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RESEARCH ARTICLE

Effect of fertilizer and organic carbon source combined with foliar spray of nano zinc and seaweed extract on growth and yield of Red bhendi

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Abstract

An experiment was Carried out at farmer's field in Sivapuri village, Chidambaram taluk, Cuddalore district, Tamil Nadu during January-April, 2023 to examine the effects of fertilizer andorganic carbon source with foliar spray of nano zinc and seaweed extract on growth and yield of red bhendi (*Kashi Lalima* var VROR 157). Kashi Lalima is a red okra variety released by IIVR, Varanasi, in 2019. The fruits are reddish-purple in color and exhibits tolerance to yellow vein mosaic disease and okra leaf curl virus. Red-fruited okra has received much attention from consumers due to its appealing color and health-promoting constituents. The experiment was laid in randomized block design (RBD) with three replications. The treatments included,T_1 - control, T_2 - 100 % RDF, T_3 – 100 % RDF + nano zinc @ 0.1 % (3 times FS), T_4 - 100 % RDF + SWE @ 2.5 % (3 times FS), T_5 – 100 % RDF + OCS @ 2.5 t ha^{-1}, T_6 - 100 % RDF + OCS @ 5.0 t ha^{-1}, T_7 - 100 % RDF + OCS@ 2.5 t ha^{-1}+ nano zinc @ 0.1 % (3 times FS), T_8 - 100 % RDF + OCS @ 5.0 t ha^{-1} + nano zinc @ 0.1 % (3 times FS), T_9 - 100 % RDF + OCS @ 2.5 t ha^{-1} + SWE @ 2.5 % (3 times FS), T_{10} - 100 % RDF + OCS @ 5.0 t ha^{-1} + SWE @ 2.5 % (3 times FS). The result showed that treatment T_8 - 100 % RDF + OCS @ 5.0 t ha^{-1} + nano zinc @ 0.1 % (3 times FS) was the most effective exhibiting better growth, yield, yield attributes and quality characters.

Keywords: foliar spray; growth; nano zinc; organic carbon source; red bhendi; yield

Introduction

Okra, *Abelmoschus esculentus* (L.) Moench, is a member of the Malvaceae family. It is an annual vegetable crop widely cultivated in tropical and subtropical parts of the world. All parts of the plant, like fresh leaves, buds, flowers, pods, stems and seeds can be used for different purpose making it is a multipurpose crop (1). Okra is recommended for consumption by World Health Organisation due to its disease- fighting abilities. Although, inorganic fertilizers boost crop yields, their ecessive use can harm arable land quality due to soil depletion, environmental pollution, and nutrient deterioration (2). At this juncture, there is an urgent need to optimize nutrient recycling to sustain crop production, preserve soil health and protect environment from pollution. To overcome this, scientists prefer biologically dynamic and sustainable farming practices, emphasizing the judicious use of organic fertilizers with chemical fertilizers to augment productivity. Soil organic carbon plays a crucial role in nutrient retention and crop productivity, especially in weathered and nutrient-poor tropical soils, as it serves as a reservoir for nutrients (3).Organic carbon sources, owing to their high carbon content, wide surface area, and cation exchange capacity, are widely utilized in soil carbon sequestration, soil restoration, and water pollution remediation (4). Seaweeds are macroscopic, multicellular marine algae commonly found in coastal regions of the oceans world-wide. The application of seaweed extract as an organic biostimulant is increasingly being accepted as an effective practice to enhance crop production (5). When applied as a foliar spray, it rejuvenates leaves, stimulate photosynthesis, result in higher yields (6). Nanotechnology is the design, characterization, production and application of structures, devices and systems by controlling shape and size at nanoscale (7). Zinc is a vital micronutrient for plant growth, playing a critical role in the regulation of indole acetic acid, chlorophyll synthesis, carbohydrate formation, and cytochrome biosynthesis. This enables plant survival and the maintenance of plasma membrane integrity (8). Nano zinc, due to its small size, easy solubility, and ease of diffusion, is expected to efficiently provide zine to plants, thereby addressing their nutritional needs and deficiencies in crop plants. Hence, the present study was carried out to investigate the effects of fertilizer, an organic carbon source with foliar spray of nano zinc and seaweed extract on the growth and yield of red bhendi.

Materials and methods

A field experiment was carried out during January-April, 2023 at a farmer's field in Sivapuri village, Chidambaram taluk, Cuddalore district, Tamil Nadu to study the effect of fertilizer, organic carbon source with foliar spray of nano zinc and seaweed extract on growth and yield of red bhendi .The experimental site is geographically located at 11 ° 24' N latitude, 74 °4' E longitude and at an altitude of ± 5.79 M above mean sea level.The experiment consisted of ten treatments replicated thrice in a randomized block design (RBD). The treatments consisted of T_1 - control, T_2 - 100 % RDF , T_3 - 100 % RDF + nano zinc @ 0.1 % (3 times FS), T_4- 100 % RDF + seaweed extract (SWE) @ 2.5 % (3 times FS), T_5 - 100 % RDF + organic carbon source (OCS) @ 2.5 t ha^{-1}, T_6 - 100 % RDF + organic carbon source @ 5.0 t ha^{-1}, T_7 - 100 % RDF + organic carbon source @ 2.5 t ha^{-1}+ nano zinc @ 0.1 % (3 times FS), T_8 - 100 % RDF + organic carbon source @ 5.0 t ha^{-1} + nano zinc @ 0.1 % (3 times FS), T_9- 100 % RDF + organic carbon source @ 2.5 t ha^{-1} + seaweed extract @ 2.5 % (3 times FS), T_{10} - 100 % RDF + organic carbon source @ 5.0 t ha^{-1} + seaweed extract @ 2.5 % (3 times FS). The land was ploughed and brought to a fine tilth. Irrigation channels and bunds were prepared according to the layout. The seeds were soaked overnight and sown in the field directly. Light irrigation was employed just after sowing. A full dose of phosphorus and potassium along with half the dose of nitrogen as per treatments, was applied just before sowing. The remaining half dose of nitrogen was applied twenty days after sowing. All cultural practices were followed regularly during crop growth and observations were recorded on growth and yield-attributing characters. The data collected were subjected to statistical analysis to draw logical conclusions (9).

Results and Discussion

It was observed that growth as well as yield attributing characters like plant height, number of leaves $plant^{-1}$, leaf area index, number of fruits $plant^{-1}$, fruit length, fruit girth, single fruit weight, fruit yield, stover yield were significantly influenced by different treatments. Application of nutrients through fertilizer and organic carbon source along with foliar spray of nano zinc, proved beneficial in increasing growth, yield and quality of red bhendi (Table 1, 2).

Plant height, Number of leaves $plant^{-1}$, Leaf area index

Among the different treatments analyzed, the application of 100 % RDF + OCS @ 5.0 t ha^{-1} + nano zinc @ 0.1 % (3 times FS) (T_8) registered the maximum plant height (108.1 cm), number of leaves $plant^{-1}$(27.83), leaf area index (5.48) which was on par with T_7 (100 % RDF+ OCS@ 2.5 t ha^{-1} + nano zinc @ 0.1 % (3 times FS) recording a plant height of 105.7 cm, number of leaves $plant^{-1}$ of 26.93 and a leaf area index of 5.32. The maximum plant height observed with organic carbon sources might be attributed to the adequate supply of nutrients that likely influenced cell division and cell enlargement resulting in better plant height (10, 11). Zinc plays a critical role in chlorophyll production and cell elongation. The timely availability of essential nutrients to the plants by zinc may have led to the production of IAA resulting in the increase of plant height (12).The increase in number of leaves might be attributed to the nutrient content of organic carbon-based fertilizer and the enhanced availability of nutrients especially nitrogen (13) which plays a vital role in the formation of new cells that can affect the vegetative growth of plants, particularly in leaf development(14, 15). Nano zinc helps in enhancing P-mobilizing enzymes along with other growth-promoting properties (16). The increase in leaf area index might be attributed to the role of nitrogen in nucleic acid and protein

Table 1. Effect of fertilizer, organic carbon source with foliar spray of nano zinc and seaweed extract on growth and yield attributing characters of red bhendi

	Plant height (cm)	Number of leaves $plant^{-1}$	Leaf area index	Number of fruits $plants^{-1}$	Fruit length (cm)	Fruit girth (cm)	Single fruit weight (g)	Fruit yield (t ha^{-1})	Stover yield (t ha^{-1})
T_1	63.50	13.99	1.46	14.41	11.74	2.69	11.11	8.28	5.10
T_2	70.73	15.69	2.85	16.47	13.14	3.14	14.10	11.85	6.72
T_3	75.59	17.39	3.34	18.32	14.94	3.59	16.07	14.01	7.59
T_4	80.05	19.09	3.74	19.56	16.72	4.06	17.32	15.83	8.41
T_5	84.51	20.79	4.29	21.11	18.00	4.50	19.13	17.80	9.26
T_6	90.09	22.49	4.74	22.97	19.33	4.86	20.17	19.72	10.11
T_7	105.73	26.93	5.32	26.09	22.32	6.07	22.51	24.97	11.78
T_8	108.12	27.83	5.48	26.28	22.81	6.15	22.57	25.52	11.83
T_9	97.01	24.19	4.98	24.51	21.13	5.48	21.47	21.72	10.94
T_{10}	100.78	25.54	5.08	24.75	20.52	5.54	21.50	22.97	10.98
S.Ed.	2.14	0.65	0.10	0.56	0.45	0.11	0.46	0.69	0.25
CD (p=0.05)	4.51	1.38	0.22	1.18	0.96	0.24	0.98	1.45	0.53

Table 2. Effect of fertilizer, organic carbon source with foliar spray of nano zinc and seaweed extract on quality parameters of red bhendi

	Ascorbic acid content	Titrable acidity	Total soluble solids	Protein content	Fibre content
T_1	14.75	0.51	3.36	1.18	13.56
T_2	15.58	0.58	3.53	1.42	12.81
T_3	16.46	0.63	3.70	1.81	12.06
T_4	17.30	0.67	3.87	2.06	11.30
T_5	18.15	0.71	4.04	2.18	10.56
T_6	18.97	0.75	4.21	2.31	9.81
T_7	20.98	0.85	4.58	2.63	8.17
T_8	21.27	0.86	4.61	2.68	8.20
T_9	19.90	0.79	4.38	2.44	9.06
T_{10}	20.00	0.81	4.41	2.50	8.95
S.Ed.	0.39	0.01	0.04	0.02	0.20
CD (p=0.05)	0.82	0.03	0.09	0.06	0.44

synthesis. Nitrogen enhances plant cell enlargement, leaf area development and participates in photosynthetic activity (17). Zinc application is also observed to increase amino acids, tryptophan and indole acetic acid, which are the key components that contribute to leaf area expansion. The addition of zinc nano particles at proper doses enhances the photosynthetic activity and cell elongation resulting in an improvement of leaf area index (18).

Number of fruits plant^{-1}and fruit length

The maximum number of fruits plant^{-1}(26.28) and fruit length (22.81cm) was recorded at 100 % RDF + OCS@ 5.0 t ha^{-1} + nano zinc @ 0.1 % (3 times FS) (T_8) followed by 100 % RDF + OCS@ 2.5 t ha^{-1} + nano zinc @ 0.1 % (3 times FS) (T_7) which recorded 26.09 and 22.32cm. However, the treatments T_8 and T_7 were on par with each other. Organic carbon sources significantly increased the number of fruits and fruit length by providing essential nutrients, enhancing their retention in the soil matrix and improving overall nutrient availability (19, 20). The increase in yield parameters with addition of NPK might be attributed to the increased availability of NPK at the critical stage of the crop growth resulting early establishment, vigorous growth and development of plants leading to longer and wider fruits (21, 22). The improvement in number of fruits and fruit length due to the addition of zinc nanoparticles may be attributed to their role in activating endogenous auxin and other growth stimuli (23, 24).

Fruit grith and single fruit weight

The maximum fruit grith (6.15 cm) and single fruit weight (22.57g) was recorded at 100 % RDF + OCS@ 5.0 t ha^{-1} + nano zinc @ 0.1 % (3 times FS) (T_8) This result was found to be on par with application of 100 % RDF + OCS@ 2.5 t ha^{-1} + nano zinc @ 0.1 % (3 times FS) (T_7) which, recorded a fruit grith of 6.07 cm and single fruit weight of 22.51g.The increase in fruit weight of okra due to organic fertilizer application could be attributed to the enhanced solubilization and gradual release of plant nutrients, leading to improved nutrient availability (25). Improved vegetative growth, balanced C:N ratio and increased synthesis of carbohydrates likely contributed to increase in fruit size. Moreover, higher nitrogen availability in NPK fertilizers may have induced protein production which promoted the production of more meri stem cells and enhanced cell division that led to higher fruit grith (26). The enhancement in fruit grith and single fruit weight following nano zinc application maybe attributed to the importance of zinc in activating various metabolic enzymes. It's nano form increases and accelerates the process of absorption through the leaves, as well as its role in regulating the metabolism of plant hormones. Zinc modifies auxin levels through the synthesis of tryptophan, while auxin plays an important role in increasing cell division and thereby increasing fruit size and weight (27).

Fruit yield and stover yield

The maximum fruit (25.52) and stover yield (11.83 t ha^{-1}) were observed at 100 % RDF + OCS @ 5.0 t ha^{-1} + nano zinc @ 0.1 % (3 times FS)- (T_8); and followed by 100 % RDF + OCS@ 2.5 t ha^{-1} + nano zinc @ 0.1 % (3 times FS)- (T_7) recording values of 24.97 and 11.78 t ha^{-1}. However, treatments T_8 and T_7 were on par with each other. The enhancement in yield following the application of organic carbon source may be due to the combination of organic carbon source with inorganic fertilizers, which may stimulate microbial activity, improve nutrient retention in soil, and nutrient uptake, enhance nutrient release and reduce nutrient leaching (28, 29). Nitrogen applied at higher levels was found to be beneficial. This might be due to the accumulation and adequate translocation of photosynthates from source to sink (30). The increase in fruit yield following nano zinc application may be attributed to the role of zinc in enhancing the production of plant hormones such as auxins, gibberellins and melatonin, which contribute to improved growth and productivity (31). The reduced particle size of nano zinc may have also improved the agronomic efficacy of the foliar fertilizer, resulting in enhanced yield and fruit quality (8, 32)

Quality parameters

The maximum ascorbic acid content (21.27 mg 100 g fruit^{-1}), titrable acidity (0.86), total soluble solids (4.6), crude protein (2.68) and minimum crude fibre content (8.20 %) was recorded at 100 % RDF + OCS @ 5.0 t ha^{-1} + nano zinc @ 0.1 % (3 times FS) (T_8) (, , ,) The result was found to be at par with 100 % RDF + OCS @ 2.5 t ha^{-1} + nano zinc @ 0.1 % (3 times FS) (T_7) with values of 20.98 mg 100 g fruit^{-1}, 0.85, 4.58, 2.63 and 8.17 % respectively. The increase in ascorbic acid content may be attributed to enhanced plant growth resulting from higher assimilation of micronutrients made available to the plant through decomposition of organic matter (33). A similar increase in ascorbic acid content was reported in previous studies (34). Organic carbon source help maintain C:N ratio by providing extra carbon to produce organic acids, such as citric acid and malic acid, which are the main contributors of fruit acidity (35). Zinc plays a crucial role in ATP and protein synthesis, starch and nucleic acid metabolism and in the activity of enzymes involved in biochemical reactions during fruit ripening (8).The increased crude protein content may be attributed to the additional nitrogen supplied to the soil by the incorporation of organic fertilizers which increased nitrogen uptake by the okra fruit, thereby increasing protein content (36, 37) . Crude fibre content is one of the most important criteria to assess the quality of okra fruit, with low crude fibre content being considered a desirable character. The decrease in crude fibre content was due to the increased fruit succulence resulting from higher nitrogen and potassium application, with potassium playing a role in strengthening the cell wall (38).

Conclusion

Based on the results of the field experiment, it is concluded that among the various treatments studied, the application of 100 % RDF + OCS @ 5.0 t ha^{-1} + nano zinc @ 0.1% (3 times FS) (T_8) was superior in performance with respect to growth, yield and quality in red bhendi. However, it was found to be comparable with the treatment involving the application of 100 % RDF + OCS @ 2.5 t ha^{-1} + nano zinc @ 0.1 % (3 times FS) (T_7). It is therefore recommended that farmers apply 100 % RDF with organic carbon source @ 2.5 t ha^{-1} and foliar spray of nano zinc @ 0.1 % (3 times FS) (T_7), boost the growth and yield of red bhendi. Farmers adopting this combination may benefit from increased crop resilience, reduced nutrient wastage and improved overall crop quality.

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Authors' contributions

NSK compiled the experimental idea and contributed to the conceptualization of the study, PP and SV. wrote the original draft manuscript, designed and supported by the faculty of Agriculture and co-authors from Annamalai University. Further, VAK and KSK reviewed and edited the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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