

Biochar based Seed Biopriming for Enhancing Yield Quality Attributes of Spinach

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Abstract— Spinach (*Spinacia oleracea*), a winter season leafy vegetable, is widely consumed due to its high nutritional value, involving Vitamin C, Vitamin K, and iron. Enhancing the productivity and nutritional quality of spinach through eco-friendly practices has become an essential component in the context of sustainable agriculture. One such promising approach involves the use of biochar, an organic carbon-rich material which produced through the pyrolysis of organic biomass. Apart from soil application, biochar can also be used as a seed biopriming agent to enhance germination rate, seedling vigor, and stress tolerance in crops. This study is designed to evaluate the combined and individual effects of biochar used as a seed biopriming agent and soil amendment on the growth and yield parameters of spinach. The field experiment was conducted at the Amity Institute of Organic Agriculture in Randomized Block Design (RBD) with six treatments as biochar at 2%, 5%, and 10% (v/v) in both seed priming and soil application, seed priming alone, soil application alone, and a control without biochar.

Keywords— Biochar, spinach, sustainable agriculture, biopriming.

I. INTRODUCTION

Spinach, scientifically known as *Spinacia oleracea*, a fast-growing crop with culinary and nutritional interests all over the world is an important vegetable crop belonging to the family Amaranthaceae. It is an annual vegetable crop grown for its nutrient-rich, dark green leaves originated in Southwest Asia and was introduced to Europe in 12th century. In India, major spinach producing states are Gujarat, Maharashtra, West Bengal and Uttar Pradesh (Rani et al., 2020). It is rich in iron, calcium, vitamin A, C and K that plays a crucial role in supporting bone health, immune functioning and thereby improving health. Spinach is a cool season crop that grown well under cool weather with well-drained soil and consistent moisture conditions. The crop faces challenges due to decline in soil fertility, water retention capacity and thereby need is there for some organic amendments for sustainable agricultural practices that improve soil health with crop growth and yield.

Biochar is an organic carbon-rich material which is produced through the action of pyrolysis of the biomass under limited oxygen conditions that has gained considerable attention as a promising tool for sustainable agriculture (Lehmann et al., 2006). The characteristics of biochar involving its porous structure, high cation exchange capacity with its ability to enhance soil fertility and water retention capacity thereby makes it a suitable candidate for its utilization as soil amendment (Liang et al., 2006; Chan et al., 2007; Ghorri et al., 2019; Enaime et al. 2021; Ramamoorthy et al., 2024). Biochar being a organic compound has the potential to influence soil microbiome with increase enzymatic activity (Lehmann et al., 2011). Seed health is as important as soil health for promoting the crop productivity. Seed biopriming, a component of seed priming is a pre sowing treatment of seeds with biological agents that activates the enzymatic reactions inside the seed and thereby conditioning it by activating defense reactions for better adaptability to growing conditions. In recent years, biochar has also been utilized as a seed biopriming agent with a potential to enhance seed germination, seedling vigor and stress tolerance (Joseph et al., 2013; Farooq et al., 2020). Seed biopriming is a type of physiological treatment strategy that enhances the plant growth even under stress conditions by utilizing hydration to promote water absorption before the radicle emergence (Takoliya et al., 2018). This method not only increases the rate and uniformity of seed germination but also strengthens the defense response of plants against the biotic stress by improving the activity of beneficial microbial activity on spermosphere (Parsad et al., 2015). Utilization of biochar as soil amendment has a potential in maintain soil pH, preventing nutrient leaching and enhancing the

activity of nutrients and organic matter in degraded soil, aids in carbon sequestration and thereby aligning with the goals of sustainable agriculture (Jeffery et al., 2011; Hussain et al., 2017; Ahmad et al., 2024).

Biochar application enhances the seed germination, vigor index with increase in plant height and shoot length which are indicative of their improved vegetative growth and biomass accumulation thereby contributing to improved quality and yield of crop (Naggar et al., 2019; Abborova et al., 2023). The present study was carried out with aim to study the potential of biochar as seed biopriming and soil amendment treatment both in combination or as alone on growth parameters of spinach for further utilization in crop growth and productivity.

II. MATERIALS AND METHODS

2.1 Experimental location and climatic conditions:

The experimental trial was carried out during the Rabi season of cropping year 2025 at Research farm of Amity Institute of Organic Agriculture, Amity University, Noida, Uttar Pradesh. The geographic coordinates of the location were 77°19'51.64"E (77.331007) longitude and 28°32'37.64"N (28.543793) latitude, and an altitude of 200 meters above sea level. The cropping area falls under Trans-Gangetic plains agro-climatic zone, which has a semi-arid, subtropical climate with hot, dry summers and freezing winters. The cultivation of the spinach crop was carried out during January as this month has the lowest temperatures of 14°C to 17°C suitable for cultivation of spinach crop. The region receives an average annual rainfall of about 700 mm, primarily from July to September, followed by dry weather from December to February, thereby making it ideal for growing cool season crops like spinach.

2.2 Seed treatments and sowing:

Firstly, the field was prepared by ploughing to a fine tilth followed by layout of experiment as per design (Table 1). For seed biopriming, spinach seeds were soaked in distilled water for 12 hours to initiate hydration before radicle emergence. After draining the water, the seeds were dried partially and then combined with biochar slurry (prepared by combining biochar with adequate water) and incubated in a shady, aerated conditions for 24 hours. For soil amendment, biochar was added to the topsoil layer as per the treatment details to enhance soil structure and nutrient retention. Sowing was carried out by implementing the broadcasting method of application for the already bio primed seeds. The seeds were then lightly covered with a thin layer of soil and thereby immediate irrigation was provided to ensure appropriate seed-soil contact and moisture availability to the sown seeds.

2.3 Treatment details:

A Randomized Block Design (RBD) with six treatments and four replication was laid out. Each plot measured 2m x 2m with 0.5m distance between plots and about 1m between the blocks. The data pertaining to different growth parameters like seed germination per centage, shoot length (cm), root length (cm) and yield (kg/plot) was recorded and the data recorded was later analyzed for the presence of variance using ANOVA tests from OPSTAT.

TABLE 1
DETAILS OF THE TREATMENTS

Sr. No.	Treatments	
1	T1	Biochar (Seed priming + Soil application) 2%
2	T2	Biochar (Seed priming + Soil application) 5%
3	T3	Biochar (Seed priming + Soil application) 10%
4	T4	Biochar (Seed priming)
5	T5	Biochar (Soil application)
6	T6	Control

III. RESULTS AND DISCUSSION

The different data recorded was analysed statistically and presented in Table 1. It was evident from observations that, among different treatments, increase in number of foliage was recorded from T4 involving alone application of seed biopriming with biochar followed by treatment combination of seed biopriming and soil application with biochar 5 % (T2) which are statistically at par with each other. However, the treatment combinations T3 and T1 also resulted in significantly increase in number of foliage as compared to control. Another growth attribute in spinach plants pertaining to plant height was recorded as highest

in T4 involving seed biopriming with biochar (23 cm) followed by treatment T2 (21 cm) which are significantly different from each other.

It is evident from Table 1, the shoot length of spinach plants was significantly improved by biochar application in comparison to control as T4 observed the highest shoot length (19.25 cm) followed by T2 with shoot length of 18 cm which are significantly different from each other. The different treatment combinations of T3 and T1 also presented significant increase in plant height. Similar results were also observed in terms of root length as the highest value was recorded for T4 treatment combination with an average value of 9 cm followed by T2 and T3 treatment combinations with value of 8.25 and 7.75 cm, respectively.

The highest yield was recorded in treatment combination involving seed biopriming with biochar as 2.5 kg per plot followed by treatment combination T2 and T3 with average yield of 2.4 and 2.2 kg per plot, respectively (Figure 1).Thus, it was evident from the different parameters that seed biopriming with biochar alone had the most positive impact on growth in spinach followed by combined application of seed biopriming with soil application.

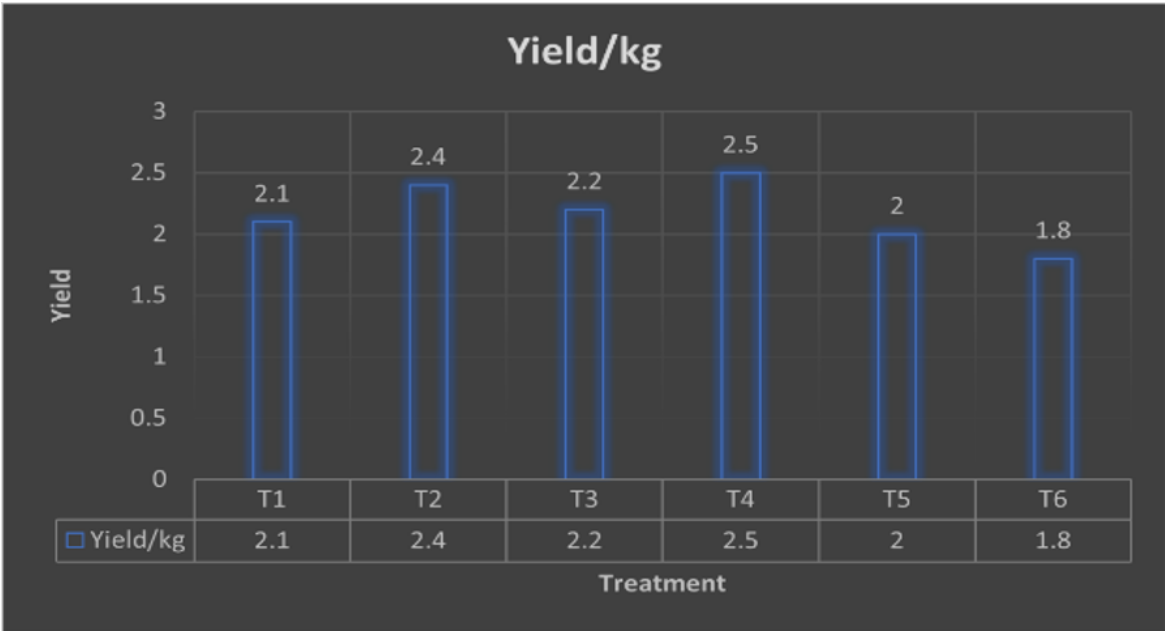


FIGURE 1: Effect of biochar combinations on yield in spinach

The results are in conformation with studies conducted by Ahmad et al. (2024) as priming of metallic nanoparticles resulted in increased growth in spinach crop under abiotic stress conditions. Similar results have been reported by some other research workers that also depicts the potential of biochar treatment in enhancing the plant growth and its different attributes (Saxena et al., 2013; Trupiano et al., 2017; Jabborova et al. 2021).

TABLE 2
EFFECT OF BIOCHAR AS SEED BIOPRIMING AND SOIL APPLICATION ON DIFFERENT GROWTH PARAMETERS OF SPINACH

Treatment	No. of leaves	Plant height (cm)	Shoot length (cm)	Root length (cm)
T1: Biochar (Seed priming + Soil application) 2%	7.50±0.28	18.50±0.24	15.50±0.28	7.25±0.18
T2: Biochar (Seed priming + Soil application) 5%	9.00±0.40	21.00±0.44	18.00±0.40	8.25±0.14
T3: Biochar (Seed priming + Soil application) 10%	8.50±0.28	19.50±0.25	17.50±0.28	7.75±0.14
T4: Biochar (Seed priming)	9.70±0.25	23.00±0.40	19.20±0.47	9.00±0.20
T5: Biochar (Soil application)	6.70±0.25	17.50±0.28	14.50±0.28	6.75±0.14
T6: Control	6.20±0.25	16.00±0.40	13.00±0.40	6.00±0.20
CD (0.05)	0.76	0.83	0.87	0.4

IV. CONCLUSION

The aim of this study was to assess the effect of biochar as soil amendment and seed biopriming on key growth parameters in spinach. It can be concluded that the treatment T4 (biochar applied as both seed biopriming and soil amendment) significantly enhanced plant height and number of leaves compared to the control. The rise in leaf number reflects enhanced photosynthetic capacity, contributing to better biomass accumulation. Biochar-based biopriming likely facilitated early seed metabolism, moisture retention, and nutrient availability, leading to improved seedling establishment and overall plant performance. These findings suggest that biochar-based seed biopriming is an effective strategy to enhance early growth traits closely linked to yield and quality in spinach.

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