



Application of Goat Manure and Coconut Shell Biochar to Improve the Growth and Yield of Lettuce (*Lactuca sativa* L.) on Inland Peat Soil

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ARTICLE INFO	ABSTRACT
Published Online: 08 September 2026	This study evaluated the effects of goat manure and coconut shell biochar on the growth and yield of lettuce (<i>Lactuca sativa</i> L.) cultivated in inland peat soil and identified the most effective combination of application rates. The experiment was conducted from March to July 2026 using a factorial completely randomized design with two factors and three replicates. Goat manure was applied at 0, 10, and 20 t/ha, equivalent to 0, 48, and 96 g/polybag, while coconut shell biochar was applied at 0, 5, and 10 t/ha, equivalent to 0, 24, and 48 g/polybag. The nine treatment combinations produced 27 experimental units. Data were analyzed using analysis of variance, followed by Tukey's honestly significant difference test at the 5% significance level. The combined application of goat manure and coconut shell biochar significantly affected lettuce growth and yield. The A2B2 treatment, consisting of 96 g/polybag goat manure and 48 g/polybag coconut shell biochar, produced the best overall response, with a plant height of 26.20 cm, 13.67 leaves, a leaf area of 166.26 cm ² , a fresh biomass weight of 121.67 g, and a shoot fresh weight of 117.00 g. These findings indicate that combining goat manure with coconut shell biochar can improve lettuce productivity on inland peat soil and may serve as a practical and sustainable soil management strategy.
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KEYWORDS: <i>Lactuca sativa</i> L., goat manure, coconut shell biochar, peat soil	

I. INTRODUCTION

Lettuce (*Lactuca sativa* L.) is a leafy vegetable with considerable economic value in Indonesia and provides nutritional benefits to consumers. Its relatively short production cycle also allows growers to plant several crops each year, offering a steady source of income. However, Wawan and Fikrawati (2021) reported that lettuce cultivation on peatlands is constrained by the inherent properties of peat soil, particularly its low fertility and acidic reaction. Although peat contains large amounts of organic matter, it is generally deficient in essential nutrients such as nitrogen, phosphorus, and potassium. Its low pH further limits nutrient availability and uptake. Peat soil also has low bulk density and very high water-holding capacity, which may restrict root development and, in turn, reduce lettuce growth and yield. Biochar has received considerable attention in recent years as a possible means of addressing these limitations. Produced through the pyrolysis of organic materials, biochar can improve cation exchange capacity, water retention, and nutrient-use efficiency. Saleh et al. (2023) found that coconut shell biochar increased the availability of essential nutrients,

particularly potassium (K), and supported soil microbial activity, thereby promoting vegetative growth, including plant height, leaf development, and root growth. Goat manure is another promising amendment because it is inexpensive, readily available, and supplies organic nutrients. Peni et al. (2023) showed that goat manure significantly improved lettuce growth and yield. Combining goat manure with biochar therefore warrants further investigation. Biochar can improve the chemical properties of peat soil and enhance nutrient availability and plant nutrient uptake, with responses varying according to biochar feedstock and application rate (Maftu'ah and Nursyamsi, 2019). Together, these materials may create a more stable rhizosphere in which nutrients from goat manure are released gradually and remain available to lettuce plants for longer periods (Peni et al., 2023).

II. MATERIALS AND METHODS

A. Time and Location

The study was conducted from March to July 2026 at the Experimental Garden Facility (IKP), Laboratory of the Department of Agronomy, Faculty of Agriculture,

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B. Materials and Equipment

The materials used were coconut shell biochar, dolomite lime, peat soil, Grand Rapids lettuce seeds, goat manure, basal NPK fertilizer, and 30 x 30 cm polybags. The equipment included a simple pyrolysis drum, a 10-mesh sieve, tarpaulins, analytical and digital balances, graduated cylinders, seedling trays, a hand sprayer, resealable plastic bags, a hoe, sacks, a ruler, a camera, and stationery.

C. Experimental Design

The experiment used a factorial completely randomized design with two factors and three replicates. Factor A was the goat manure rate: A0, 0 t/ha (control); A1, 10 t/ha (48 g/polybag); and A2, 20 t/ha (96 g/polybag). Factor B was the coconut shell biochar rate: B0, 0 t/ha (control); B1, 5 t/ha (24 g/polybag); and B2, 10 t/ha (48 g/polybag). The two factors produced nine treatment combinations. Each treatment was replicated three times, resulting in 27 experimental units.

D. Data Analysis

The data were subjected to analysis of variance (ANOVA) at a 5% significance level ($\alpha = 0.05$). Significant effects were further examined using Tukey's honestly significant difference (HSD) test at the same significance level.

III. RESULTS AND DISCUSSION

A. Results

1) Plant Height (cm)

Table I. Mean Plant Height of Lettuce

Plant Age	Goat Manure	Coconut Shell Biochar			Mean (A)
		B0	B1	B2	
7	A0	3.00 a	4.17 a	2.67 a	3.28
		A	A	A	
	A1	3.67 a	4.17 a	3.83 a	3.89
		A	A	A	
	A2	2.67 a	2.33 a	10.30 b	5.10
		A	A	B	
Mean (B)		3.11	3.56	5.60	
5% HSD Value					
A*B = 3.13					
14	A0	4.67	7.17	4.17	5.33
		A	A	A	
	A1	6.67	6.50	6.17	6.44
		A	A	A	
	A2	5.00	4.00	6.83	5.28
		A	A	A	
Mean (B)		5.44	5.89	5.72	

5% HSD Value						A*B = 4.37
21	A0	9.83	13.67	9.00	10.83	
		A	A	A		
	A1	12.00	13.17	12.83	12.67	
		A	A	A		
	A2	9.83	9.83	13.33	11.00	
		A	A	A		
Mean (B)		10.56	12.22	11.72		
5% HSD Value						A*B = 5.86
28	A0	16.00	19.83	15.50	16.50	
		A	A	A		
	A1	19.00	18.67	17.50	18.06	
		A	A	A		
	A2	14.50	15.67	19.17	17.39	
		A	A	A		
Mean (B)		17.11	18.39	16.44		
35	A0	18.33 a	21.50 a	16.87 a	18.90	
		A	A	A		
	A1	21.33 a	21.77 a	20.80 ab	21.30	
		A	A	A		
	A2	17.30 a	20.17 a	26.20 b	21.22	
		A	A	B		
Mean (B)		18.99	21.14	21.29		
5% HSD Value						A*B = 8.14
Note: Mean values followed by the same letter within the same row are not significantly different according to Tukey's HSD test at the 5% level; A0: 0 t/ha (control); A1: 10 t/ha (48 g/polybag); A2: 20 t/ha (96 g/polybag); B0: 0 t/ha (control); B1: 5 t/ha (24 g/polybag); B2: 10 t/ha (48 g/polybag).						
2) Number of Leaves						
Table II. Mean Number of Leaves of Lettuce						
Plant Age	Goat Manure	Coconut Shell Biochar			Mean (A)	
7	A0	3.67	4.33	4.00	4.00	
		A	A	A		
	A1	4.67	3.67	4.00	4.11	
		A	A	A		
	A2	4.00	3.67	4.00	3.89	
		A	A	A		
Mean (B)		4.11	3.89	4.00		
14	A0	5.00	5.33	5.67	5.33	
		A	A	A		
	A1	5.00	6.33	5.67	5.67	

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		A	A	A	
	A2	5.00	5.67	5.67	5.44
		A	A	A	
Mean (B)		5.00	5.78	5.67	
	A0	5.67	6.33	6.67	6.22
		A	A	A	
21	A1	6.33	6.67	7.33	6.78
		A	A	A	
	A2	6.33	6.67	7.00	6.67
		A	A	A	
Mean (B)		6.11 a	6.56 ab	7.00 b	
5% HSD Value		B = 0.65			

	A0		7.00	7.67	8.00	7.56
			A	A	A	
28	A1		6.67	7.33	8.00	7.33
			A	A	A	
	A2		7.33	7.00	9.00	7.78
			A	A	A	
Mean (B)		7.00 a	7.33 a	8.33 b		
5% HSD Value		B = 0.73				
	A0		7.67 a	8.33 a	9.33 a	8.44
			A	AB	B	
35	A1		7.67 a	8.33 a	9.67 a	8.56
			A	AB	B	
	A2		11.67 b	8.33 a	13.67 b	11.22
			B	A	C	
Mean (B)		9.00	8.33	10.89		
5% HSD Value		A*B = 1.90				

Note: Mean values followed by the same letter within the same row are not significantly different according to Tukey's HSD test at the 5% level; A0: 0 t/ha (control); A1: 10 t/ha (48 g/polybag); A2: 20 t/ha (96 g/polybag); B0: 0 t/ha (control); B1: 5 t/ha (24 g/polybag); B2: 10 t/ha (48 g/polybag).

3) Leaf Area (cm²)

Table III. Mean Leaf Area of Lettuce

Goat Manure	Coconut Shell Biochar			Mean (A)
	B0	B1	B2	
A0	110.99	117.91	126.00	118.30
	A	A	A	
A1	111.14	131.30	137.86	126.77
	A	A	A	
A2	113.07	134.71	166.26	138.01
	A	A	A	
Mean (B)		111.73 a	127.97 ab	143.37 b
5% HSD Value		B = 29.05		

4) Fresh Biomass Weight

Table IV Mean Fresh Biomass Weight of Lettuce

Goat Manure	Coconut Shell Biochar			Mean (A)
	B0	B1	B2	
A0	32.00 a	56.33 a	81.67 a	56.67
	A	B	C	
A1	53.67 b	47.33 a	61.67 a	54.22
	A	A	A	
A2	63.67 b	81.00 b	121.67b	88.78
	A	A	B	
Mean (B)		49.78	61.56	88.33
5% HSD Value		A*B = 28.85		

5) Shoot Fresh Weight

Table V Mean Fresh Biomass Weight of Lettuce

Goat Manure	Coconut Shell Biochar			Mean (A)
	B0	B1	B2	
A0	30.33 a	54.00 a	79.67 a	54.67
	A	B	C	
A1	51.33 b	45.00 a	59.67 a	52.00
	A	A	A	
A2	61.33 b	79.00 b	117.00 b	85.78
	A	A	B	
Mean (B)		47.67	59.33	85.44
5% HSD Value		A*B = 28.82		

6) Root Fresh Weight

Table VI Mean Fresh Biomass Weight of Lettuce

Goat Manure	Coconut Shell Biochar			Mean (A)
	B0	B1	B2	
A0	1.67 a	2.33 a	2.00 a	2.00
	A	A	A	
A1	2.33 a	2.33 a	2.00 a	2.22
	A	A	A	
A2	2.33 a	2.00 a	4.67 b	3.00
	A	A	B	
Mean (B)		2.11	2.22	2.89
5% HSD Value		A*B = 1.90		

7) Dry Biomass Weight

Table VII Mean Fresh Biomass Weight of Lettuce

Goat Manure	Coconut Shell Biochar			Mean (A)
	B0	B1	B2	
A0	3.22	6.15	4.27	4.55
	A	A	A	
A1	2.62	5.65	4.36	4.21
	A	A	A	
A2	3.47	6.03	11.87	7.12
	A	A	A	
Mean (B)		3.10 a	5.94 ab	6.83 b
5% HSD Value		B = 3.18		

8) Shoot Dry Weight

Table VIII Mean Shoot Dry Weight of Lettuce

Goat Manure	Coconut Shell Biochar			Mean (A)
	B0	B1	B2	
A0	3.09 A	5.84 A	4.06 A	4.33
A1	2.45 A	5.30 A	4.23 A	3.99
A2	3.32 A	5.82 A	11.18 A	6.77
Mean (B)	2.95 a	5.65 ab	6.49 b	
5% HSD Value	B = 2.92			

9) Root Dry Weight

Table IX Mean Root Dry Weight of Lettuce

Goat Manure	Coconut Shell Biochar		Mean (B)
	B0	B1	
A0	0.13 A	0.31 A	0.15
A1	0.17 A	0.33 A	0.29
A2	0.16 A	0.22 A	0.35
Mean (A)	0.22	0.21	0.35

B. Discussion

Overall, goat manure and coconut shell biochar improved the growth and yield of lettuce cultivated in inland peat soil. Their combined application increased nearly all measured variables, including plant height, number of leaves, leaf area, fresh biomass weight, shoot fresh weight, root fresh weight, dry biomass weight, shoot dry weight, and root dry weight. The most consistent response was obtained with 96 g/polybag goat manure combined with 48 g/polybag coconut shell biochar. This result suggests that the two organic amendments acted synergistically by improving peat soil conditions and increasing the efficiency of plant nutrient uptake. The improvement in growth was closely related to the ability of goat manure to supply macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), as well as micronutrients needed during vegetative growth (Mounirou et al., 2023). Nitrogen is essential for chlorophyll and protein formation and therefore supports stem and leaf growth. Phosphorus promotes root development and energy metabolism, whereas potassium regulates enzyme activity, photosynthesis, and the translocation of photoassimilates to plant organs (Hawkesford et al., 2012). A more adequate nutrient supply allowed the plants to grow more effectively and accumulate greater vegetative biomass. In addition to supplying nutrients, goat manure improved the physical, chemical, and biological properties of the soil. The added

organic matter enhanced soil aggregation, water-holding capacity, cation exchange capacity, and the activity of microorganisms involved in organic matter decomposition and nutrient mineralization (Du et al., 2020; Diacono and Montemurro, 2010). These changes created a more favorable rooting environment, enabling roots to develop more fully and take up water and nutrients more efficiently. Coconut shell biochar also made an important contribution to plant growth and yield. Its porous structure increased soil porosity, improved aeration and water retention, and reduced nutrient losses through leaching (Edeh et al., 2020; Laird et al., 2010). In peat soil, which is generally acidic and has low fertilizer-use efficiency, biochar acted as a soil amendment that retained nutrients released from goat manure in the root zone for a longer period.

The combined application of goat manure and coconut shell biochar increased lettuce plant height, with A2B2 (96 g/polybag goat manure and 48 g/polybag biochar) producing the tallest plants. A2B2 also gave the best results for nearly all measured variables: plant height of 26.20 cm, 13.67 leaves, leaf area of 166.26 cm², fresh biomass weight of 121.67 g, shoot fresh weight of 117.00 g, root fresh weight of 4.67 g, dry biomass weight of 11.87 g, and shoot dry weight of 11.18 g. Root dry weight also tended to be higher under this treatment, although differences among treatments were not statistically significant. These improvements indicate that the combination of goat manure and coconut shell biochar enhanced the physical, chemical, and biological properties of peat soil, increased nutrient availability and retention, and created a more favorable rooting environment. The resulting conditions supported water and nutrient uptake and allowed photosynthesis to proceed more effectively, leading to greater vegetative growth and biomass accumulation. Based on these findings, A2B2 can be recommended as the most effective treatment for improving the growth and yield of lettuce cultivated in peat soil.

C. Laboratory Analysis Results

Laboratory analysis showed that the peat soil had a pH (H₂O) of 5.18, total N of 0.76%, Bray I P of 101.37 ppm, and exchangeable K of 0.21 me/100 g (UPA Laboratorium Terpadu, 2026). The pH indicated that the soil was slightly acidic; consequently, the availability of several nutrients, particularly phosphorus and potassium, may not have been fully optimal for lettuce growth. Although the total N content was relatively high, nitrogen in peat soil is not always immediately available because much of it is bound in organic matter and must first undergo mineralization (Choo et al., 2022). Bray I P was high, whereas exchangeable K was low, making potassium an important consideration in fertilizer management. Goat manure had a pH of 8.27, total N of 1.59%, Bray I P of 280.64 ppm, and exchangeable K of 0.28 me/100 g (UPA Laboratorium Terpadu, 2026). These

values show that goat manure was alkaline and contained more N and P than the peat soil. It could therefore supply nitrogen for vegetative growth and leaf formation and phosphorus for root development (Hawkesford et al., 2012). Its alkaline reaction may also help reduce peat soil acidity (Ano & Ubochi, 2007). Coconut shell biochar had the highest pH (9.05), with total N of 0.58%, Bray I P of 112.26 ppm, and exchangeable K of 0.31 me/100 g (UPA Laboratorium Terpadu, 2026). Because its total N content was lower than that of goat manure, biochar was not the main nitrogen source. Its primary role was as a soil amendment. Its alkaline reaction may raise peat soil pH, while its porous structure improves aeration, porosity, water retention, and nutrient-holding capacity (Edeh et al., 2020; Laird et al., 2010).

(Utami et al., 2024). The exchangeable K content of biochar (0.31 me/100 g) was higher than that of peat soil (0.21 me/100 g) and goat manure (0.28 me/100 g), indicating that biochar may also increase potassium availability in the growing medium (Maftu'ah & Nursyamsi, 2019). When peat soil, goat manure, and coconut shell biochar are combined, their properties can complement one another.

IV. CONCLUSION

The results indicate that goat manure and coconut shell biochar can improve lettuce growth and yield on inland peat soil. The best treatment produced a plant height of 26.20 cm, 13.67 leaves, a fresh biomass weight of 121.67 g, a shoot fresh weight of 117.00 g, and a root fresh weight of 4.67 g.

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