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Growth and yield attributes of okra (*Abelmoschus esculentus* L.) in response to combined application of biochar and vermicompost under varying irrigation levels

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Abstract
An experiment was conducted during summer 2023 at Instructional Farm, Vellanikara to assess the influence of organic soil amendments and irrigation levels on growth and yield of okra (*Abelmoschus esculentus* L.). The treatments were combinations of organic soil amendment treatments (biochar @ 10 t ha^{-1}, vermicompost @ 10 t ha^{-1}, biochar @ 5 t ha^{-1} + vermicompost @ 5 t ha^{-1}) along with absolute control and two irrigation levels (1.0 E pan and 0.5 E pan) in a factorial completely randomized design replicated thrice. Soil amendments and irrigation levels had significant influence on growth parameters and yield of okra. Combined application of biochar @ 5 t ha^{-1} and vermicompost @ 5 t ha^{-1} recorded superior growth parameters such as plant height, number of leaves, leaf area, leaf area index and number of branches across all stages. Irrigation at 1.0 E pan significantly enhanced vegetative growth compared to 0.5 E pan, and interaction effects were significant for plant height, leaf area index and leaf area at later growth stages. Yield and yield attributes were also markedly affected by both factors. The combined application of biochar @ 5 t ha^{-1} + vermicompost @ 5 t ha^{-1} recorded the highest number of fruits per plant (7.60), fruit weight per plant (136.81 g) and total yield (7.29 t ha^{-1}). Biochar @ 10 t ha^{-1} recorded lower yield and growth parameters compared to other organic amendments. Irrigation at 1.0 E pan significantly improved yield (9.43 t ha^{-1}), which was three times higher than irrigation at 0.5 E pan. Significant interaction effects were observed for the combined biochar @ 5 t ha^{-1} + vermicompost @ 5 t ha^{-1} treatment under irrigation at 1.0 E pan, with the highest number of fruits per plant (11.76), fruit weight per plant (219.23 g), and harvest index (0.82). The study confirmed the potential of combined application of biochar @ 5 t ha^{-1} and vermicompost @ 5 t ha^{-1} under optimal irrigation for improving growth and productivity of okra.

Keywords: Soil organic amendments, coconut biochar, biochar+ vermicompost, okra growth attributes, per plant okra yield

Introduction
Okra (*Abelmoschus esculentus* L.) is one of the important vegetable crops cultivated in India, valued for its high nutritional content, short duration, and market demand. India is the largest producer of okra globally, accounting for 7.3 million tonnes production in 2023-24 (GoI, 2024). However, productivity of okra is often constrained by declining soil fertility, low nutrient use efficiency and sub-optimal water management, particularly under intensive cropping systems.

Improving soil health through appropriate soil management practices is essential for sustaining crop productivity. Organic soil amendments play a crucial role in enhancing soil physical, chemical and biological properties, thereby improving nutrient availability and crop performance. Biochar has received considerable attention as a soil amendment due to its high carbon content, porous structure and capacity to improve soil aggregation, water holding capacity and nutrient retention (Lone *et al.*, 2015) [10]. The lack of standardized biochar application doses under field conditions limits its wider adoption in crop production systems. Standardization of rate of biochar either alone or in combination with organic amendments such as vermicompost, is therefore essential to maximize its benefits without adverse effects on crop growth or soil properties. Also biochar is inherently low in nutrient content with high C:N ratio, enriching is essential to improve its nutrient content (Rashid *et al.,* 2021) [11]. Vermicompost is a widely used organic amendment rich in readily available nutrients, beneficial microorganisms and plant growth–promoting hormone. Several studies have indicated that the combined application of biochar and vermicompost has synergistic effects by improving nutrient availability and water use efficiency (Shrestha *et al.*, 2024, EL Mogy *et al.*, 2024) [14, 5]. Furthermore, adequate soil moisture availability plays a critical role in soil nutrient dynamics and crop response. Hence, evaluation of biochar and vermicompost under different irrigation levels was studied sary to develop site-specific and resource-efficient management strategies for okra. Under this background, the present study was undertaken to assess the effect of coconut based biochar and vermicompost under varying irrigation levels, on growth and yield attributes of okra.

Materials and Methods

A field experiment to study the effect of different soil amendment treatments on growth and yield attributes in okra (*Abelmoschus esculentus* L.) was conducted during the summer season 2023 at Instructional Farm Vellanikara in micro-plots (5 m x 1 m). The experimental soil was acidic in reaction (pH 5.47), high in organic carbon (0.87%) and low available nitrogen (178 kg ha^{-1}), with medium levels of available phosphorus (14.78 kg P_2O_5 ha^{-1}) and medium levels of available potassium (227.47 kg K_2O ha^{-1}). The experiment was laid out in a factorial completely randomized design (CRD) with eight treatment combinations, comprising four soil amendment treatments and two irrigation levels, and replicated thrice. The soil amendments included biochar @ 10 t ha^{-1}, vermicompost @ 10 t ha^{-1}, biochar @ 5 t ha^{-1} combined with vermicompost @ 5 t ha^{-1}, and an absolute control, while irrigation was scheduled at 0.5 E pan and 1.0 E pan levels. The biochar for the experiment was prepared by using coconut husk as raw material by kiln method. The respective organic soil amendments were incorporated into the furrows one week prior to sowing. The okra variety 'Anjitha' was sown on ridges at a spacing of 60 × 30 cm by placing at a depth of 4–5 cm. Measured quantity of irrigation was applied based on average daily pan evaporation data (13 litres and 26 litres of water supplied per 5-m-long furrow to maintain 0.5 and 1.0 E pan irrigation levels respectively with irrigation interval of one day). Hand weeding carried out at 15 days after sowing (DAS). Nutrient management for okra was undertaken as per the Kerala Agricultural University (KAU) Package of Practices recommendation of 110:35:70 kg N:P_2O_5: K_2O ha^{-1} in all treatments except the absolute control. At sowing, phosphorus was applied basally at 35 kg P_2O_5 ha^{-1} in the form of rock phosphate. Nitrogen and potassium were applied at 15 DAS at the rate of 55 kg N ha^{-1} and 70 kg K_2O ha^{-1}, respectively, using urea and muriate of potash as nutrient sources. Liming @ 600 kg ha^{-1} was applied only in the treatment receiving vermicompost @ 10 t ha^{-1} (S_2).

Five plants were randomly selected and tagged from each micro-plot, and biometric observations were recorded from these plants. Data on growth parameters, yield and yield attributes were collected at appropriate growth stages. Okra fruits were harvested manually using a knife, commencing at 45 DAS and continued at weekly intervals, with a total of seven harvests during the cropping period. The experimental data were subjected to statistical analysis using Fisher's method of analysis of variance (ANOVA) as outlined by Gomez and Gomez (1984) [7]. Data processing and analysis were carried out using the RAISINS statistical software package (Hisham *et al*., 2025) [8], specifically developed for agricultural research applications.

Results

Plant height of okra varied significantly among organic soil amendment treatments at all growth stages (Table 1). The combined application of biochar @ 5 t ha^{-1} + vermicompost @ 5 t ha^{-1} resulted in higher plant height, while the absolute control recorded the lowest values. Irrigation at 1.0 E pan significantly increased plant height at 30 and 60 DAS compared to 0.5 E pan, whereas the effect was non-significant at 90 DAS. A significant interaction effect was observed at 60 and 90 DAS (Table 2), with the combined application under irrigation at 1.0 E pan recorded the maximum plant height (103.33 cm) and the absolute control under 0.5 E pan recorded the minimum (33.00 cm) at 90 DAS.

The number of leaves per plant differed significantly among organic soil amendment treatments throughout crop growth (Table 3). Vermicompost @ 10 t ha^{-1} recorded the highest number of leaves (20.67) which was found to be on par with combined application of biochar @ 5 t ha^{-1} + vermicompost @ 5 t ha^{-1}, while the absolute control recorded the lowest (9.98) at 90 DAS. Irrigation at 1.0 E pan significantly increased the number of leaves at all growth stages. The interaction effect was non-significant. Irrigation at 1.0 E pan significantly increased leaf area at 60 and 90 DAS. A significant interaction effect was observed (Table 4), with the combined application of biochar @ 5 t ha^{-1} + vermicompost @ 5 t ha^{-1} under irrigation at 1 E Pan recorded maximum leaf area (2222 cm^2), where as sole application of biochar @ 10 t ha^{-1} recorded significantly lower leaf area(1222.87 cm^2).

The number of branches per plant varied significantly among organic soil amendment treatments (Table 6), with the combined application of biochar @ 5 t ha^{-1} + vermicompost @ 5 t ha^{-1} recorded the highest number of branches (3.8) and the absolute control the lowest (1.77) and it was on par with vermicompost 10 t ha^{-1}(3). Significantly lower number branches (2.6) were observed in biochar 10 t ha^{-1} as compared to combined application at 90 DAS. Irrigation at 1.0 E pan significantly increased branch number at all stages, while the interaction effect was non-significant.

Yield and yield attributes were significantly influenced by organic soil amendments and irrigation levels (Table 7). The combined application of biochar @ 5 t ha^{-1} + vermicompost @ 5 t ha^{-1} recorded the highest number of fruits per plant fruit yield (7.6), per fruit length (14.58 cm) fruit yield per plant (136.81 g) and total yield(7.29 t/ha), followed by vermicompost @ 10 t ha^{-1}, while the absolute control recorded the lowest values. Irrigation at 1.0 E pan significantly improved all yield parameters as compared to 0.5 E Pan levels. The interaction effect was significant for number of fruits per plant, fruit yield per plant and total yield (Table 8 & figure 1), with the combined application of biochar @ 5 t ha^{-1} + vermicompost @ 5 t ha^{-1} under irrigation at 1.0 E pan was recorded the highest fruit number per plant (11.76) fruit yield per plant (219.23 g) and harvest index (0.77), whereas the absolute control under reduced irrigation at 0.5 E Pan recorded the lowest values. The sole application of biochar@ 10 t ha^{-1} was recorded significantly lower fruit number per plant (6.25) yield per plant (110.30 g), and harvest index (0.68).

Discussion

The present investigation demonstrated that growth, yield attributes, and yield of okra were markedly influenced by organic soil amendments and irrigation levels. The superiority of the combined application of biochar and vermicompost over sole and control treatments indicates a strong synergistic effect on okra crop performance. The higher plant height, number of leaves, branches, leaf area, leaf area index and yield attributes observed under the combined application of biochar and vermicompost at the rate of 5 t ha^{-1} in the present study are consistent with the findings of Subedi and Sapkota (2025) [15], who reported improved growth and fruit yield of okra with integrated biochar and vermicompost application compared to individual amendments and the control.

Significantly higher plant height observed under the combined application of biochar @ 5 t ha^{-1} + vermicompost @ 5 t ha^{-1} can be attributed to improved soil physical and biological properties which favoured better root growth and nutrient availability. Biochar is known to enhance soil porosity, moisture retention, and cation exchange capacity, while vermicompost supplies readily available nutrients, growth-promoting substances, and beneficial microorganisms. Their combined application likely improved root growth and nutrient uptake resulted in enhanced vegetative growth. In contrast, the lowest plant height in the absolute control reflects poor nutrient availability and suboptimal soil conditions. Irrigation at 1.0 E pan significantly increased plant height at early and mid-growth stages (30 and 60 DAS), suggesting that adequate moisture availability during active vegetative growth is critical for cell expansion and biomass accumulation. The non-significant effect at 90 DAS may be due to the crop approaching physiological maturity, where vegetative growth slows down. The significant interaction at 60 and 90 DAS further emphasizes that adequate irrigation enhances the beneficial effects of organic amendments, particularly the combined treatment. EL Mogy *et al*. (2024) [5] reported similar results in pepper, where the combined application of biochar and vermicompost significantly increased plant height, number of leaves, leaf area and fruit yield compared to individual amendments and the control, supporting the positive response of growth and yield parameters observed under biochar–vermicompost application in the present study.

The higher number of leaves per plant under vermicompost @ 10 t ha^{-1} and the combined application indicates improved nitrogen availability and enhanced microbial activity, both of which promote leaf initiation and expansion. Vermicompost is rich in humic substances and plant growth regulators, which could have contributed to increased leaf production. The significant effect of irrigation at 1.0 E pan across all stages highlights the importance of sufficient soil moisture in sustaining leaf development and delaying senescence. The non-significant interaction suggests that leaf number was primarily governed by the main effects of amendments and irrigation rather than their combined influence.

Leaf area was significantly higher under the combined application of biochar and vermicompost under irrigation at 1.0 E pan. Enhanced LAI reflects better canopy growth and greater photosynthetically active surface area, which directly contributes to higher dry matter accumulation and yield. The significant interaction effects observed for leaf area indicate that the positive influence of organic amendments was maximized only when adequate irrigation was provided. The relatively lower leaf area under sole biochar application at 10 t ha^{-1} may be due to temporary nutrient immobilization or insufficient immediate nutrient supply, especially nitrogen, during early growth stages as reported by Tammeorg *et al*., 2014 [16].

The increased number of branches per plant under the combined application and vermicompost @ 10 t ha^{-1} suggests better nutritional status and balanced nutrient supply, promoting axillary bud development. Biochar alone at higher rates resulted in poor branching, which may be attributed to limited nutrient availability in the absence of sufficient organic nutrient sources. Adequate irrigation at 1.0 E pan consistently enhanced branching, likely due to adequate moisture availability and improved nutrient transport within the plant. The non-significant interaction effect indicates that branching was largely influenced by independent effects of organic amendments and irrigation.

Yield and yield components showed pronounced improvement under the combined application of biochar and vermicompost, confirmed that enhanced vegetative growth translated into higher reproductive efficiency. Increased fruit number, fruit length, fruit yield per plant, total yield, and harvest index can be linked to improved source–sink relationships, higher photosynthetic efficiency, and better nutrient availability throughout the crop growth period. Vermicompost supplies essential macro- and micronutrients, while biochar improves nutrient retention and water use efficiency, together creating a favourable rhizosphere environment. Irrigation at 1.0 E pan significantly improved all yield parameters, emphasising the critical role of adequate moisture in flower initiation, fruit set, and fruit development in okra. Changade *et al*. (2023) [3] reported that irrigation at 1.0 ETc under drip irrigation significantly enhanced pod yield (15.59 t ha^{-1}), number of pods per plant and overall crop performance in okra compared to lower irrigation levels, indicating that adequate moisture supply at full evapotranspiration favours improved growth and yield attributes. Lokesh *et al.*, (2024) [9] reported that drip irrigation scheduled at 1.0 Epan created optimum soil moisture conditions in the root zone, resulting in significantly higher plant height, above-ground dry matter, green pod yield, water use efficiency (WUE), and economic returns in summer okra compared to deficit (0.75 Epan) and excess (1.25 Epan) irrigation levels.

The significant interaction effects for key yield parameters further indicate that the benefits of organic amendments were fully realized only under optimal irrigation conditions. The poor performance of sole biochar @ 10 t ha^{-1} in terms of yield attributes suggests that biochar alone may not be sufficient to meet the nutrient demand of okra unless supplemented with nutrient-rich organic or inorganic sources. The reduced growth and yield of okra observed under the sole application of coconut biochar at 10 t ha^{-1} can be mainly attributed to its high C:N ratio and low inherent nutrient content. Application of biochar at a higher rate likely caused temporary immobilization of soil nitrogen, as soil microorganisms utilized available mineral nitrogen to decompose labile carbon fractions, thereby reducing nitrogen availability to the crop during critical growth stages. This resulted in poor early vegetative growth, reduced leaf area, fewer branches, and ultimately lower yield attributes. In addition, coconut biochar supplies minimal readily available nutrients and, when applied alone, was insufficient to meet the nutrient demand of okra. Its strong nutrient adsorption capacity may have further limited the immediate availability of nitrogen and other nutrients to plants. Moreover, the alkaline nature of biochar could have reduced micronutrient availability, adversely affecting physiological processes related to flowering and fruit development. These combined effects explain the significantly lower fruit number, fruit yield per plant, and harvest index recorded under biochar @ 10 t ha^{-1}, highlighting the need for integrating high C:N biochar with nutrient-rich organic amendments rather than using it as a sole input.

The reduced okra yield under sole application of coconut biochar at 10 t ha^{-1} can be further justified by earlier reports indicating that most biochar materials are not substitutes for fertilizers and cannot supply adequate nutrients on their own. Biochar generally contains low amounts of readily available nitrogen and other essential nutrients; therefore, its application without supplementary nutrient inputs may not improve, and can even reduce, crop yield due to nutrient immobilization and dilution effects. Similar yield reductions at higher biochar application rates have been documented in previous studies. Rondon *et al.* (2007) [12] reported that application of an extremely high rate of biochar (165 t ha⁻¹) to poor soil reduced crop yields to levels comparable with the unamended control, mainly due to nutrient limitations. Likewise, Asai *et al.* (2009) [2] observed that while upland rice yields in Laos improved with biochar at 4 t ha⁻¹, higher application rates of 8 and 16 t ha⁻¹ did not result in yield advantages over the control. Supporting these findings, Gaskin *et al.* (2010) [6] reported that peanut hull and pine chip biochar applied at 11 and 22 t ha⁻¹ reduced corn yields below control levels, even under standard fertilizer management, on a poor acidic soil in the USA. These studies collectively indicate that higher rates of biochar application, particularly without adequate nutrient supplementation, can negatively affect crop performance. In the present study, the lower yield observed with coconut biochar @ 10 t ha⁻¹ may therefore be attributed to nitrogen immobilization, insufficient immediate nutrient supply, and altered nutrient availability, reinforcing the importance of integrating biochar with nutrient-rich organic amendments such as vermicompost for achieving yield benefits in okra.

Akshatha *et al.* (2025) [1] reported that the combined application of paddy straw biochar at 12 t ha⁻¹ with farmyard manure and vermicompost significantly improved growth and yield attributes of field bean compared to sole biochar application, indicating a strong synergistic effect of biochar–organic amendment integration on crop productivity. Sarma and Gogoi (2015) [13] reported that vermicompost was more effective than biochar in okra, recorded higher seed germination, plant height, leaf area, biomass accumulation, which was attributed to its finer structure, favourable C:N ratio and greater availability of nutrients and growth-promoting substances compared to biochar. Overall, the results of this experiment suggest that the integrated use of coconut biochar 5t ha⁻¹ and vermicompost 5 t ha⁻¹, coupled with irrigation at 1.0 E pan, significantly enhanced growth, canopy development, yield attributes and yield of okra and hence can be recommended as a viable strategy for improving okra production under similar agro-climatic conditions.

Table 1: Effect of soil amendments and irrigation on plant height of okra at different growth stages

Treatment	30 DAS	60 DAS	90 DAS
Factor A: Soil amendments			
S_1: Biochar @ 10 t/ha	12.42 ± 2.29	52.75 ± 13.82	53.80 ± 14.09
S_2: Vermicompost @ 10 t/ha	13.98 ± 2.35	65.17 ± 18.94	66.47 ± 19.31
S_3: Biochar @ 5t/ha + Vermicompost 5 t/ha	13.92 ± 2.31	72.17 ± 35.13	73.60 ± 35.81
S_4: Absolute control	9.32 ± 1.93	38.00 ± 8.72	38.77 ± 8.87
CD (p=0.05)	1.48	13.23	13.5
S.Em ±	0.51	4.59	4.68
Factor B: Irrigation			
I_1: Irrigation @ 1E pan	14.88 ± 2.64	80.47 ± 21.56	82.08 ± 22.00
I_2: Irrigation @ 0.5E pan	11.69 ± 2.02	48.06 ± 10.49	49.03 ± 10.69
CD (p=0.05)	0.74	6.61	6.75
S.Em ±	0.26	2.30	2.34
Interaction	NS	S	S

Table 2: Interaction effect of soil amendments and irrigation on plant height at 60 DAS & 90 DAS

60 DAS				
Factors	**S_1- Biochar @ 10 t/ha**	**S_2- Vermicompost @ 10 t/ha**	**S3- Biochar @ 5t/ha + Vermicompost 5 t/ha**	**S8- Absolute control**
I_1: Irrigation @ 1E pan	61.00 ± 16.46	78.67 ± 17.24	101.33 ± 19.01	43.67 ± 9.45
I_2: Irrigation @ 0.5E pan	44.50 ± 1.50	51.67 ± 7.23	43.00 ± 13.08	32.33 ± 2.08
CD(0.05)	18.71			
90 DAS				
I_1: Irrigation @ 1E pan	62.20 ± 16.81	80.23 ± 17.59	103.33 ± 19.41	44.53 ± 9.60
I_2: Irrigation @ 0.5E pan	45.40 ± 1.50	52.70 ± 7.38	43.87 ± 13.31	33.00 ± 2.14
CD (0.05)	19.09			

Table 3: Effect of soil amendments and irrigation on number of leaves in okra at different growth stages

Treatment	30 DAS	60 DAS	90 DAS
Factor A: Soil amendments			
S_1: Biochar @ 10 t/ha	8.00 ± 2.19	14.83 ± 4.36	15.60 ± 4.59
S_2: Vermicompost @ 10 t/ha	8.25 ± 2.82	19.67 ± 8.31	20.67 ± 8.75
S_3: Biochar @ 5t/ha + Vermicompost 5 t/ha	9.00 ± 2.00	18.00 ± 7.77	18.92 ± 8.16
S_4: Absolute control	5.83 ± 1.94	9.50 ± 2.81	9.98 ± 2.96
CD (p=0.05)	1.84	3.53	3.71
S.Em ±	0.64	1.23	1.29
Factor B: Irrigation			
I_1: Irrigation @ 1E pan	10.00 ± 2.31	22.90 ± 5.99	24.06 ± 6.29
I_2: Irrigation @ 0.5E pan	6.93 ± 1.46	13.12 ± 3.75	13.79 ± 3.94
CD (p=0.05)	0.92	1.77	1.86
S.Em ±	0.32	0.61	0.64
Interaction	NS	NS	NS

Table 4: Effect of soil amendments and irrigation on leaf area of okra at different growth stages

Treatment	30 DAS	60 DAS	90 DAS
Factor A: Soil amendments			
S_1: Biochar @ 10 t/ha	460.03 ± 47.65	1102.33 ± 217.25	881.87 ± 173.80
S_2: Vermicompost @ 10 t/ha	621.96 ± 104.11	1614.30 ± 490.29	1291.44 ± 392.24
S_3: Biochar @ 5t/ha + Vermicompost 5 t/ha	634.23 ± 53.31	1787.35 ± 497.13	1429.88 ± 397.71
S_4: Absolute control	308.53 ± 62.65	730.10 ± 123.85	584.08 ± 99.08
CD (p=0.05)	92.58	228.67	182.93
S.Em ±	32.14	79.38	63.50
Factor B: Irrigation			
I_1: Irrigation @ 1E pan	594.88 ± 198.17	1929.25 ± 588.60	1543.40 ± 470.88
I_2: Irrigation @ 0.5E pan	578.16 ± 192.35	1132.29 ± 280.93	905.83 ± 224.74
CD (p=0.05)	NS	114.33	91.47
S.Em ±	-	39.69	31.75
Interaction	NS	S	S

Table 5: Interaction effect of soil amendments and irrigation on leaf area at 60 DAS & 90 DAS

Factors	S_1- Biochar @ 10 t/ha	S_2- Vermicompost @ 10 t/ha	S3- Biochar @ 5t/ha + Vermicompost 5 t/ha	S8- Absolute control
60 DAS				
I_1: Irrigation @ 1E pan	1222.87 ± 269.25	2046.00 ± 44.23	2222.00 ± 150.88	813.47 ± 83.23
I_2: Irrigation @ 0.5E pan	981.80 ± 43.73	1182.60 ± 199.80	1352.70 ± 168.30	646.73 ± 102.81
CD(0.05)	323.38			
90 DAS				
I_1: Irrigation @ 1E pan	978.29 ± 215.40	1636.80 ± 35.38	1777.60 ± 120.70	650.77 ± 66.58
I_2: Irrigation @ 0.5E pan	785.44 ± 34.99	946.08 ± 159.84	1082.16 ± 134.64	517.39 ± 82.25
CD(0.05)	258.71			

Table 6: Effect of soil amendments and irrigation on number of branches of okra at different growth stages

Treatment	30 DAS	60 DAS	90 DAS
Factor A: Soil amendments			
S_1: Biochar @ 10 t/ha	1.20 ± 0.48	2.17 ± 0.41	2.60 ± 0.49
S_2: Vermicompost @ 10 t/ha	1.50 ± 0.84	2.50 ± 0.55	3.00 ± 0.66
S_3: Biochar @ 5t/ha + Vermicompost 5 t/ha	1.50 ± 0.55	3.17 ± 0.98	3.80 ± 1.18
S_8: Absolute control	0.78 ± 0.25	1.50 ± 0.55	1.77 ± 0.70
CD (p=0.05)	0.59	0.83	1
S.Em ±	0.20	0.50	0.72
Factor B: Irrigation			
I_1: Irrigation @ 1E pan	1.98 ± 0.67	3.04 ± 0.91	3.65 ± 1.09
I_2: Irrigation @ 0.5E pan	1.22 ± 0.61	2.38 ± 0.88	2.84 ± 1.06
CD (p=0.05)	0.29	0.42	0.5
S.Em ±	0.10	0.14	0.17
Interaction	NS	NS	NS

Table 7: Effect of soil amendments and irrigation on yield attributes of okra

Treatment	Fruit no/ Per plant	Fruit length	Fruit weight/plant	Yield (t/ha)
Factor A: Soil amendments				
S_1: Biochar @ 10 t/ha	5.12 ± 1.30	11.92 ± 1.02	78.19 ± 35.36	4.16 ± 1.88
S_2: Vermicompost @ 10 t/ha	5.97 ± 1.37	14.08 ± 1.11	105.72 ± 37.47	5.63 ± 1.98
S_3: Biochar @ 5t/ha + Vermicompost 5 t/ha	7.60 ± 4.57	14.58 ± 1.28	136.81 ± 90.58	7.29 ± 4.81
S_8: Absolute control	4.32 ± 0.79	12.50 ± 0.84	67.10 ± 14.92	3.57 ± 0.78
CD (p=0.05)	0.8	1.26	8.56	0.26
S.Em ±	0.28	0.44	2.97	0.09
Factor B: Irrigation				
I_1: Irrigation @ 1E pan	8.85 ± 2.98[a]	14.00 ± 1.16	177.12 ± 77.69	9.43 ± 4.12
I_2: Irrigation @ 0.5E pan	4.91 ± 1.22[b]	12.85 ± 1.50	70.40 ± 20.05	3.75 ± 1.06
CD (p=0.05)	0.4	0.63	4.28	0.13
S.Em ±	0.14	0.22	1.49	0.05
Interaction	S	NS	S	S

Table 8: Interaction effect of soil amendments and irrigation on yield attributes of okra

Factors	S_1- Biochar @ 10 t/ha	S_2- Vermicompost @ 10 t/ha	S3- Biochar @ 5t/ha + Vermicompost 5 t/ha	S8- Absolute control
Fruit no/ Per plant of okra				
I_1: Irrigation @ 1E pan	6.25 ± 0.48	7.21 ± 0.28	11.76 ± 0.30	4.95 ± 0.35
I_2: Irrigation @ 0.5E pan	3.95 ± 0.19	4.72 ± 0.24	3.41 ± 0.14	3.67 ± 0.53
CD(0.05)	0.8			
Fruit yield (g/plant)				
I_1: Irrigation @ 1E pan	110.30 ± 5.50	139.60 ± 7.00	219.23 ± 10.95	80.43 ± 4.05
I_2: Irrigation @ 0.5E pan	46.10 ± 2.30	71.80 ± 3.60	54.40 ± 2.70	53.80 ± 2.70
CD(0.05)	8.56			

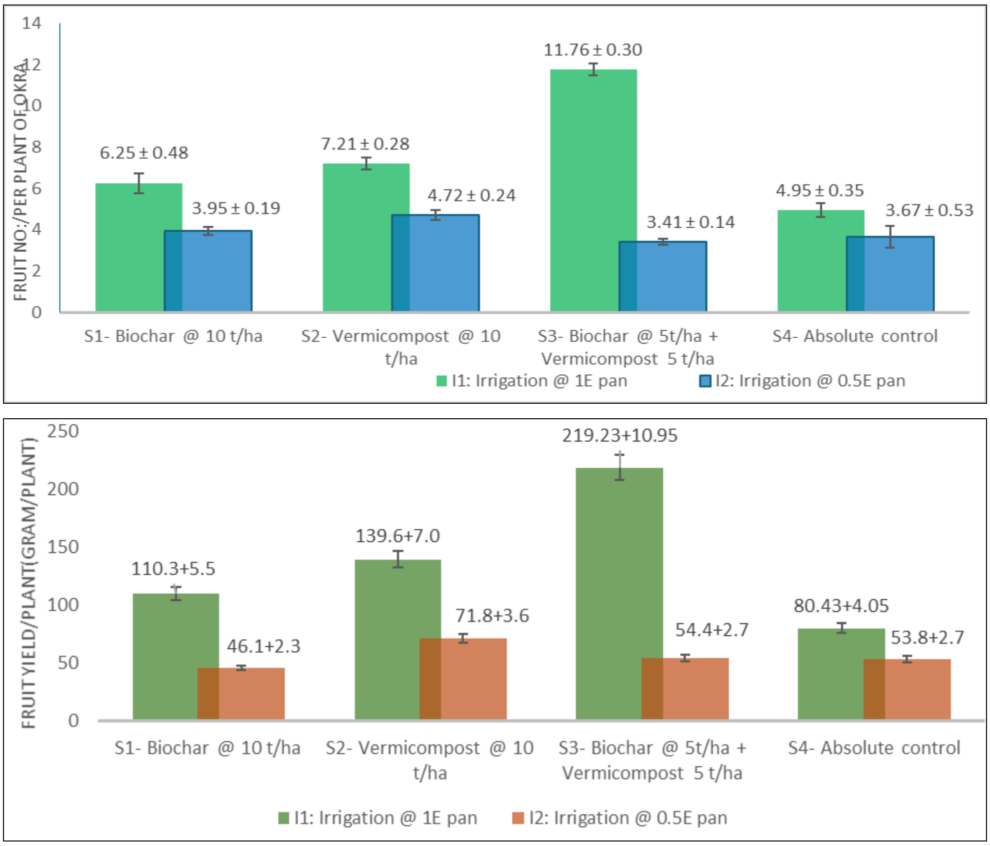

Fig 1: Effect of organic soil amendments and irrigation on yield attributes of okra

Conclusion

The present study indicated that both organic soil amendments and irrigation levels significantly influenced growth and yield of okra. Among the organic soil amendment treatments, the combined application of biochar @ 5 t ha^{-1} and vermicompost @ 5 t ha^{-1} proved superior by enhanced plant height, leaf production, leaf area, leaf area index, branching and yield attributes compared to sole applications of vermicompost, biochar and the absolute control. Irrigation scheduled at 1.0 E pan ensured adequate soil moisture availability, resulted in improved vegetative growth and higher yield parameters over irrigation at 0.5 E pan. The significant interaction effects observed for key growth and yield traits indicated that the beneficial influence of organic soil amendments such as biochar and vermicompost was maximized under adequate irrigation. Overall, the combined use of biochar @ 5 t ha^{-1} and vermicompost @ 5 t ha^{-1}under irrigation at 1.0 E pan can be recommended as an effective management practice for improving productivity of okra under acidic soil of similar agro-climatic conditions.

Disclaimer

The products used for this research are commonly used for agriculture purpose. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company.

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Competing Interests

Authors have declared that no competing interests exist.

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