RESEARCH ON THE PRODUCTION OF BIOCHAR FROM COCONUT FIBER AND SOYBEAN STALKS TO ENHANCE SOIL QUALITY AND BOOST CORN YIELD IN NORTHERN VIETNAM

Nguyen Tuan Khoi
Doctor of Biological Sciences, Faculty of Agronomy, Bac Giang Agriculture and Forestry University, Viet Yen town, Bac Giang province, VietNam
https://doi.org/10.5281/zenodo.11087650

Abstract

Biochar, a byproduct of biomass pyrolysis, possesses a high surface area and cation exchange capacity. Corn, being a crop that extracts significant nutrients from the soil, contributes to the rapid depletion of soil fertility, especially under monoculture crop rotations. To sustain soil fertility, it is imperative to implement a suite of measures aimed at its preservation. The utilization of biochar as a means to enhance soil quality represents a novel approach that has seen limited adoption in Vietnam.

We undertook a study to assess the soil amendment potential and investigate the impact of biochar derived from coconut fiber and soybean stalks on the growth, development, and yield of the NK4300 corn variety. The research was conducted during the 2019 winter cropping season in Northern Vietnam, focusing on the NK4300 corn variety, a product of Syngenta Vietnam. The timeline for biochar material preparation spanned from August 25, 2019, to September 5, 2019, with corn seed sowing occurring on September 15, 2019.

The experimental results indicated that the utilization of biochar for the NK4300 corn variety led to notable enhancements in leaf area, leaf area index, and the effective percentage of corn compared to non-utilization. Yields of the NK4300 corn variety increased by 2.9% to 15.4% with the application of biochar.

This research aims to produce biochar from coconut fiber and soybean stalks to enhance soil fertility and consequently augment corn yield. The experiment demonstrated that the highest yield of the NK4300 corn variety reached 58.4 c/ha, achieved through the application of 150 kg N + 90 kg P_2O_5 + 90 kg K_2O + 1 t of biochar/ha. Utilizing biochar resulted in a yield increase of 7.8 c/ha compared to its non-utilization

Keywords: Soil improvement, biochar, coir, soybean stalk, NK4300, degraded soil.

INTRODUCTION

Maize production in Vietnam encounters challenges attributed to escalating demand and diminishing arable land, primarily due to increased industrialization, population expansion, and mangrove encroachment [1]. Climate change significantly impacts corn growth and development. Soil degradation during corn cultivation is another pressing issue, necessitating measures to enhance soil fertility.

Soil is indispensable for plant growth and development, profoundly influencing crop yield quality. However, continuous cultivation exhausts soil nutrients over time, failing to meet subsequent crop nutrient requirements. Moreover, excessive chemical fertilizer usage acidifies and salinizes the soil, impeding plant growth. Hence, annual soil improvement is imperative to foster an optimal soil environment devoid of detrimental factors, facilitating optimum tree growth. Soil enhancement methods include tillage, liming, legume cultivation, green manuring, and organic and manure fertilizer application.

In Vietnam, the predominant approach to soil fertility enhancement involves organic fertilizer utilization [2]. However, organic fertilizers suffer drawbacks such as low nutrient content and high transportation costs [2]. Biochar production and application offer a solution to challenges associated with organic fertilizers. Biochar boasts minimal environmental pollutants [2], absence of soil pathogenic bacteria [2], and shorter production duration compared to organic fertilizers (approximately 2 days versus 2-4 months). Moreover, establishing biochar pyrolysis facilities near usage sites reduces transportation expenses.

Nevertheless, biochar's low macronutrient content necessitates supplementing it with organic or mineral fertilizers, advocating for a combined approach.

Given these practical imperatives, this research aims to investigate and produce biochar from coir stalks and soybeans to enhance soil quality and augment corn yield in Northern Vietnam. We anticipate that the research findings presented herein will serve as a foundation for further exploration into organic material selection, production process design, and biochar application as a soil amendment, fostering increased crop yields and mitigating greenhouse gas emissions.

MATERIALS AND METHODS OF RESEARCH

The research was conducted during the 2019 winter cropping season in Northern Vietnam, focusing on the NK4300 corn variety, a product of Syngenta Vietnam. The research comprised two stages:

Stage 1: Preparation of biochar materials. The deadline for material preparation ranged from August 25, 2019, to September 5, 2019.

Stage 2: Implementation of field experiments using the NK4300 corn cultivar with pre-existing biochar material samples. The sowing period commenced on September 15, 2019.

The experimental design followed a completely randomized layout with 5 treatments and 3 replicates, resulting in a total of 15 experimental units. Each plot measured 14 m^2, thus yielding a total experimental area of 210 m^2.

The specific fertilizer formulas per hectare were as follows:

T1: 150 kg N + 90 kg P_2O_5 + 90 kg K_2O (Do not use biochar - control)
T2: 150 kg N + 90 kg P_2O_5 + 90 kg K_2O + 1 ton biochar
T3: 150 kg N + 90 kg P_2O_5 + 90 kg K_2O + 0.8 tons biochar
T4: 150 kg N + 90 kg P_2O_5 + 90 kg K_2O + 0.6 tons biochar
T5: 150 kg N + 90 kg P_2O_5 + 90 kg K_2O + 0.4 tons biochar

Experimental scheme

Security strip

T3	T2	T1	T4	T5	Repeat 1
T4	T5	T3	T2	T1	Repeat 2
T1	T4	T5	T3	T2	Repeat 3

Security strip (between rows, and on the left and right sides): Security strip

Biochar is produced from a blend of coconut fiber and soybean stalks. These materials are mixed in specific proportions and then dried under anaerobic conditions at 450°C for a duration of 1 hour.

[Table 1]

Results of the quality analysis of biochar from coconut palm Stems and soybeans

Formula	C (%)	Total N (%)	Total P_2O_5 (%)	Total K20 (%)	CaO (%)	MgO (%)	SiO2 (%)
Ratio 5:1	69,832	0,835	0,378	4,502	0,528	0,538	2,25
Ratio 4:1	67,352	0,864	0,371	4,496	0,526	0,531	2,25
Ratio 3:1	62,267	0,907	0,375	4,489	0,532	0,534	2,23
Ratio 2:1	***61,824***	***0,926***	***0,382***	***4,521***	***0,522***	***0,521***	***2,26***

The NK4300 corn variety, developed by Syngenta Vietnam, was utilized in conjunction with NPK fertilizer. The soil within the study areas is classified as poor gleysoic according to FAO standards. Chemical analysis revealed acidic soil conditions (pH-H_2O ranging from 5.01 to 5.29, pH-KCl from 4.19 to 4.49). Soil cation exchange capacity varies from low to medium-low, ranging from 9.24 to 10.47 mg eq/100 g of soil. Base saturation of the soil is only 22% to 29%. Organic carbon and total nitrogen content in the arable soil layer were found to be moderate, with levels ranging from 1.21% to 1.53% OC and 0.12% to 0.15% N, respectively. Total and readily available phosphorus content in the arable soil layer varied from rich to very rich (0.11% to 0.15% P_2O_5 and 10.09 to 23.48 mg P_2O_5/100 g soil). However, total and readily available potassium content in the surface soil layer were very low (total potassium ranging from 0.19% to 0.58% K_2O, and readily available potassium ranging from 5.79 to 15.08 mg K_2O /100 g of soil) [3].

The soil's granulometric composition ranged from sandy loam to loam, with clay particles comprising 13% to 17% in the surface layer and 16% to 20% in the subsoil layer. Topsoil density varied from 1.23 to 1.26 g/cm3, with porosity ranging from 50% to 52%. Low organic matter and potassium content in the gray soil are significant limitations in agricultural production and necessitate remediation [3].

Based on the analysis results presented in Table 1 and considering the biological characteristics of corn, a biochar sample at a 2:1 ratio (bold italics) was selected for the field experiment.

Monitoring parameters included growth duration, plant height, leaf count, leaf area, leaf area index, lodging resistance, effective corn grain count, corn grain effectiveness percentage, 1000-grain weight, theoretical yield, and actual yield.

The data was statistically analyzed using Excel and IRRISTAT 5.0.

RESEARCH RESULTS AND DISCUSSION

Monitoring the growth duration, stages, and development of the studied maize crop is crucial for crop management, variety selection, and assessing the impact of effective agronomic practices. The growth duration of corn varieties spans from sowing to full maturity and is subject to variations based on ecological regions, seasons, and cultivation practices.

Germination serves as a vital indicator of seed quality, influenced by the variety and external conditions during sowing. Table 2 demonstrates that the germination rates of corn varieties range from 86.3% to 92.3%.

[Table 2]

Effect of Biochar from coconut fiber and soybean stalks on the growth time of corn variety NK4300

Formula	Germination rate (%)	Growth time
T1	86,3	108
T2	92,3	106
T3	91,1	107
T4	90,3	108
T5	89,6	106

The growth duration was calculated from sowing to physiological maturity. Following the processes of pollination and fertilization, corn grains undergo formation and development; this period is influenced by various factors including varieties, weather conditions, climatic factors, and agricultural practices. The ripening phase is identified by the appearance of a distinct black spot at the base of the seed [4]. The findings outlined in Table 2 indicate that the growth duration of the NK4300 corn variety across the different treatments ranged from 106 to 108 days, categorizing it within the group of medium-early maturing varieties.

Plant height serves as a significant parameter associated with lodging resistance, plant density, and yield. It is measured as the distance from the ground to the tips of the upright leaves [6]. This parameter accurately reflects the growth and development of corn, allowing for the determination of growth rates during various stages. Plant height is a morphological trait influenced by genetic factors, environmental conditions, and agronomic practices. The monitoring results are detailed in Table 3.

[Table 3]

Effect of biochar from coir stalks and soybeans on the growth of corn varieties NK4300

Formula	5th October (cm)	12th October (cm)	19th October (cm)	26th October (cm)	3rd November (cm)	10th November (cm)
T1	55,2	78,7	105,3	138,5	176,1	207,3
T2	56,7	81,2	111,0	145,6	185,1	211,1
T3	55,3	80,3	108,2	140,9	180,0	213,2
T4	55,2	79,1	106,3	140,6	182,2	217,3
T5	55,3	79,2	106,2	140,3	183,6	216,3
CV%	2,9	2,0	5,4	5,3	1,8	2,8
$LSD_{0,05}$	3,2	3,1	10,7	13.8	6,3	10,4

During the study, it was observed that the NK4300 corn variety, when fertilized with biochar, exhibited significant growth in height. By the 6th week of observation, the tallest plants were recorded in the T4 group, while the shortest plants were observed in the T1 group. However, no statistically significant differences in plant height growth were detected among the experimental treatments, with a confidence level of 95%.

Distinct biochar formulations displayed varying growth rates throughout each week of observation. From the first to the second week of observation, plant height growth rates ranged from 23.5 to 25.0 cm/week/plant, while from the second to the third week of observation, they ranged from 26.6 to 29.8 cm/week/plant.

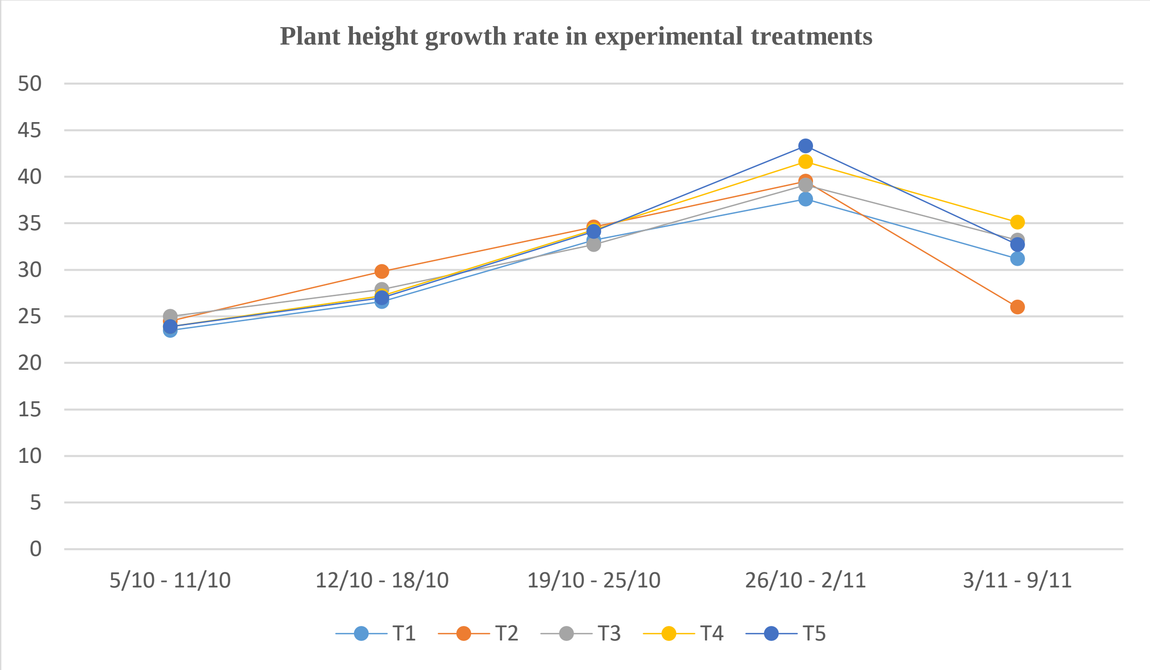
During the period from the 3rd to the 5th week of observation, a rapid growth stage was evident, characterized by vigorous corn plant growth, rapid leaf expansion, and strong root development. By the 4th to 5th week of observation, corn plants reached their peak growth rate across all experimental variants, ranging from 37.6 to 43.3 cm/week. Subsequently, there was a tendency for the rate of height growth to decelerate by the 6th week of observation, ranging from 26.0 to 35.1 cm/week. The progression of tree height growth rates is summarized in Table 4 and depicted in Figure 1.

[Table 4]

The effect of biochar from coir and soybean stalks on plant height growth of the NK4300 corn variety

Formula	From 5th-October to 12th-October cm/plant/week	From 12th-October to 19th-October cm/plant/week	From 19th-October to 26th-October cm/plant/week	From 26th-October to 3rd-November cm/plant/week	From 3rd-November to 10th-November cm/plant/week
T1	23,5	26,6	33,2	37,6	31,2
T2	24,5	29,8	34,6	39,5	26,0
T3	25,0	27,9	32,7	39,1	33,2
T4	23,9	27,2	34,3	41,6	35,1
T5	23,9	27,0	34,1	43,3	32,7

Graph 1: Plant height growth rate in experimental treatments



The number of leaves serves as an indicator reflecting the growth and development of corn over time. Corn leaves play a crucial role in utilizing light and conducting photosynthesis to produce food for the plant and its corn kernels.

Leaf count and longevity are closely linked to leaf area and leaf area index. A rapid leafing rate signifies robust plant growth, while a slower rate suggests otherwise. Corn, being a C4 plant adapted to high light intensity, exhibits a light utilization efficiency of 4-5%, in contrast to C3 plants with a utilization efficiency of 3-4% [7].

Corn varieties possess an optimal stem structure, with leaves positioned at a favorable angle relative to the slender stem. Larger leaves facilitate higher light capture. Additionally, the presence of trichomes on leaf surfaces can reduce water evaporation and curling. Structurally, these trichomes can function as gutters, facilitating water drainage [7].

Leaves located along the midsection of the stalk experience the most robust growth and significantly contribute to nutrient transport within the corn plant. Consequently, monitoring leaf growth is essential for implementing appropriate agronomic practices to ensure optimal leaf development.

[Table 5]

Effect of biochar from coir and soybean stalks on the growth of leaves of corn variety NK4300

Formula	5th October (leaves)	12th October (leaves)	19th October (leaves)	26th October (leaves)	3rd November (leaves)	10th November (leaves)
T1	5,1	6,9	8,8	10,8	13,2	17,9
T2	5,2	7,0	9,1	11,4	14,0	18,9
T3	5,2	7,0	8.9	11,1	13,9	18,9
T4	5,1	7,0	9,1	11,2	13,9	18,9
T5	5,2	7,0	9,0	11,1	13,8	18,7
CV%	1,2	2,3	2,5	1,7	1,5	0,7
$LSD_{0,05}$	0,1	0,3	0,4	0,4	0,4	0,2

In the following weeks, we observed no significant difference in the leaf count of the NK4300 corn variety among treatments (at a confidence level of 95%). The number of leaves in the experimental groups steadily increased, reaching its peak at the 6th week of observation. Throughout the 6-week monitoring period, the leaf count consistently reached its maximum when treated with T2 fertilizer, corresponding to the application of 1 ton of biochar/ha.

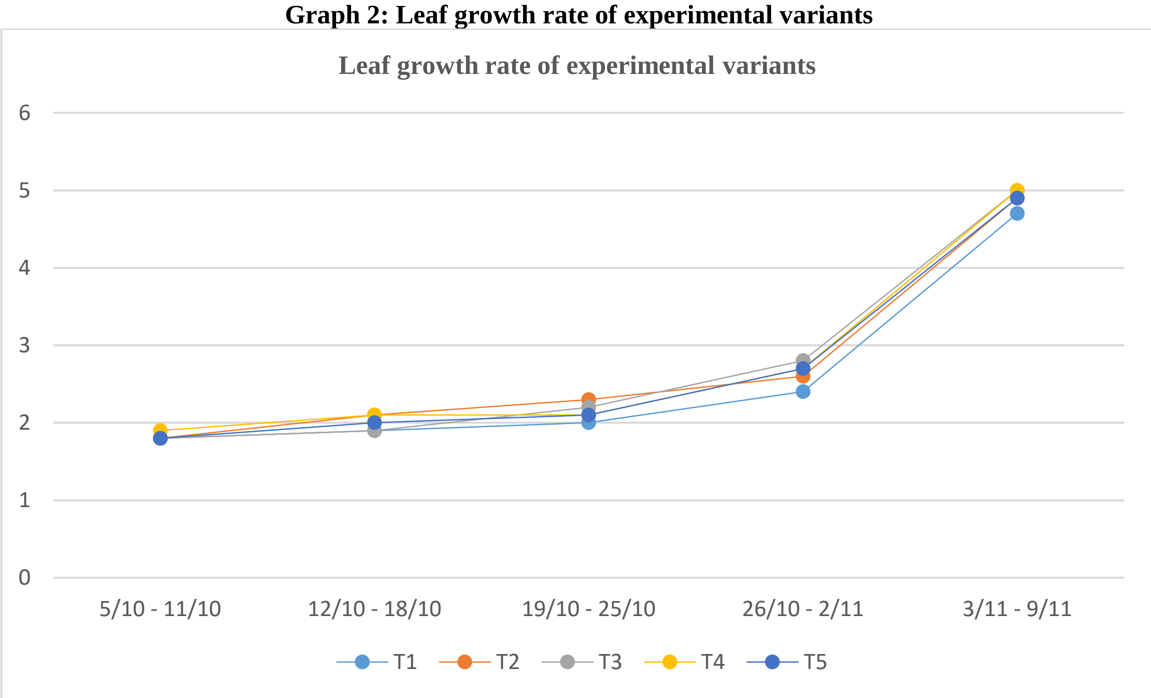
[Table 6]

Effect of biochar from coir and soybean stalks on the growth rate of leaves of corn variety NK4300

Formula	From 5th-October to 12th-October leaves/plant/week	From 12th-October to 19th-October leaves/plant/week	From 19th-October to 26th-October leaves/plant/week	From 26th-October to 3rd-November leaves/plant/week	From 3rd-November to 10th-November leaves/plant/week
T1	1,8	1,9	2,0	2,4	4,7
T2	1,8	2,1	2,3	2,6	4,9
T3	1,8	1,9	2,2	2,8	5,0
T4	1,9	2,1	2,1	2,7	5,0
T5	1,8	2,0	2,1	2,7	4,9

Table 6 illustrates that during the initial stages, the leaf growth rate of the treatments exhibited a relatively sluggish pace, gradually intensifying thereafter. From October 5 to October 12, the leaf production rates ranged between 1.8 and 1.9 leaves/plant/week. Subsequently, during the week spanning from October 19 to 26, foliage increased further, reaching between 2 and 2.3 leaves/plant/week. In the ensuing weeks, corn plants continued their growth trajectory, peaking at a rate of 4.7-5 leaves/plant/week. The leaf growth rates are depicted in Table 6 and Graph 2.

Graph 2: Leaf growth rate of experimental variants



Final plant height constitutes a critical parameter in corn breeding, intimately linked to corn growth, development, stability, yield, and mechanized harvesting. It was measured at the completion of flowering, extending from ground level to the first branching point [8]. Corn, being a prototypical cross-pollinated plant, encounters challenges with pollination if plant height and ear size are diminished. Conversely, taller plants in low-light environments exhibit decreased resistance to leaf drop.

[Table 7]

Effect of biochar from coir and soybean stalks on the morphological traits of the corn variety NK4300

Formula	Final tree height (cm)	Corn height (cm)	Corn Height Ratio (%)
T1	173,7	79,7	45,9
T2	183,0	86,9	47,5
T3	177,7	82,2	46,3
T4	175,8	82,9	47,1
T5	174,1	80,3	46,1
CV%	2,0	3,4	3,0
LSD 0.05	6,5	5,3	2,7

The data presented in Table 7 indicates that the final plant height of maize ranges from 173.7 cm to 183 cm. Maize plants treated with biochar at the T2 level exhibited the tallest final plant height of 183 cm, surpassing those without biochar application (measuring 173.7 cm in total). This disparity is statistically significant at the 95% confidence level. Corn height serves as a crucial indicator for assessing growth status, shatter resistance, and mechanization capability of corn varieties.

Varieties with shorter corn heights typically exhibit lower mechanization potential, hinder the pollination process, and are more susceptible to pest and disease damage. The tassel height was calculated from the base to the first effective tassel joint. The tassel height capability is contingent upon variety characteristics and cultivation conditions; generally, varieties with shorter growing seasons display lower tassel heights compared to those with longer growing seasons.

Corn stalk heights varied among treatments, ranging from 79.7 cm to 86.9 cm. However, the difference in corn height between biochar treatments was not statistically significant (at the 95% confidence level). The positioning of the corn cob influences the plant's shatter resistance and pollinator acceptance. Proper cob placement facilitates efficient pollen reception, fertilization, and nutrient accumulation, thereby enhancing yield potential.

Our findings indicate that all experimental treatments yielded satisfactory cob heights (ranging from 45.9% to 47.5%). Photosynthesis plays a crucial role in determining crop yield, accounting for 90-95% of yield variation. The leaf green index, reflecting chlorophyll accumulation in leaves, serves as a simpler alternative to complex chlorophyll measurement methods (SPAD). Experimental results are summarized in Table 8.

[Table 8]

Effect of Biochar from coir stalks and soybeans on the SPAD of corn variety NK4300

Formula	Period 7-9 leaves	Curling period	Milk ripening period
T1	44,0	47,1	50,4
T2	44,3	48,3	51,0
T3	45,0	47,9	52,1
T4	45,6	48,9	50,6
T5	45,6	48,5	50,8
CV%	1,9	2,3	3,9
LSD 0.05	1,6	2,1	3,7

Table 8 displays the variation of SPAD readings across different observation periods, with peak values observed during the tasseling stage. During the 7-9 leaf stage, SPAD indices of the experimental treatments ranged from 44 to 45.6. Subsequently, during the tasseling phase, SPAD readings ranged from 47.1 to 48.9, and during the reproductive stage, SPAD levels ranged from 50.4 to 52.1.

Corn leaves serve as the primary nutrient-absorbing organs responsible for photosynthesis, generating dry matter for the plant. Approximately 60% of the dry matter in seeds is transported by leaves, while 38% is transported by stems [9].

Corn leaves are characterized by numerous stomata, with an average corn leaf containing approximately 2-6 million stomata. Stomata respond swiftly to external conditions, partially closing to regulate transpiration rates. Additionally, the curvature of corn leaves facilitates the capture and channeling of water from the leaf surface to the base of the plant, even under minimal rainfall conditions. With as little as 7-8 mm of rainfall, up to 8% of the soil surrounding corn roots can retain an amount of water equivalent to 50-60% of the total rainfall [10].

Consequently, maize leaves play a pivotal role in enhancing crop yield. Increasing yield necessitates attention to optimizing leaf area and leaf area index within the plant.

[Table 9]

Effect of biochar from coir and soybean stalks on leaf area and leaf area index of corn cultivar NK4300

Formula	Period 7-9 leaves		Curling period		Milk ripening period	
	Leaf area (m^2 leaves/plant)	LAI (m^2 leaves/ m^2 soil)	Leaf area (m^2 leaves/plant)	LAI (m^2 leaves/ m^2 soil)	Leaf area (m^2leaves/plant)	LAI (m^2 leaves/ m^2soil)
T1	0,08	0,47	0,34	1,93	0,51	3,08
T2	0,10	0,54	0,36	2,03	0,60	3,57
T3	0,09	0,50	0,39	2,25	0,58	3,39
T4	0,09	0,49	0,35	1,98	0,55	3,13
T5	0,09	0,50	0,38	2,14	0,54	3,23
CV%	7,10	7,10	8,60	8,60	8,20	8,2
LSD 0,05	0,01	0,07	0,06	0,33	0,09	0,48

Table 9 illustrates the gradual improvement in leaf area and leaf area index across different growth stages in the experimental treatments. During the reproductive stage, characterized by lactation, corn plants exhibit heightened nutrient demands for seed production, resulting in the highest leaf area and leaf area index. Across all three growth stages, formula T2 (1 ton of biochar/ha) consistently demonstrated the highest leaf area and leaf area index.

Corn diameter and length are key factors influencing corn yield, as they determine kernel size and the number of kernel rows. Larger corn diameters correlate with increased grain counts per row, consequently leading to higher yields. Morphological indicators for monitoring maize in the experimental variants are outlined in Table 10.

[Table 10]

The influence of biochar from coir and soybean stalks on the morphological characteristics of corn variety NK4300

Formula	Corn length (см)	Corn diameter (см)	Bead row length (см)
T1	14,7	4,4	12,0
T2	15,3	4,5	12,7
T3	15,0	4,4	12,4
T4	15,0	4,4	12,5
T5	14,9	4,5	12,4
CV%	1,8	2,0	2,7
LSD 0,05	0,5	0,2	0,6

The lengths of corn in formulas T2, T3, and T4 did not exhibit significant differences (at a 95% confidence level), but variations were observed between formulas T2, T3, T4, and T1 (at a 95% confidence level). Conversely, the diameters of corn in the experimental variants showed no significant differences (at a 95% confidence level). The length of the seed row peaked in formula T2 (12.7 cm) and was lowest in formula T1 (12.0 cm), with this difference being statistically significant at the 95% confidence level.

Yield components such as the number of seeds per corn row, number of seeds per row, and effective corn per plant are closely associated with the yield of the NK4300 corn variety. Productivity serves as a crucial criterion, as it encompasses various factors reflecting growth trajectory, developmental patterns, resilience to adverse environmental conditions, and adaptability of corn to external influences [11]. Therefore, meticulous attention to these factors is essential to enhance corn yield and quality. The outcomes of our monitoring efforts are detailed in Table 11.

[Table 11]

Effect of biochar from coir and soybean stalks on the yield and yield components of corn variety NK4300

Formula	Number of rows/corn	Number of seeds/row	Effective Corn Percentage	Weight of 1000 seeds	Actual yield (c/ha)
T1	13,3	32,2	89,5	333,7	50,6
T2	13,9	34,6	93,3	335,3	58,4
T3	13,9	32,8	92,1	335,8	56,6
T4	14,0	33,5	91,6	334,5	55,0
T5	13,9	33,5	90,4	329,7	52,2
CV%	3,1	2,3	1,5	-	7,3
LSD 0,05	0,8	1,5	2,6	-	9,9

The effective ratio of corn per plant is a crucial parameter influencing corn yield. As depicted in Table 11, formula T2 exhibits the highest effective percentage of corn at 93.3%, while formula T1 records the lowest at 89.5%. Formulas T3, T4, and T5 display effective corn ratios of 92.1%, 91.6%, and 90.4%, respectively.

The number of seed rows per corn is contingent upon corn diameter and kernel size. In the experiment, the number of grain rows per corn ranged from 13.3 to 14 rows, with this variance deemed statistically insignificant (at a 95% confidence level). Therefore, biochar does not appear to influence the number of rows per corn, as this factor is primarily determined by corn variety.

The number of seeds per row reflects the quantity of pollinated flowers, influenced by both variety and environmental conditions during tasseling and silking [12]. This serves as a pivotal indicator determining corn yield, essential for effective seasonal planning and appropriate agronomic practices. Table 11 illustrates that the number of seeds per row ranges from 32.8 to 34.6 seeds/row, with formula T2 recording the highest number of seeds per row at 34.6.

Actual yield represents the ultimate outcome of corn growth and development, reflecting the combined influence of genetic, environmental, and management factors. Analysis and ANOVA are conducted to discern differences among formulas and identify the formula yielding the highest production potential. Table 11 indicates relatively uniform actual yields across formulas, with all biochar-treated formulas outperforming those without. However, excessive biochar application may lead to reduced corn yields. Formula T2 exhibits the highest actual yield at 58.4 c/ha, while formula T1 records the lowest net yield at 50.6 c/ha.

CONCLUSIONS

The mixing ratio of coconut fiber and soybean stalk influences the composition of macro- and micronutrients in biochar.

When mixing coir and biochar in a 2:1 ratio (2 coir - 1 soybean), the ratio of total K_2O to total nitrogen is higher than other ratios.

Corn variety NK4300 when applied with Biochar had higher plant height, leaf number, leaf area, leaf area index and actual yield than without Biochar.

The Biochar fertilizer formula in the ratio 2:1 (2 coir - 1 soybean) with 150 kg N + 90 kg P_2O_5 + 90 kg K_2O gave the highest yield of corn NK4300.

References:

1. Dinh The Loc, Vo Nguyen Quyen, Bui The Hung and Ngo The Hung (2000). Textbook of Maize - Volume 1. Agriculture Publishing House – Hanoi

2. Nguyen Duy Phuong. Study on the effects of organic fertilizers and biochar on crop yield and some properties of gray soil in Hiep Hoa district, Bac Giang province. Thesis of Doctor of Agriculture. Specialization in Soil Science. Code 9620103. 2017

3. Tran Viet Cuong. Research on the application of biochar from rice by-products to improve the degraded gray soil environment. Doctoral thesis in agriculture. Specializing in Land and Water Environment. Code 62440303. 2015

4. Minh Tang Chang, Peter L. Keeling, "Corn Breeding Achievement in Unitted States", Report in Nineth Asian Regional Maize Worshop, Beijing, Sep. 2005.

5. Bauman Loyal F. Review of methods used by breeders to develop superior corn inbreds, 36th annual corn and sorghum reseach coference. 1981. pp. 1-3.

6. Mengel D. B. Fertilizing corn grown using conservation tillage. Agronomy Guide, AY-268, Purdue University. Coop. Ext. Service. West Lafayette, IN. 1991

7. Cerrato M. E., Blackmer A. M. "Relationships between leaf N concentrations and the N status of corn" Journal of Production Agriculture. 1991. 4:525-531.

8. Mitsuru Osaki, Mika Matsumoto, Toshiaki Tadano. Parameters determining yield of field crops in relation to the amount of nitrogen absorbed. 1994.

9. Bejing Maize Reseach Center, Bejing Academy of Agriculture & Foresty Sciences. "New maize hybrids", Report in Nineth Asians Regional maize workshop, Beijing. Sep - 2005

10. K. Letrat, N. Thongnarin. "Novel approach to eating quality improvement in local waxy corn: Improvement of sweet taste in local waxy corn variety with mixed kernels from super sweet corn" . 2001

11. Genetic Contributions to National Maize Yield Increases in Hungary, 1891 – 1995 (The Genetics and Exploitation of Heterosis in Crops,1997, Mexico)

12. Dinh Cong Chinh et al. "Analysis of genetic diversity and ability to combine pure glutinous maize lines". Vietnam Journal of Agricultural Science and Technology, No. 4/2010. 2010. pp.7-12

SUMMARY

Soil serves as the primary source of nutrients for plants. Over time, prolonged tree cultivation can lead to soil compaction, nutrient depletion, and reduced water permeability. Soil enhancement prior to sowing is crucial for enhancing crop yield. While various methods exist for improving agricultural soil, the recent application of combining biochar with chemical fertilizers has gained traction in Northern Vietnam. Biochar not only addresses environmental pollution but also serves as an effective soil amendment.

The objective of this study is to determine the optimal dosage of biochar derived from coir and soybean stalks in combination with NPK fertilizer for maize variety NK4300 under winter crop conditions in Northern Vietnam. The study was conducted from August 2019 to January 2020 in Bac Giang province, Vietnam, focusing on maize variety NK4300, with planting executed on September 15, 2019.

The experiment employed a fully randomized design with 5 treatments and 3 replications, totaling 15 plots with an area of 14 m^2 each, resulting in a total experimental area of 210 m^2. The fixed mineral fertilizer base comprised 150 kg N + 90 kg P_2O_5 + 90 kg K2O. The application of biochar, ranging from 0 to 1 ton/ha, was conducted 10 days before seed sowing (September 5, 2019). Mineral fertilizers were applied thrice at the stages of 5 true leaves, 8 true leaves, and tasseling.

The experimental treatments included:
T1: 150 kg N + 90 kg P_2O_5 + 90 kg K_2O (No biochar)
T2: 150 kg N + 90 kg P_2O_5 + 90 kg K_2O + 1 ton biochar/ha
T3: 150 kg N + 90 kg P_2O_5 + 90 kg K_2O + 0.8 tons biochar/ha
T4: 150 kg N + 90 kg P_2O_5 + 90 kg K_2O + 0.6 tons biochar/ha
T5: 150 kg N + 90 kg P_2O_5 + 90 kg K_2O + 0.4 tons biochar/ha

The soil in the study area exhibited a grain composition ranging from sandy to loamy, with pH levels ranging from 5.01 to 5.29, classified as gray forest soil. Throughout the experiment, various parameters of maize variety NK4300 were evaluated, including germination rate, leaf length and plant height growth, SPAD index, leaf area and leaf area index, and yield components.

The experimental results indicated similar growth durations among treatments, with varying germination rates, highest at 92.3% in treatment T2. Maize variety NK4300 exhibited enhanced height growth when treated with biochar, with all biochar-treated formulas resulting in greater plant height compared to the control formula during the monitoring period.

The growth rate of plant height exhibited a gradual increase during leaf development, followed by a gradual decrease during tasseling. Similarly, the number of leaves and leafing rate were superior in biochar-treated formulas. The number of leaves in treatment T2 consistently reached the highest value throughout the 6-week follow-up.

The positioning of corn cobs was deemed reasonable across experimental formulas, with percentages ranging from 45.9% to 47.5%. The SPAD index varied

across follow-up periods, peaking during tasseling. Treatments T4 and T5 exhibited the highest SPAD index during the 7-9 period, while treatment T3 recorded the highest SPAD index during tasseling. Leaf area and leaf area index gradually improved across growth periods, with treatment T2 consistently exhibiting the highest levels. Corn length did not differ significantly among treatments.

Corn diameter also showed no significant differences. However, the length of seed rows was significantly greater in treatment T2 compared to T1. The number of grain rows per corn ranged from 13.3 to 14, with no significant differences observed among treatments, indicating that biochar did not affect the number of rows per corn for maize variety NK4300.

All biochar-treated formulas yielded higher actual yields compared to the control. Additionally, as the level of biochar increased, the yield of maize variety NK4300 also increased, reaching a maximum of 58.4 quintals/ha with treatment T2.

The article includes 1 Figure, 11 Tables, 2 Charts, and 12 References.

The Authors declare no conflict of interest.