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RESEARCH ARTICLE

OPTIMIZATION OF BIOCHAR AND COMPOST DOSAGE TO IMPROVE YIELD AND QUALITY OF MALABAR SPINACH (BASELLA ALBA)

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Abstract

The application of biochar and compost in agriculture has gained significant attention for its potential to enhance soil health and crop productivity. This study investigates the optimal dosage of biochar and compost to maximize the yield and quality of Malabar spinach (Basella alba L.). A series of field experiments were conducted, employing a randomized complete block design with various combinations of biochar and compost treatments. Key parameters, including plant height, leaf area, chlorophyll content, and overall yield, were measured and analyzed. Results demonstrated that specific ratios of biochar and compost significantly improved the growth and nutritional quality of Malabar spinach compared to control treatments. The findings suggest that precise management of biochar and compost applications can be a sustainable strategy to boost crop performance, offering valuable insights for both researchers and practitioners in the field of sustainable agriculture.

Introduction:-

Malabar spinach (Basella alba L.) is a widely cultivated leafy vegetable valued for its high nutritional content and adaptability to various growing conditions. As consumer demand for nutritious and sustainably grown produce increases, there is a growing interest in enhancing agricultural practices to improve both the yield and quality of crops. Among the various agronomic practices, the use of biochar and compost has emerged as a promising approach to enhance soil fertility, improve plant growth, and contribute to sustainable agriculture.

Biochar, a carbon-rich product obtained from the pyrolysis of organic materials, has been shown to improve soil physical properties, increase water retention, and enhance nutrient availability. Compost, derived from the controlled decomposition of organic waste, serves as a rich source of organic matter and nutrients. The synergistic application of biochar and compost has the potential to create a more favorable soil environment, promoting plant growth and health.

Despite the recognized benefits of biochar and compost, there is a lack of detailed research on the optimal dosages required to maximize their positive effects on specific crops, such as Malabar spinach. Most studies have focused on the individual impacts of biochar or compost, without addressing the combined and interactive effects of these amendments on crop performance. Understanding the optimal combination and dosage of biochar and compost is crucial for developing effective management practices that enhance crop yield and quality while maintaining environmental sustainability.

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This study aims to fill this gap by systematically investigating the effects of varying dosages of biochar and compost on the yield and quality of Malabar spinach. Through a series of field experiments, we seek to determine the optimal combination of these soil amendments to achieve the best agronomic outcomes. By elucidating the interactions between biochar and compost in improving crop performance, this research will provide valuable insights for farmers and agricultural practitioners, contributing to the advancement of sustainable agricultural practices.

Materials and Research Methods:-

Materials:-

Biochar: Sourced from coconut coir, pyrolyzed at 400°C for 3 hours.
Compost: Produced from crop residues (straw and vegetable waste) using EM microbial inoculant.

Methods:-

The experiment was arranged in a completely randomized block design (RCBD). Each experiment included 6 treatments with 3 replications.Total number of plots/experiment: 18 plots, plot area: 50 m², total experimental area: 900 m².

T1: 8 tons of compost/ha and 2 tons of biochar/ha (Control)
T2: 9 tons of compost/ha and 2 tons of biochar/ha
T3: 10 tons of compost/ha and 2 tons of biochar/ha
T4: 8 tons of compost/ha and 3 tons of biochar/ha
T5: 9 tons of compost/ha and 3 tons of biochar/ha
T6: 10 tons of compost/ha and 3 tons of biochar/ha

Security strip

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T2	T1	T6	T5	T3	T4	Repeat 1
Security strip						
T4	T6	T3	T1	T2	T5	Repeat 2
Security strip						
T3	T5	T1	T4	T6	T2	Repeat 3

Security strip

Fig. 1:- Scheme of the experiment.

Data were processed using the IRRISTAT 5.0 program to calculate basic statistical parameters and perform ANOVA on the experimental results.

Research Results and Discussion:-

Table 1:- Effect of compost and biochar dosage on the growth duration of Malabar spinach.

Formulas	**Time from sowing to germination**	**Time from sowing to first harvest**	**Time from sowing to second harvest**	**Time from sowing to third harvest**	**Time from sowing to fourth harvest**	**Time from Sowing to final harvest**	**Total growth duration**
T1 (Control)	10	43	57	71	85	99	99
T2	10	43	57	71	85	99	99

T3	10	43	57	71	85	99	99
T4	10	43	57	71	85	99	99
T5	10	43	57	71	85	99	99
T6	10	43	57	71	85	99	99

Unit: days

Germination is the starting point of life processes and plays a crucial role in determining the survival and vigor of the plant. It marks the transition from a dormant state to the growth and development of a new organism. This period is extremely important for the plant as it involves the conversion of stored substances in the seed into nutrients, allowing the seed to germinate and emerge from the soil. This phase begins when 80% of the seeds in the experiment have germinated and emerged from the ground.

From Table 1, it can be seen that despite the different fertilizer treatments, the germination rates are not significantly different among the treatments. This indicates that the germination process occurs fairly uniformly, ensuring stability and uniformity across the entire experimental field.

The time from sowing to harvest is measured when 40-50% of the plants in the experiment have reached harvestable criteria. This period directly impacts the yield and growth duration of the plant.

The data in Table 1 show that the time from planting to the various harvest stages is consistent across the different experimental treatments. However, there are differences in growth and development parameters among the treatments.

Table 2:- Effect of compost and biochar dosage on plant height and leaf number of Malabar spinach at different harvest times.

Formulas	First harvest		Second harvest		Third harvest		Fourth harvest		Final harvest	
	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves
T1 (Control)	23.8	11.4	20	10.4	20.5	10.7	20	9.9	18.6	9.7
T2	23.9	10.6	20.5	10.5	21	10.9	19.4	10.1	18.7	9.7
T3	23.8	11.2	20.2	10.8	20.8	11.1	19.6	10.1	19	9.6
T4	26.6	11.4	20.5	11	20.5	11.3	20	10.3	19.5	10.2
T5	25.7	11.6	21.2	11.5	21.2	11.2	19.8	10.5	20.1	10.1
T6	25.5	11.7	21.6	11.5	22.2	11.3	21	10.9	20.4	10.3
CV%	2.7	1.8	2.8	2.7	2.6	2.4	1.5	1.8	2.3	2
$LSD_{0.05}$	1.2	0.4	1.2	0.5	1.2	0.5	0.7	0.3	1	0.4

By monitoring and comparing plant height and leaf number at different harvest times, the growth potential of Malabar spinach under various fertilization treatments can be assessed. Table 2 shows that plant height and leaf number vary significantly among treatments at different harvest times:

At the first harvest:
The highest average height is observed in T4 (26.6 cm), which is 2.8 cm greater than the control. The lowest height is in T1 (23.8 cm), with minor differences between T2, T3, and T5,6. The highest average leaf number is found in T6 (11.7 leaves/plant), which is higher compared to the other treatments, while the lowest is in the control T2 (10.6 leaves).

At the second harvest:
The tallest plants are in T6 (21.6 cm), followed by T5 (21.2 cm), T2 and T4 (20.5 cm), T3 (20.2 cm), with T1 being the shortest (20 cm). T6 also has the highest number of leaves compared to the other treatments (11.5 leaves), followed by T5 (11.5 leaves), T4 (11 leaves), T3 (10.08 leaves), T2 (10.5 leaves), and the control T1 (10.4 leaves).

At the third harvest:
The tallest plants are in T6 (22.2 cm), and the shortest are in T1 and T4 (20.5 cm). The heights of the remaining treatments are as follows: T5 (21.2 cm), T3 (20.8 cm), and T2 (21 cm). The highest leaf number is in T6 and T4 (11.3 leaves), followed by T5 (11.2 leaves), with the lowest in T1 (10.7 leaves).

At the fourth harvest:
The tallest plants are in T6 (21 cm), followed by T1 and T4 (20 cm), T3 (19.6 cm), and the shortest is T2 (19.4 cm). T6 also has the highest number of leaves compared to the other treatments (10.9 leaves), followed by T5 (10.5 leaves), T4 (10.3 leaves), T3 and T2 (10.1 leaves), with the lowest being the control T1 (9.9 leaves).

At the final harvest:
The tallest plants are in T6 (20.4 cm), followed by T5 (20.1 cm), T4 (19.5 cm), T3 (19 cm), T2 (18.7 cm), and the shortest is T1 (18.6 cm). The highest leaf number is in T6 (10.3 leaves), followed by T5 (10.1 leaves), T4 (10.2 leaves), and the lowest in T3 (9.6 leaves).

The results from Table 2 indicate that T6 performs better than the control in terms of both plant height and leaf number. The differences between the two treatments at various harvest stages are statistically significant at the 95% confidence level.

Table 3:- Effect of compost and biochar dosage on Leaf area and Leaf Area Index (LAI) of Malabar spinach.

Fomurlas	Leaf area (dm^2)			Leaf Area Index (LAI) (m^2 leaves/m^2 soil)		
	15 days after sowing	**30 days after sowing**	**First harvest**	**15 days after sowing**	**30 days after sowing**	**First harvest**
T1 (Control)	1,5	2,7	4,0	0,4	0,8	1,2
T2	1,4	2,8	3,4	0,4	0,8	1,0
T3	1,4	2,8	3,5	0,4	0,8	1,0
T4	1,3	2,6	3,9	0,4	0,7	1,2
T5	1,7	2,7	4,1	0,5	0,8	1,2
T6	1,8	2,8	4,3	0,5	0,8	1,3

Leaf Area Index (LAI):
During the seedling stage, the lowest LAI was observed in T4 (0.39 m^2 leaves/m^2 soil) and the highest in T6 (0.54 m^2 leaves/m^2 soil). In the vegetative growth stage, T6 (0.84 m^2 leaves/m^2 soil) exhibited the highest LAI, with the differences between the remaining treatments being insignificant. At the first harvest stage, the highest LAI was recorded in T6 (1.29 m^2 leaves/m^2 soil), while the lowest was in T2 (1.02 m^2 leaves/m^2 soil). The intermediate

values were observed in T3 (1.05 m² leaves/m² soil), T4 (1.17 m² leaves/m² soil), T1 (1.20 m² leaves/m² soil), and T5 (1.23 m² leaves/m² soil).

Table 4:- Effect of compost and biochar dosage on various physiological parameters of Malabar spinach.

Fomurlas	SPAD			Fresh plant weight (g)			Dry Matter Content (%)		
	15 days after sowing	30 days after sowing	First harvest	15 days after sowing	30 days after sowing	First harvest	15 days after sowing	30 days after sowing	First harvest
T1 (Control)	31,5	37,9	43,6	5,5	21,0	27,9	7,8	6,8	10,2
T2	31,7	38,2	43,7	5,6	19,0	27,4	11,9	6,9	10,3
T3	31,7	38,0	43,4	5,2	17,4	26,5	10,7	8,6	9,9
T4	31,8	38,4	43,2	5,8	18,3	26,6	9,7	8,1	10,2
T5	31,7	37,7	43,7	5,3	19,5	27,0	10.6	7,3	10,6
T6	32.2	38,1	43,0	5,4	20,6	27,3	8.8	6,4	11,4

SPAD value:
During the seedling and vegetative growth stages, there were no significant differences between the treatments. At the first harvest stage, all treatments had SPAD values ranging from 43 to 43.6.

Fresh plant weight:
During the seedling stage, the highest fresh weight was observed in T4 (5.84 g), and the lowest in T3 (5.16 g). The other treatments had the following fresh weights: T5 (5.37 g), T6 (5.47 g), T1 (5.50 g), and T2 (5.60 g). In the vegetative growth stage, T1 had the highest total fresh weight of 21 g, while T3 had the lowest at 17.4 g. At the first harvest stage, T1 had the highest total fresh weight of 27.9 g, and the lowest was in T3 (26.52 g), with the remaining treatments approximately around 27 g.

Table 5:- Effect of compost and biochar dosage on pest and disease incidence in Malabar spinach.

Fomurlas	Brown spot disease		Green caterpillar		Snail	
	Rate of affected plants	Severity of damage	Rate of affected plants	Severity of damage	Rate of affected plants	Severity of damage
T1 (Control)	2,67	1,87	1,63	1,60	1,50	1,60
T2	2,67	1,93	1,80	1,67	1,67	1,73
T3	3,13	1,93	1,77	1,67	1,27	1,53
T4	2,17	1,93	2,01	1,80	1,53	1,80

T5	1,60	1,67	1,73	1,73	1,60	1,67
T6	2,93	2,00	1,63	1,73	1,73	1,80

The pest and disease situation on Malabar spinach is quite complex, with increasing diversity and density of pests and diseases occurring at nearly all stages of plant growth. Effective management practices are needed to ensure optimal yield and quality. Common pests and diseases affecting Malabar spinach include:

Brown spot disease (Cercospora Leaf Spot):
This disease becomes more severe during the rainy season and is caused by the fungus Cercospora sp. The fungus primarily affects leaves and stems. On the leaves, the initial symptoms are small, round, brown-purple spots. As the disease progresses, the spots enlarge to about 3-5 mm in diameter, with a grayish-white center and a brown-purple border. Multiple spots may coalesce, leading to torn and stunted leaves, reduced yield, and quality. The disease typically affects mature and intermediate-aged leaves. On the stems, the fungus causes small, sunken brown spots that hinder the growth of the vines. The fungus thrives in high humidity, which is favorable during the rainy season, and persists on plant debris, spreading to subsequent crops. To manage brown spot disease, it is recommended to collect and destroy affected plant parts.

Green caterpillar:
Green caterpillars, which feed on leaves, are also common on Malabar spinach. The adult green caterpillar is a small moth (about 10 mm) with silver-white wings and brown margins. The larvae are light green with two white stripes running along their backs. They typically feed on the tips and undersides of leaves, causing them to curl and create holes when small. As they grow, they can defoliate the young shoots and leaves. Fully grown caterpillars pupate in dry leaves on the ground. Green caterpillars can cause damage from the early stages of leaf development, affecting both young and mature leaves, reducing photosynthesis, and stunting plant growth. Green caterpillars are polyphagous and can affect a wide range of crops throughout the year. Moths are active at night and hide during the day. A single female moth can lay between 200 and 1,000 eggs, which are scattered on the leaves. Newly hatched larvae are very mobile and spread rapidly to different parts of the plant. The life cycle of green caterpillars ranges from 30 to 40 days but can extend up to 80 days. Optimal conditions for their development are temperatures of 22-28°C and humidity around 70%. Mature larvae pupate in the soil for 5-8 days. Effective control measures include a combination of techniques depending on the crop season. Initial measures should focus on good field sanitation and thorough plowing to kill pupae in the soil. Manual methods such as light traps and bait traps can be used to capture adult moths. Protecting natural enemies and regularly inspecting fields to detect and destroy eggs and young larvae are also crucial.

Snails:
Snails are a common pest on various crops and develop rapidly. Small snails, about 1-1.5 cm in diameter, live and cause damage to leaves and other plant parts. To manage snails, field sanitation is important to prevent their breeding. Chemical treatments are often ineffective, so manual methods such as destroying egg masses or hand-picking snails in the evening are recommended to reduce their numbers.

Table 6:- Effect of compost and biochar dosage on the yield of Malabar spinach.

Fomurlas	**Number of harvested shoots per plant**	**Average shoot weight (g)**	**Individual yield (g/plant)**	**Harvested yield (t/ha)**	**Theoretical yield (t/ha)**
T1 (Control)	7	18,3	128,1	27,9	38,4
T2	8	16,4	131,2	27,3	39,3
T3	8	17.5	140,0	28,7	42,0
T4	8	17,4	139,2	28,4	41,7

T5	8	19,3	154,4	30,2	46,3
T6	8	20,1	160,8	31,2	48.2
CV%	1,0	2,0	2,2		
$LSD_{0.05}$	0,15	0,65	1,8		

Average number of shoots per plant:
The average number of shoots obtained from each Malabar spinach plant ranges from 7 to 8. There is also a significant variation in the average shoot weight among the treatments. The highest average shoot weight is observed in T6 (20.1 g/shoot), while the lowest is in T2 (16.4 g/shoot).

Individual yield:
The highest individual yield is achieved in T6 (160.8 g/plant), and the lowest in T1 (128.1 g/plant). This difference is significant at a 95% confidence level.

Theoretical yield:
The treatment with the highest theoretical yield is T6 (48.24 t/ha), followed by T5 (46.32 t/ha), with the lowest being T1 (38.43 t/ha).

Harvested yield:
The highest harvested yield is in T6 (31.2 t/ha), while the lowest is in T2 (27.3 t/ha).

Table 7:- Effect of compost and biochar dosage on the quality indicators of Malabar spinach in the first harvest.

Formulas	**Shoot length (cm)**	**Leaf length (cm)**	**Leaf width (cm)**	**Number of leaves per shoot**	**Shoot diameter (mm)**
T1 (Control)	15,44	8,09	7,23	11,60	6,20
T2	15,79	8,01	6,77	10,73	6,13
T3	16,19	7,91	6,92	11,5	6,20
T4	17,19	8,70	7,64	11,80	6,33
T5	16,37	8,99	7,87	11,80	6,33
T6	16,80	8,89	7,82	12,80	6,47
CV%	0	3,5	4,8	5,1	2,3
$LSD_{0.05}$	0,81	1,05	0,74	0,67	0,49

Length:
The treatment with the longest average shoot length was T6 (16.8 cm), while the shortest was T1 (15.44 cm). This difference is significant at a 95% confidence level.

Shoot Diameter:
The treatment with the highest average shoot diameter was T6 (6.47 mm), and the lowest was T2 (6.13 mm). This difference is significant at a 95% confidence level.

Number of Leaves per Shoot:
The treatment with the highest average number of leaves per shoot was T6 (12.8 leaves/shoot), and the lowest was T2 (10.73 leaves/shoot). This difference is significant at a 95% confidence level. The average number of leaves in T6 significantly surpassed the other treatments.

Leaf Length:
The treatment with the longest average leaf length was T6 (8.89 cm), which was higher than the other treatments.

Leaf Width:
The treatment with the widest average leaf width was T5 (7.87 cm), and the narrowest was T2 (6.77 cm).

Based on the data combined with field observations, it was found that treatment T6 produced the highest quality shoots with the longest shoots (16.8 cm), the largest shoot diameter (6.47 mm), the most leaves (12.8 leaves), and the largest and greenest leaves. The results indicate that increasing the amount of organic compost and biochar to the level of T6 resulted in significantly higher effectiveness compared to the control.

Conclusion:-

The germination rates across different fertilizer treatments are notably similar, demonstrating that the germination process is relatively uniform regardless of the specific treatment applied. This uniformity is crucial as it ensures stability and consistency in the experimental field, allowing for a reliable assessment of the impact of various treatments on subsequent growth stages.

The analysis reveals substantial differences in plant height and leaf number at various harvest stages among the different treatments. Specifically, treatment T6 consistently shows superior growth parameters compared to other treatments. For instance, T6 not only achieves the tallest plants but also has the highest number of leaves per plant, which suggests that the application of organic compost and biochar in T6 significantly enhances plant growth and development.

During all growth stages, T6 demonstrates the highest Leaf Area Index (LAI), which is indicative of better leaf development and coverage. LAI is a critical measure of how effectively plants capture light for photosynthesis. The superior LAI in T6 implies that this treatment promotes more robust leaf growth and a higher capacity for photosynthesis, contributing to overall plant vigor.

The study highlights the complexity of managing pests and diseases affecting Malabar spinach, including brown spot disease caused by Cercospora sp., green caterpillars, and snails. Effective management practices are essential to control these issues and ensure optimal yield and quality. The research underscores the need for integrated pest management strategies, including field sanitation, manual removal of pests, and protection of natural enemies.

Treatment T6 stands out for achieving the highest values in several key performance metrics, including individual yield, theoretical yield, and harvested yield. Additionally, T6 exhibits the longest shoot length, largest shoot diameter, and highest number of leaves per shoot. These metrics indicate that T6 not only enhances the quantity of the crop but also improves its overall quality compared to other treatments.

The findings suggest that treatment T6 provides the most significant improvements in the quality of Malabar spinach. Specifically, T6 produces the longest, thickest shoots and the largest, greenest leaves compared to the control and other treatments. This enhancement in quality, combined with the higher yield, demonstrates that increasing the amount of organic compost and biochar to the T6 level has a markedly positive effect on both the quantity and quality of Malabar spinach.

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