parameters viz. plant height, number of leaves, leaf length, leaf area and total fresh yield/plot, recorded at 30

and 45 DAS. The quality parameters of palak leaves viz., total chlorophyll content (Arnon, 1949), ascorbic acid content (AOAC. 2007), total carotenoids (Jensen, 1971), and protein (Lowry, 1951) were analyzed as per standard protocol on the 45th day after sowing baring total chlorophyll content which was also estimated on the 30th DAS. Benefit: cost ratio was calculated by dividing gross return by cost of cultivation.

Statistical analysis was performed following Panse and Sukhatme's (1987) recommendations for Randomized Block Design. Online Statistical tools OPSTAT and WAP-I from ICAR, CCARI, Goa were utilized for computation.

Results and Discussion

The findings pertaining to the stated characters have been enlisted in Table 1 (30 DAS) and Table 2 and 3 (45 DAS). The cost benefit ratio have been presented in Table 4 and 4(a).

Plant Height

The pooled mean data presented in Table 1 indicated that mean plant height of (13.26) was significantly higher in treatment T_{13}which was at par with all the treatments except T_9 and T_{10} at 30 DAS whereas treatment T_8 at 45 DAS exhibited highest plant height (28.88cm) and was at par with T_7(Table 2). Significant increase in plant height may be attributed to beneficial effects of nanoparticles which have high reactivity because of more specific surface area, more density of reactive areas or increased reactivity of these areas on the particle surfaces. The increased plant height might also be due to the adequate supply of zinc which accelerated the activity of several enzymes and chlorophyll content thereby increasing auxin metabolism in the plant system (Nithya *et al.,* 2018). Moreover, nano DAP meets the immediate requirement of nitrogen and phosphorus. It triggers the enzymatic activity and protein assimilation pathways that lead to significant enhancement in biomass production and crop growth rate. The findings corroborated with the findings of Singh *et al.* (2021), Kaundal *et al.* (2024).

Table 1. Effect of nano fertilizers on the number of leaves, leaf area (sq cm), chlorophyll, Leaf Length and plant height at 30 DAS of the Palak var. 'Arka Anupama'

Treatment	Plant height (cm)			Number of leaves			Leaf Length (cm)			Leaf area (sq cm)			Total chlorophyll(mg/g)		
	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean
T_1	13.327	12.66	12.993	6.22	5.167	5.693	6.867	6.827	6.847	46.69	42.25	44.47	25.607	33.05	29.328
T_2	13.427	11.923	12.675	7.213	4.917	6.065	10.063	8.793	9.428	60.56	82.717	71.638	37.133	37.567	37.35
T_3	11.587	11.847	11.717	5.85	5.467	5.658	6.593	6.523	6.558	43.53	64.36	53.945	27.19	24.47	25.83
T_4	11.95	11.403	11.677	6.72	5.72	6.22	7.91	7.593	7.752	53.26	78.973	66.117	29.417	28.447	28.932
T_5	12.123	11.3	11.712	6.32	5.82	6.07	7.05	7.17	7.11	47.25	43.607	45.428	29.78	30.41	30.095
T_6	12.973	13.44	13.207	6.33	5.933	6.132	7.257	7.34	7.298	50.43	64.947	57.688	30.513	34.803	32.658
T_7	13.47	11.65	12.56	6.997	5.993	6.495	10.183	9.13	9.657	62.4	50.65	56.525	37.767	32.27	35.018
T_8	13.513	12.617	13.065	7.133	6.633	6.883	11.293	9.85	10.572	64.86	89.4	77.13	38.7	37.433	38.067
T_9	11.443	10.343	10.893	5.967	4.717	5.342	6.713	6.763	6.738	44.67	54.27	49.47	24.073	27.853	25.963
T_{10}	11.777	9.497	10.637	6.123	5	5.562	6.807	7.04	6.923	46.07	44.7	45.385	24.627	29.527	27.077
T_{11}	12.747	12.747	12.747	6.273	5.867	6.07	9.19	8.603	8.897	56.36	68.27	62.315	31.09	29.65	30.37
T_{12}	13.66	10.947	12.303	6.397	5.907	6.152	9.64	8.873	9.257	57.91	61.15	59.53	31.89	23.843	27.867
T_{13}	12.89	13.647	13.268	6.367	5.857	6.112	8.85	7.81	8.33	53.97	71.55	62.76	30.557	29.737	30.147
T_{14}	12.277	10.27	11.273	6.263	5.61	5.937	7.463	8.13	7.797	51.36	52.063	51.712	28.133	27.73	27.932
T_{15}	12.937	10.753	11.845	6.103	5.823	5.963	8.93	7.65	8.29	54.81	54.037	54.423	30.883	27.15	29.017
T_{16}	12.347	13.667	13.007	6.647	5.667	6.157	7.643	9.97	8.807	52.9	55.593	54.247	28.927	35.817	32.372
T_{17}	14.1	13.9	14	7.267	5.887	6.577	9.84	7.537	8.688	59	87.247	73.123	36.683	35.627	36.155
CD at 5%	1.391	1.704	2.017	0.9	1.677	1.033	1.313	1.161	3.087	6.13	7.897	9.169	5.556	3.473	6.01

Number of leaves

In a similar manner treatment T_8 recorded highest pooled mean data for number of leaves (6.88) at 30 DAS and (7.28) at 45 DAS .T_8 was at par with all the treatments except T_1,T_3,T_9 and T_{10} at 30DAS (Table 1) where as at 45 DAS, T_8 was at par with T_2,T_6,T_7, T_{11},T_{13},T_{16} and T_{17} (Table 2). Basal application of chemical fertilizers along with or without the foliar application of nano DAP enhanced the photosynthetic activity in most of the plants which ultimately led to the accumulation of photosynthates and also increased activity of enzymes and auxin metabolism in plants leading to taller plants and more number of nodes and leaves. Our results validate the findings of Prakash *et al.* (2023) in soybean and Kaundal *et al.* (2024) in maize.Similar set of results were expressed by Yuvakumar *et al.* (2011) and Kurdekar (2021) in maize and aerobic rice respectively.

Leaf Length

Leaf length at 30 DAS was highest (10.57cm) for T_8 and was at par with T_2,T_4, T_7,T_{11},T_{12},T_{13},T_{14},T_{15},T_{16} and also with control (Table 1). Same trend for leaf length (21.68cm) was recorded under T_8 at 45 DAS followed by T_7 (Table 2). The minimum leaf length(6.55cm) was found in T_3 at 30 DAS whereas it was T_{10} at 45DAS (14.3cm). Adequate flush of nutrients can lead to an increase in the rate of cell division and elongation as agreed upon by Buzeaa *et al*. (2007). It seems that with aging of the plant Zn ions may have played a greater role in enhancing the cation exchange capacity of the roots which in turn supported higher nutrient up take and equally an uprise in IAA content that have sustained the leaf length increase in T_8 over a longer period.

Leaf Area

Leaf area was highest (77.13 cm^2) in T_8 at 30DAS which was synonymous with T_2 and T_{17} (control) as depicted in Table 1 while at 45 DAS T_8 continued its trend and the leaf area stood at 193.30$cm^2$and was observed to be at par with T_2,T_4,T_7,T_{11},T_{13} and T_{17} (Table 2). The minimized particle size of the nano particles increased fertilizer's specific surface area and particle count per unit area, which led to a significant increase in the leaf area index. Kaundal *et al.* (2024) found

Table 2. Effect of nano fertilizers on the plant height (cm), number of leaves and leaf length (cm) of the Palak var. 'Arka Anupama'at 45 DAS

Treatments	Plant height (cm)			Number of leaves			Leaf length (cm)			Leaf Area (sq cm)			Fresh yield (q/ha)		
	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean
T_1	20.68	19.40	20.04	6.57	5.90	6.24	16.13	17.33	16.73	172.84	155.10	163.97	74.51	78.68	76.60
T_2	30.35	19.23	24.79	7.36	6.04	6.70	20.42	14.88	17.65	197.87	171.16	184.51	76.74	79.73	78.24
T_3	19.27	17.72	18.50	6.26	5.74	6.00	14.58	15.30	14.94	165.73	180.80	173.27	81.37	57.02	69.19
T_4	22.69	16.91	19.80	6.83	6.05	6.44	18.53	15.04	16.79	182.87	181.39	182.13	83.12	71.53	77.33
T_5	21.15	19.90	20.53	6.59	6.11	6.35	16.42	15.87	16.15	175.08	175.51	175.29	83.89	82.43	83.16
T_6	21.37	22.20	21.79	6.65	6.55	6.60	16.59	17.66	17.13	176.71	178.23	177.47	87.69	85.40	86.55
T_7	29.64	24.35	27.00	7.50	6.67	7.08	20.26	21.01	20.64	193.79	181.09	187.44	104.02	92.08	98.05
T_8	32.63	25.12	28.88	7.38	7.20	7.29	22.14	21.42	21.78	203.76	182.84	193.30	107.44	94.37	100.90
T_9	19.54	14.34	16.94	6.55	5.29	5.92	15.66	13.31	14.49	168.04	143.63	155.84	95.40	83.95	89.68
T_{10}	19.70	16.06	17.88	6.53	6.13	6.33	15.83	12.77	14.30	172.52	174.88	173.70	97.55	85.35	91.45
T_{11}	26.54	19.33	22.94	6.68	6.33	6.51	19.46	16.69	18.07	188.60	181.16	184.88	98.07	67.75	82.91
T_{12}	28.55	19.68	24.12	6.71	6.13	6.42	19.90	17.17	18.54	192.20	165.66	178.93	99.76	67.20	83.48
T_{13}	24.42	20.22	22.32	6.86	6.26	6.56	18.79	15.96	17.38	185.00	181.59	183.30	93.65	69.02	81.33
T_{14}	21.88	17.29	19.58	6.59	5.99	6.29	16.86	13.53	15.20	177.07	174.94	176.00	92.57	67.22	79.89
T_{15}	25.76	17.36	21.56	6.48	6.00	6.24	19.23	12.89	16.06	186.87	154.40	170.64	100.73	71.40	86.06
T_{16}	22.46	20.68	21.57	6.98	6.20	6.59	17.23	17.75	17.49	178.55	177.80	178.17	101.89	79.77	90.83
T_{17}	31.02	19.34	25.18	7.32	6.13	6.73	20.90	16.60	18.75	201.81	164.24	183.03	103.08	89.02	96.05
CD st 5%	2.82	1.53	2.95	0.72	0.56	0.84	1.63	1.97	2.35	9.92	9.96	12.89	5.22	10.96	11.14

similar findings in maize. An adequate supply of nano nutrient and nano zinc at the right concentration might have helped in production of more number of leaves due to reduced competition among the plants for nutrients, which in turn helped to achieve higher leaf area (Fathi *et al.,* 2017).

Total Fresh Yield

Among various treatments, the pooled mean data for total fresh yield was highest (100.90 q/ha) for T_8 given in Table 2 and was at par with T_7,T_{10},T_{16}, and T_{17}(control). Least yield (69.19q/ha) was recorded in treatment T_3. Foliar application of Nano DAP resulted in better plant growth due to a higher accumulation of photosynthates with an increase in photosynthetic rate and ultimate increase in yield. Compared to the conventional fertilizers, nanofertilizers exhibit higher surface area thus enabling more sites for various metabolic processes in the plant system. As spinach beet is a leafy vegetable crop having ample moisture content, the photosynthetic rate enhancement lowers the CO_2 concentration and transpiration loss which helps in better moisture retention. The results do suffice the findings of Bhawna Aatkurwar *et al.* (2024) in rice. Nano DAP meets immediate requirement of nitrogen and phosphorus, triggeres the enzymatic activity and protein assimilation pathways that led to significant enhancement in biomass production as well as crop growth rate. The increase in yield attributes could be due to supplementation of nutrients at the critical stages of crop growth without physiological stress.

Protein content

The pooled mean data presented in Table 2 indicated that highest protein content of 3.632% was observed in T_8 which was at par with all the treatments. T_{11} had the least protein content of 2.67%. Greater availability of N and P and regular supply of metabolites for protein synthesis improved translocation of nutrients from source to sink which ultimately increased protein content. As nitrogen and phosphorus were available in sufficient amounts through RDF and foliar application of nano DAP, it increased the synthesis of amino acids which ultimately lead to increased protein content. Nano DAP being a slow release fertilizer had a balancing act between N and P components which provided the plants a synchronized uptake of nutrients and improved the protein content. Similar observations have been recorded by Burhanand AL-Hassan (2019) in wheat when the crop was sprayed with nano Phosphorous fertilizer@90mg/ l. Dhansil *et al*. (2018) in pearl millet, Duraisamy and Mani (2001) in horse gram and Nget *et al*. 2020 in soyabean filed similar reports with respect to enhancement in pro-

Table 3. Effect of nano fertilizers on the Chlorophyll, Protein, Ascorbic Acid and Total Carotenoid content of the Palak var. 'Arka Anupama'

Treatments	Protein Content (%)			Asccorbic Acid (mg/100g)			Total Carotenoids (mg/100g)			Chlorophyll at 45 DAS (mg/g)		
	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean
T_1	3.3	2.547	2.923	57.57	62.33	59.95	2.35	2.39	2.37	23.97	24.18	24.08
T_2	3.35	3.637	3.493	75.51	62.50	69.01	2.71	2.95	2.83	32.68	29.70	31.19
T_3	3.26	2.407	2.833	62.44	50.00	56.22	1.82	1.98	1.90	24.45	23.66	24.06
T_4	3.32	2.87	3.095	63.49	62.70	63.10	2.12	2.25	2.19	28.59	17.64	23.11
T_5	3.4	2.74	3.07	67.18	55.00	61.09	2.31	2.30	2.31	27.89	18.05	22.97
T_6	3.55	2.533	3.042	69.98	56.25	63.12	2.46	2.70	2.58	28.00	21.65	24.82
T_7	3.61	3.22	3.415	71.84	68.58	70.21	2.58	2.66	2.62	32.38	28.88	30.63
T_8	3.647	3.617	3.632	77.74	64.50	71.12	2.62	2.54	2.58	34.27	27.02	30.64
T_9	2.767	2.693	2.73	73.62	52.08	62.85	1.83	1.80	1.82	25.37	24.84	25.11
T_{10}	2.9	3.493	3.197	75.24	46.87	61.06	2.21	2.14	2.18	27.01	27.88	27.45
T_{11}	3.057	2.283	2.67	60.70	64.25	62.48	2.24	2.38	2.31	29.95	21.98	25.97
T_{12}	2.773	2.95	2.862	75.93	61.17	68.55	1.99	1.97	1.98	28.89	14.37	21.63
T_{13}	2.817	3.05	2.933	76.27	55.00	65.63	2.12	2.41	2.27	30.34	22.73	26.53
T_{14}	2.933	2.833	2.883	76.86	51.25	64.06	2.11	2.13	2.12	27.33	26.16	26.75
T_{15}	2.977	3.12	3.048	77.18	54.17	65.67	1.92	1.83	1.87	29.95	26.22	28.09
T_{16}	3.023	2.48	2.752	77.59	58.50	68.05	1.96	2.07	2.01	27.60	23.22	25.41
T_{17}	2.787	3.43	3.108	70.59	59.91	65.25	2.58	2.60	2.59	33.11	19.54	26.33
CD at(0.05)	0.234	0.62	1.112	4.48	8.12	8.50	0.304	0.38	0.447	5.69	3.19	5.98

tein content.

Ascorbic acid

The pooled mean data of ascorbic acid as presented in Table 3 revealed T_8 had the highest mean value of 70.21 mg/100 g of ascorbic acid which was at par with most of the treatments baring T_1, T_3, T_5, T_{10} and T_{11}. Least ascorbic acid content of 56.22 mg /100 g was recorded in the treatment T_3. Due to presence of Zinc there may be an increase in the ascorbic acid content as zinc plays a very vital role in many enzymatic reactions. Zn plays a vital role as a cofactor for several enzymes like superoxide dismutase, alcohol dehydrogenase and RNA polymerase as well as an important structural component which alleviates different physio-biochemical processes in plants such as photosynthetic rate , carbohydrate and protein metabolism and nutrient uptake in plants. Besides it helps the plants to evade biotic and abiotic stresses through increase in ascorbic acid levels.

Total Carotenoid Content

The pooled mean data for carotenoids indicated significant influence by application of inorganic fertilizers. The carotenoid content was highest (2.83mg/100g) for T_2 which showed similarity with T_6, T_7, T_8 and T_{17} (Table 3). The lowest carotenoid was found in T_3. The absorption of nano nutrients helps in contributing to improvement in carotenoid content. This might be due to the application of liquid Nano DAP which helped in phosphorous solubilization and stimulated the plant growth hormones providing better nutrient uptake and increased biosynthesis of biochemicals of the plant. Further, carotenoids are present in both primary and specialized metabolites and delivers specific functions. Similar findings on enhancement of carotenoids through use of nano fertilizers have been reported by Mahmoud *et al*. (2019) in red radish through nano ZnO and Siddiqui *et al.* (2019) in tomato through nano SiO_2 application, both of which are micronutrients. Use of ZnO too along with DAP may have a role to play as supported by the works of Tondey *et al.*, 2021 who observed an increase in carotenoid content in maize when seed was primed with nano ZnO solution. Zn in presence of N and P interferes in the structural and catalytic component of proteins and enzymes and plays a pivotal role in pigment biosynthesis and overall photosynthetic activation.

Chlorophyll content

The chlorophyll content of the leaves in Spinach beet was influenced by nano nutrients. The pooled mean data for chlorophyll content was highest (38.06mg/g) at 30 DAs for T_8 which showed resemblance with T_2, T_6, T_7, T_{16} and T_{17} at 30 DAS (Table 1). But at 45 DAS pooled mean data was highest for T_2 which was at par with most of the treatments except T_1, T_3, T_4, T_5, T_6, T_9 and T_{12} given in Table 3. The lowest chlorophyll was found in treatment T_3. The increase in chlorophyll content could be attributed to increased N content in the leaves which is a constituent of chlorophyll pigment thus leading to enhanced synthesis of chlorophyll. It is hypothesized that ZnO nanoparticles are involved in the enhancement of transcription and translational increase in chlorophyll content in plants and overall the photosynthetic rate.

Cost Benefit Ratio

The maximum net return was with T_8. It was Rs.1,05.680 in 2023 whereas in 2024 the maximum net return was Rs. 86,080 (Table 4 and 4a). Similarly, the B:C ratio was also highest for T_8 having 2.91 in

Table 4. Economic Analysis of Cost of Cultivation and Benefit Cost Ratio of Spinach Beet in Response to Nano Nutrient Applications

SL No	Particular activity	Number	Rate	Amount
1	Cleaning of Land	5	@300	1500
2	Field preparation by Tractor	5hr	@800/hr	4000
3	Preparation of Bed, Bund and water channel	15	@300	4500
4	Sowing of Seeds	20	@300	4500
5	Irrigation	10	@300	3000
6	Intracultural operations	40	@300	12000
7	Harvesting,cleaning	40	@300	12000
8	Seed	15kg	@400	6000
9	Pesticides(fungicide)	5kg	@700	3500
			Total	51000

Table 4(a). Treatment cost per hectare area of Spinach beet

S. No.	Treatment	Treatment cost	Common Cost (Per ha.)	Total Cost (per ha.)	2022-23 Avg yield (q/ha)	2022-23 Gross Return /ha	2022-23 Net Return /ha	2022-23 B:C ratio	2023-24 Avg yield (q/ha)	2023-24 Gross Return /ha	2023-24 Net Return /ha	2023-24 B:C ratio	Mean B: C ratio
1	T_1	2875	51000	53875	83.12	124680	70805	2.31	78.68	118020	64145	2.19	2.25
2	T_2	4075	51000	55075	103.08	154620	99540	2.81	79.73	119595	64520	2.17	2.49
3	T_3	2600	51000	53600	74.51	111765	58160	2.09	57.02	85530	31930	1.60	1.84
4	T_4	2780	51000	53780	95.40	143100	89320	2.66	71.53	107295	53515	2.00	2.33
5	T_5	3075	51000	54075	83.89	125835	71765	2.33	82.43	123645	69570	2.29	2.31
6	T_6	3275	51000	54275	87.69	131535	77260	2.42	85.40	128100	73825	2.36	2.39
7	T_7	4275	51000	55275	104.02	156030	100755	2.82	89.02	133530	78255	2.42	2.62
8	T_8	4475	51000	55475	107.44	161160	105680	2.91	94.37	141555	86080	2.55	2.73
9	T_9	2800	51000	53800	76.74	115110	61315	2.14	83.95	125925	72125	2.34	2.24
10	T_{10}	3000	51000	54000	81.37	122055	68055	2.26	85.35	128025	74025	2.37	2.32
11	T_{11}	2980	51000	53980	99.76	149640	95665	2.77	67.75	101625	47645	1.88	2.33
12	T_{12}	3180	51000	54180	100.73	151095	96910	2.79	67.20	100800	46620	1.86	2.32
13	T_{13}	1700	51000	52700	97.55	146325	93630	2.78	69.02	103530	50830	1.96	2.37
14	T_{14}	1680	51000	52680	92.57	138855	86170	2.64	67.22	100830	48150	1.91	2.27
15	T_{15}	1750	51000	52750	98.07	147105	94360	2.79	71.40	107100	54350	2.03	2.41
16	T_{16}	1700	51000	52700	93.65	140475	87770	2.67	79.77	119655	66955	2.27	2.47
17	T_{17}	2500	51000	53500	101.89	152835	99340	2.86	92.08	138120	84620	2.58	2.72

2023 and 2.73 in 2024. A minimum net return of Rs 58,160 and Rs 31,930 was found in treatment T_3 during 2023 and 2024 respectively. The highest net return was due to higher growth and productivity which might be due to higher doses of nano DAP and nano zinc. Kumar *et al.* (2014) concluded that 50 percent of recommended nano fertilizers as nano rock phosphate recorded significantly the highest B:C ratio of rice crop followed by 100 percent recommended NPK without nano fertilizers.

Conclusion

The growth and yield parameters viz., plant height, number of leaves, leaf length, leaf area, yield of fresh weight of leaves per hectare were found to be highest in T_8 and minimum in T_3 as basal fertilizer application. This finding indicated that Nano DAP with Nano ZnO has a positive effect on the growth parameters and yield of Palak.

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