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EFFICIENCY OF USING BIOCHAR AND DROUGHT TOLERANT MAIZE VARIETIES IN COSTAL SANDY SOIL AREA OF THANH HOA PROVINCE

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ABSTRACT

The coastal area of Thanh Hoa province has a large proportion of sandy soils, about 24% of the natural land; this is a group of land with poor water and nutrition holding capacity. Studies show that biochar can improve soil environment, improve soil production through reducing acidity, increasing cation exchange capacity, increasing water and nutrient holding capacity. In addition, with advances in plant varieties, in Vietnam, hybrid varieties of maize with drought, cold tolerance, and good productivity and quality have been developed. This study conducted two factors: the amount of biochar applied and the drought tolerant maize varieties to evaluate the effects of biochar as well as the maize varieties in the dry sandy soil condition in coastal areas of Thanh Hoa province. Research results show that, when applying biochar at 5 tons / ha, the yield of maize varieties reaches the highest and is equivalent to applying 10 tons of manure. As such, biochar can replace manure used in maize cultivation in the study area. Experimental results of three drought tolerant maize varieties showed that, with the amount biochar applied was 5 tons / ha, the variety LVN061 has higher actual productivity than the two varieties of LVN092 and LVN17. For LVN061 maize variety, the level of fertilizing 10 tons of manure, 5 tons of biochar and 6 tons of biochar achieved the highest productivity and were similar at the 95% confidence level. With biochar applied at 5 tons / ha, the maize varieties actual productivitymore than 6 tons / ha, higher than the current average maize actual productivityin the study area (below 6 tons / ha). The economically optimal amount of biochar applied for the three maize varieties LVN092, LVN17 and LVN061 were 4.98 tons / ha, 4.81 tons / ha and 4.65 tons / ha respectively. This is the amount of fertilizing for high economic efficiency as well as ensuring nutrition supply for growing maize.

Keywords: biochar, manure, maize, drought, thanh hoa.

1. INTRODUCTION

Biochar is a product produced during the pyrolysis of organic compounds in anaerobic or airless conditions [1]. Applying biochar to the soil increases the ability to absorb and retain water in the soil and provide it back to the plant during the drought period [2]. The large surface area of biochar is responsible for increasing water retention and increasing soil absorption capacity [3-5]. In soil, biochar interacts with a variety of minerals and organic compounds, thereby enhancing microbial activity and plant roots. Biochar in the soil increases microorganisms that are beneficial for nitrification and denitrification [6], soil microorganisms associated with biochar can increase the ability to resolve nutrients that have been fixed in the soil, making them retain in microbial biomass [3, 7, 8]. Applying biochar to soil increases the ability to absorb nutrients and limit leaching, making chemical fertilizers less likely to be lost due to water leaching, increasing growth and crop productivity [9, 10]. The results of the study by Bhupinder *et al*., 2010 showed that with the wetting-drying (W-D) cycles, biochar applied to the soil (Alfisol and Vertisol) reduced 54 - 93% of ammonium loss due to leaching. This study propose that the increased effectiveness of biochar in reducing N_2O emissions and ammonium leaching over time was due to increased sorption capacity of biochar through oxidative reactions on the biochar surfaces with ageing [11].

In Vietnam, biochar has been used for years; farmers call it the cinder, using the method of burning smouldering straw and using water to quell the fire quickly to create it. Farmers using this coal combined with manure for composting. However, this method creates dust burning coal causes environmental pollution, increasing greenhouse gas emissions. In recent years, there has been much research on biochar and its application in agriculture. Nguyen C.V. *et al*. [12] studied the use of biochar in combination with NPK fertilizer, compost to apply for vegetables and rice in the northern mountainous region (Thai Nguyen and Thanh Hoa province), the results showed that compared with only NPK fertilizer, rice yields were increased by 5.9-22.3% in treatments with biochar and by 26.3- 34.2% in treatments of compost mixed with 5% biochar. Application of biochar for vegetables increased the yields by 4.7-25.5%, compared with farmer practices in both sites [12]. Using biochar in combination with compost to apply for leafy vegetables and rice in sandy soil in Central Vietnam (Ha Tinh, Quang Tri and

Quang Nam Provinces) shows that, applying biochar at the rate of 2.5 - 5.0 ton/ha for leafy vegetables and rice can partially replace or completely replace manure for coastal sandy soil in study areas. Using 2.5 tons of TSH added 10 tons of compost for yield of green mustard increased from 54 - 65%, cabbage yield increased by 38.4% and rice yield increased from 15.4 to 27.9% compared with NPK fertilizer application [13]. Research results of Hoang T.L.T *et al*. [14] show that biochar substitutes for 20% of mineral fertilizer (NPK), maize still has good growth and development ability and yields 4.27 tons / ha equivalent to the control formula.

The sandy soils in coastal areas of Thanh Hoa province have less acidic neutral reaction, coarse soil texture, low fertility, poor water and nutrition holding capacity. This soil group accounts for about 24% of the natural area, most of the area of sand soil has been used in agricultural production. This soil group is suitable for growing vegetables, cash crops and short-term industrial crops. In addition, it is possible to grow fruit trees such as coconuts, oranges, lemons ... where low terrain can grow rice. Although sandy soil has low fertility, if improved well, it still gives high crop productivity. Using sandy soils, it is important to pay attention to irrigation methods to retain water, increase fertilizer, but it should be applied sparingly, deeply and repeatedly applied. At the same time, using additional organic fertilizer to improve physical properties, increasing the ability of moisture and nutrition for the soil. In addition, to protect the soil, to retain moisture, to retain nutrition, it is necessary to build windbreak forest belts [15, 16].

To evaluate the effect of using biochar and drought-tolerant maize varieties in coastal sandy soil of Thanh Hoa province, two-factor experiments of biochar and three drought tolerant maize were conducted with objectives: (i) Assess the impact of biochar on the productivity and productivity components of maize varieties; (ii) Determine the amount of biochar applied to achieve maximum theoretical productivity and economically optimal yield as a basis for proposing appropriate amount of biochar applied.

2. MATERIALS AND METHODS

2.1 Materials

Produced from firewood, twigs and burned under the condition of lack of oxygen in DK-TR3 furnace at a temperature of 600^0C.The main components of biochar include total carbon 24%; N0.86%; P_2O_5 1.36%; K_2O 1.5%; Mg 0.021%; Cu 0.019%; Zn 0.018%.

Fertilizers used include manure, lime, urea fertilizer, superphosphate, and potassium chloride Drought tolerant maize varieties include LVN061, LVN17 and LVN092.

2.2 Methods

2.2.1 Field experiment methods

The experiment was conducted in the winter crop (October 2018 to February 2019) at 3 sites in 2 coastal districts of Thanh Hoa Province: Tinh Gia District (Hai Chau and Hai An communes) and Hau Loc District (Phu Loc commune).

The experiment consists of 2 factors: The first factor is a drought-tolerant variety including 3 maize varieties LVN092 (N1); LVN17 (N2) and LVN061 (N3). The second factor is the amount of biochar applied according to the different formulas shown in Table-1.

Table-1. Experimental fertilizer formulas.

Notation	Formulars	Additional carbon (ton/ha)	Amount of Biochar	
			Ton/hectare	kg/20m^2 (area of an experimental plot)
T0	Manure(10 ton/ha) + NPK$^{(*)}$+Lime	1.5	0	0
T1	NPK$^{(*)}$+ Lime	0	0	0
T2	Biochar+ NPK$^{(*)}$+Lime	1.5$^{(**)}$	3.0	6
T3	Biochar + NPK$^{(*)}$+Lime	2.0	4.0	8
T4	Biochar + NPK$^{(*)}$+Lime	2.5	5.0	10
T5	Biochar + NPK$^{(*)}$+Lime	3.0	6.0	12

Note: The formula T0 is the formula based on current farming techniques in the study area; $^{(*)}$ The amount of NPK fertilizer used for 1heactare is as follows: Super phosphate: 150kg; Urea: 30 kg; Potassium chloride: 40 kg, lime powder 200kg; $^{(**)}$ The amount of organic carbon in Biochar is calculated equal to the organic carbon content in the 10 tons of manure per one hectare, this is the dose to be used locally.

Experiments were arranged in large and small plots (large plots: amount of biochar factors; small plots: variety factors) with 3 replicates in different fields. Small plot area is 20m^2; large plot area is 60m^2.

2.2.2 Methods of determining productivity

Theoretical productivity (PT): Before harvesting, the following trees must be harvested separately for each plot, each formula, and marked to measure the indicators of productivity.

$$PT = A \times B \times C \times D \times 10^{-5} \text{ (tons/ha)} \quad (1)$$

In which: A is the number of trees per area unit; B is the number of effective corn on the tree; C is the number of grains on the corn; D is the weight of 1000 seeds (these parameters are directly measured in experimental plots).

Actual productivity (PA): Calculated after drying, cleaning and weighing each experimental plot individually.

2.2.3 Statistic analysis

Data are stored, synthesized and graphed with Microsoft Excel software. Comparison of nutrient retention capacity of fertilizer formulas were evaluated by software IRRISTAT 5.0 and formula's means were compared by least significance difference (LSD) at the probability of 0.05% [17].

Determination of maximum technical fertilizer and economic optimum based on determination of regression equation (level 2) between fertilizer amount and crop productivity according to the formula of Michel Lecompt, 1985 (cited from Vu Huu Yem, 1998[18]):

$$MT = \frac{-b}{2a} \quad (2)$$

$$OE = \frac{y' - b}{2a} \quad (3)$$

In which : MT is Maximum amount of fertilizing technically; OE is Optimal amount of fertilizing economically; a, b are coefficients of the second-degree regression equation between crop yield and fertilizer amount; y'is the amount of product (kg) needed to sell to buy 1 kg of fertilizer

3. RESULTS AND DISCUSSIONS

3.1 The Effect of Biochar Application on the Productivity of Maize Varieties

Maize productivity depends on many factors such as: number of corns per tree, number of seed rows per corn, number of seeds per row, weight of 1000 seeds (P1000), length of corn and diameter of corn,...In addition, maize productivity also depends on external conditions such as climate, soil conditions, farming techniques and pest control.

The results of monitoring the productivity components of experimental drought-tolerant maize cultivars planted in costal sandy soil area of Thanh Hoa province are shown in Table-2.

Table-2. Effect of biochar application on productivity components and productivity of maize varieties (The average data of three study sites).

Formulas		Tree density (trees/m^2)	Corns per tree (corn)	Number of seed rows per corn (row)	Number of seeds per row (seed)	P1000 (g)	Theoretical productivity (PT) (tons/ha)	Actual productivity (PA) (tons/ha)
T0 (NPK + 10 tons Manure)	N1	5.6	1.0	13.8	37.2	270.2	7.77	6.408
	N2	5.9	1.0	15.1	32.2	280.2	8.04	6.678
	N3	5.9	1.0	16.0	33.6	295.5	9.37	7.373
T1 (NPK)	N1	5.0	1.0	12.9	33.7	256.8	5.58	4.622
	N2	5.2	1.0	14.0	29.8	250.6	5.44	4.577
	N3	5.2	1.0	14.9	30.5	276.6	6.54	5.376
T2 (NPK + 3tonsBio char)	N1	5.2	1.0	13.1	34.8	260.6	6.18	5.018
	N2	5.3	1.0	14.3	30.6	260.5	6.04	4.881
	N3	5.3	1.0	15.2	31.2	280.7	7.06	6.095
T3 (NPK+ 4 tons Biochar)	N1	5.2	1.0	13.4	35.6	264.5	6.56	5.201
	N2	5.4	1.0	14.5	31.8	268.8	6.69	5.333
	N3	5.7	1.0	16.0	32.1	284.3	8.32	6.763
T4 (NPK + 5 tons Biochar)	N1	5.4	1.0	13.6	37.5	268.6	7.4	6.347
	N2	5.8	1.0	15.0	32.1	278.6	7.78	6.57
	N3	5.8	1.0	15.8	33.3	297.4	9.08	7.115
T5 (NPK + 6 tons Biochar)	N1	5.4	1.0	13.7	37.5	269.2	7.47	6.447
	N2	5.8	1.0	15.1	32.1	279.5	7.86	6.681
	N3	5.8	1.0	15.8	33.4	296.6	9.08	7.127
$LSD_{0.05}$ (T)		0.2	-	0.2	1.0	-	-	0.34
$LSD_{0.05}$ (N)		0.1	-	0.6	3.1	-	-	0.46
$LSD_{0.05}$ (T*N)		0.2	-	0.3	1.6	-	-	0.28
CV%		6.2	-	4.8	5.6	-	-	0.72

Tree density varies between maize varieties as well as between the amount of biochar applied and ranges from 5.0 to 5.9 trees/m^2 at harvest. In the same amount of biochar applied, LVN17 and LVN061 maize varieties had higher plant density than LVN092, with $LSD_{0.05}$ (N) = 0.2, this difference is significant at the 95% confidence level. In general, the formulas with biochar applied were higher in density than T1 formula (only applied NPK), when increasing the amount of biochar applied at 5 tons/ha, the density of plants equivalent to the formula of 10 tons manure, continue to increase the level of biochar to 6 tons/ha, the tree density does not increase and is equivalent to the level of 5 tons/ha.

The index of corns per tree is an important component of productivity, it depends mainly on varieties and farming techniques.When a maize has more corn, the corn above will be pollinatedbetter, so will grow better than the corn below. For maize planted to harvest seeds, the required number of corn is 1 to 2 corn (usually 1 corn) for maize to focus on nourishing corn, if the P1000 index (weight of 1000 seeds) is high, the yield will be high. on the other hand, the number of corn on the tree is high, the pollination process is inadequate, the corn is poorly developed, the trees consume a lot of nutrients to feed the corn, so the productivity is not high [19, 20]. In all three maize varieties with different amounts of biochar applied, the number of maize per tree is 1 corn / tree. The main reason is that these are hybrid maize varieties that have been bred, selected to achieve high productivity and are resistant to pests, drought and cold conditions [21-23].

The number of seed rows per corn index is a genetic factor determined by the maize variety and is determined during the formation of female flowers (Corn). The number of seed rows per corn is always even because the characteristic of corn flowers is double flower [20, 24]. The results in Table-2 show that the number of seed rows per corn of maize varieties ranges from 12.9 to 16.0 rows. In particular, LVN061variety has the largest number of seed rows per corn (14.9 -16.0 rows), followed by LVN17variety with 14.0 -15.1 rows and the lowest variety (LVN092) is 12. 9 -13.8 rows. In addition, the amount of biochar applied also has a significant impact on the

number of seed rows per corn, the formulas added with biochar have a higher the number of seed rows per corn than the T1 formula (only applied NPK).

The number of seeds in per row depends on the genetic characteristics of the maize variety, besides it also depends a lot on pollination and fertilization. When corn flowering, sprinkling, spraying stubble with adverse conditions can reduce the number of stubble produced, leading to reduced fertilization of the oocytes and limiting the number of seeds developed. The unfertilized oocytes will be seedless and degenerate, causing the phenomenon of cornless peaks, reducing the number of seeds per row [20, 24]. The data in Table-2 shows that the number of seeds per row of the experimental formulas ranged quite large, from 29.8 to 37.5 seeds per row. In particular, the main difference is caused by the maize varieties factor, the variety with the largest number of seeds per row is LVN092, followed by LVN061 and the lowest is LVN17.There is little difference among biochar applied, only from the level of 5 tons/ha, the number of seeds per row has a significant difference compared to the formula T1 (only applied NPK).

The weight of 1000 seeds (P1000) depends on each maize variety and many external factors such as weather, climate, soil, farming techniques, etc. if the fertilization process meets unfavourable conditions like pigs lacking water, pests, etc, limiting the process of transporting nutrients to seeds, limiting the accumulation of dry matter and reducing seeds weight [20, 24]. Experimental results in Table-2 show that different maize varieties have different P1000 value, in which LVN061 variety is the largest, ranging from 276.6 -297.4 g. Biochar has a significant impact on the P1000 value of the maize varieties in the experiment, in the formula T1 (only applied NPK), the value of P1000 is much lower than the formula manure applied (formula T0) as well as biochar applied. In general, at the level of 5 tons of biochar per hectare, the value of P1000 achieved the highest and equivalent to that applied with manure fertilizer (formula T0).

Theoretical productivity (PT) reflects the productivity potential of each variety under certain ecological conditions, as a result of the constituent factors. Calculation results according to formula (1) are summarized in Table-3, in the experimental formulas with theoretical productivity ranging from 5.44 to 9.37 tons / ha.In particular, the experimental formula T0N3 (NPK + 10 tons Manure and maize variety LVN061) achieved the highest theoretical productivity and the lowest was the T1N2 experimental formula. As for the variety factor, the theoretical productivity is significantly different, LVN061 (N3) has the highest theoretical productivity (6.54 -9.37 tons/ha), higher than the two varieties N1, N2 at 95% confidence level. The factor of biochar also has a strong impact on the theoretical productivity. In general, when the amount of biochar applied is increased, the productivity tends to increase. From the application of 5.0 tons / ha, the productivity of maize varieties was the highest and equivalent to the formula using manure (T0).

Actual productivity (PA) is a general indicator of factors, reflecting the genetic characteristics and the situation of growth and development of the variety under certain ecological and cultivation conditions. Varieties with high potential can only exert that potential when nurtured in appropriate conditions, so in the same climatic, soil conditions and cultivation techniques, which varieties are suitable to be able to growth performance, good tolerance and high productivity [18]. The results in Table-2 show that different experimental formulas have different actual productivity, the T0N3 formulas have the actual productivity of 7.37 tons / ha, the T4N3 formula is 7.12 tons / ha and the T5N3formula is 7.13 tons / ha. These are the three formulas with the same productivity (with $LSD_{0.05}$ (T*N) = 0.28 tons / ha) and also the formulas with the highest actual productivity, higher than the remaining formulas (with a confidence level of 95%). The formulas with the lowest actual productivity were T1N2 (4.58 tons / ha) and T1N1 (4.62 tons / ha). With biochar applied at 5 tons / ha, the maize varieties actual productivitymore than 6 tons / ha (with $LSD_{0.05}$ (T*N) = 0.28 tons / ha), higher than the current average maize actual productivityin the study area (below 6 tons / ha).

The individual impact of each factor of maize varieties and the amount of biochar applied to the theoretical and actual productivitywas summarized in Table-3.

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Table-3. Individual productivity of different amounts of biochar applied and maize varieties.

Formulas		Theoretical productivity (PT) (tons /ha)	Actual productivity (PA) (tons /ha)
Amount of biochar applied (tons/ha)	**T0 (10 tonsmanure)**	**8.39**	**6.82**
	T1 (NPK)	5.85	4.86
	T2 (NPK + 3 tons Biochar)	6.43	5.33
	T3(NPK + 4 tons Biochar)	7.19	5.77
	T4(NPK + 5 tons Biochar)	8.08	6.68
	T5(NPK + 6 tons Biochar)	8.14	6.75
	$LSD_{0.05}$	-	3.4
	CV%	-	7.2
Maize varieties	N1 (LVN092)	6.83	5.67
	N2 (LVN17)	6.98	5.79
	N3 (LVN061)	8.24	6.64
	$LSD_{0.05}$	-	0.46
	CV%	-	7.2

For the amount of biochar applied: The formula applied with manure and the formulas applied biochar have significantly higher actual productivity than the T1 formula (4.86 tons/ha) at the significant level 95 %. When increasing the amount of biochar applied from 0 to 5 tons / ha (Formula T1, T2, T3 and T4), the actual yield increased gradually. However, at the biochar levels of 6 tons / ha (formula T5), the actual productivity increased slightly, only equivalent to the formula T4. Thus, the appropriate biochar applied to maize varieties is 5 tons / ha.

For the variety factor: With $LSD_{0.05}$ (N) = 0.46 tons / ha, the maize varieties LVN092 and LVN17 have similar productivity (5.67 - 5.79 tons/ha). LVN061 maize variety achieved a remarkable actual productivity of 6.64 tons / ha, which is certainly higher than LVN092 and LVN17 varieties at a 95% confidence level. Thus, LVN061 maize varieties are most suitable for climatic, soil conditions and cultivation techniques compared to LVN092 and LVN17 varieties.

3.2 Determining the Maximum Amount of Biochar Applied Technically and Economically

The correlation between actual productivity and the amount of biochar applied to different maize varieties is shown in Figure-1, Figure-2, and Figure-3. The results show that the amount of biochar applied was positively correlated and that very tight with actualproductivity.

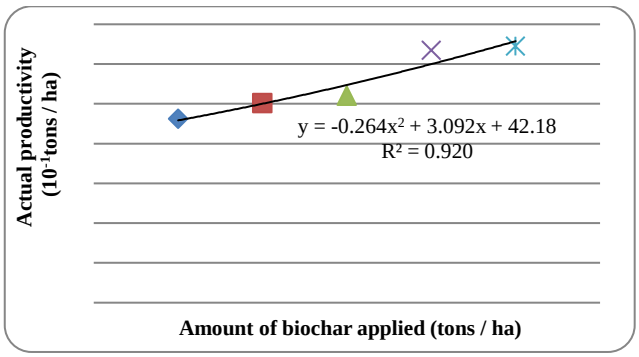

Figure-1. Correlation between maize productivity and the amount of biochar applied to N1 maize variety (LVN092).

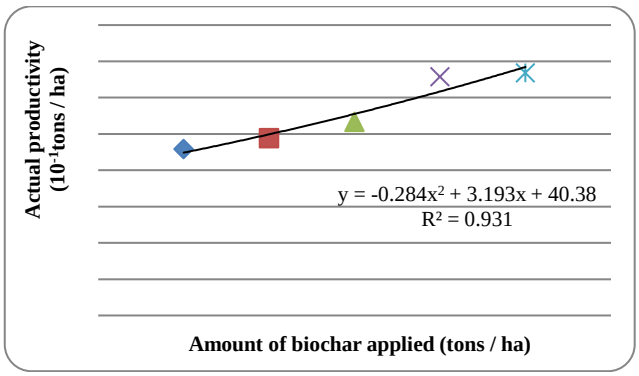

Figure-2. Correlation between maize productivity and the amount of biochar applied to N2 maize variety (LVN17).

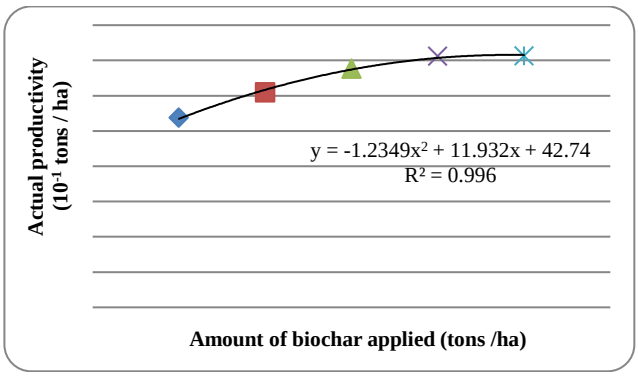

Figure-3. Correlation between maize productivity and the amount of biochar applied to N3 maize variety (LVN061)

Correlation between maize productivity (y) and the amount of biochar applied (x) to N1 maize variety (LVN092): $y = -0,264x^2 + 3,092x + 42,18$; correlation coefficients $R^2 = 0,920$.

Correlation between maize productivity (y) and the amount of biochar applied (x) to N2 maize variety (LVN17): $y = -0,284x^2 + 3,193x + 40,38$; correlation coefficients $R^2 = 0,931$;

Correlation between maize productivity (y) and the amount of biochar applied (x) to N3 maize variety (LVN061): $y = -1,234x^2 + 11,93x + 42,74$; correlation coefficients $R^2 = 0,996$;

From the equations of correlation between the amount of biochar applied and the actual productivity, it is possible to determine the maximum technical and economic optimum level of biochar applied on different varieties. The maximum amount of fertilizing technically is the level of fertilization to achieve the maximum productivity of crops in certain ecological conditions and cultivation techniques, while the optimal amount of fertilizing economically is the appropriate level of fertilizer to achieve highest economy efficiency [18]. The results of determination of the maximum technical and economical biochar applications are presented in Table-4.

Table-4. The maximum technical and economical biochar applications in different varieties of maize.

Order	Maize varieties	Maximum amount of fertilizing technically (tons/ha)	Optimal amount of fertilizing economically (tons/ha)
1	LVN092	5.85	4.98
2	LVN17	5.62	4.81
3	LVN061	4.83	4.65

From the results in Table-4, the maize variety LVN092 has the maximum biochar applied at the technical level of 5.85 tons / ha and the economic optimum level is 4.98 tons / ha. The LVN17 maize variety has the maximum biochar application at 5.62 tons / ha and the economic optimum level is 4.81 tons / ha. The LVN061 maize variety has the maximum biochar dose at 4.83 tons / ha and the economic optimum level is 4.65 tons / ha.

4. CONCLUSIONS

Applying biochar has a positive effect on the growth and development of maize varieties. At the application rate of 5.0 tons of biochar / ha, the growth and productivity indicators reached the highest and equivalent to the formula of 10 tons of manure. Thus, biochar can be substituted for manure in maize cultivation in the study area.

The productivity and the productivity constituent elements of the maize varieties achieved the highest value when applying biochar at 5.0 tons / ha. Among the three varieties, the variety LVN061 has higher actual productivity than the two varieties of LVN092 and LVN17. For LVN061 maize variety, the level of fertilizing 10 tons of manure, 5 tons of biochar and 6 tons of biochar achieved the highest productivity and were similar at the 95% confidence level.With biochar applied at 5 tons / ha, the maize varieties actual productivitymore than 6 tons / ha (with $LSD_{0.05}$ (T*N) = 0.28 tons / ha), higher than the current average maize actual productivityin the study area (below 6 tons / ha).

The economically optimal amount of biochar applied for the three maize varieties LVN092, LVN17 and LVN061 were 4.98 tons / ha, 4.81 tons / ha and 4.65 tons / ha respectively. This is the amount of fertilizing for high economic efficiency as well as ensuring nutrition supply for growing maize.

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