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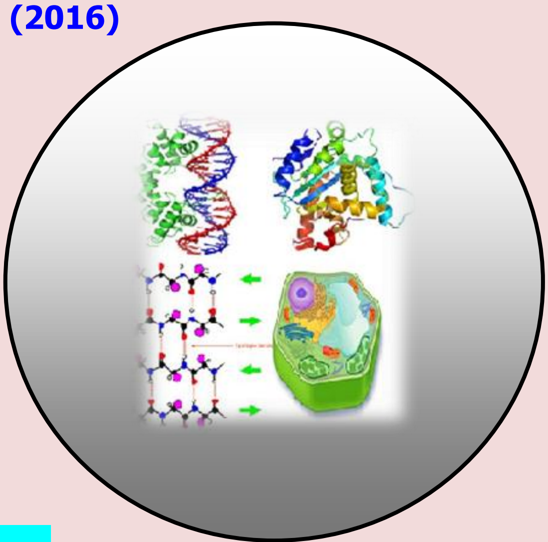

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Agronomic Effectiveness of Bamboo Biochar on Corn Cultivation in Dryland

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ABSTRACT

This study aims to determine the biochar agronomic effectiveness combined with compost and phonska in increasing corn yield in dryland. This study used a randomized block design with two-factor factorial pattern and 3 replications. The first factor was the treatment of biochar dosage consisting of 4 levels, namely: without biochar, 5.26 t ha-1, 10.52 t ha-1, and 15.78 t ha-1. The second factor is the type of fertilizer with four types, namely: without fertilizer, compost, phonska, and compost+phonska. The results showed that the dosage of biochar 10.52 t ha-1 combined with compost and phonska gave the highest yield of dry corn seeds per ha of 13.71 tons, which Increased by 106.67% when compared with treatment without biochar, compost, and phonska. The combination of biochar 10.52 t ha-1 with compost and phonska gave the highest value of Relative Agronomics Effectiveness (RAE) of 113.99% which is highly effective for corn cultivation in dryland.
Keywords: Charcoal, Manure, Phonska Fertilizer and Maize.

INTRODUCTION

Biochar is a carbon-rich material produced by pyrolysis through incomplete combustion process of agricultural biomass. Biochar can be used as a soil enhancer to bind carbon, producing good fibers and highly porous charcoal that can help the soil to retain nutrients and water (IBI, 2012). Biochar has the ability to hold and absorb water and nutrients in the soil. The addition of biochar to the soil can increase the availability of phosphorus, N-total, cation exchange capacity, and reduce the risk of nutrient leaching especially potassium and $N\text{-}NH_4$ in the soil (Bambang, 2012). Biochar is more effective in holding back nutrients for its availability to crops than any other organic matter. Giving biochar to the soil can increase N, P, CEC, pH, and can keep the C and N balance in the soil for long periods of time (Gani, 2009).

The effectiveness of biochar on soil quality and crop yield depends on the source, type, and quantity of raw materials used. The results showed that biochar dosage of 4-8 t ha^{-1} increased crop productivity by 20-220%, depending on the cultivated commodity (Gani, 2009). Rostaliana, *et al*. (2012), states that the utilization of biochar 12 t ha^{-1} has a significant effect on the weight of volume and available K, and the height of the maize plant. The research of Situmeang and Sudewa (2013) showed that bamboo biochar dosage of 10 t ha^{-1} had a significant effect on plant height, the total wet weight of the plant, and total oven dry weight of corn plant. Utilization of biochar dosage 10 t ha^{-1} and phonska NPK 300 kg ha^{-1} as well as cow dung compost 20 t ha^{-1} can increase the growth and yield of hybrid Bisi-2 (Situmeang *et al*., 2015). Situmeang *et al*. (2016) reported that the dosage of biochar 5-10 t ha^{-1} gave the best fresh weight of the cob and the compost dosage of 7.50-15.00 t ha^{-1} gave the best results on plant height, fresh weight of cobs, and fresh weight of corn stover. Furthermore, Situmeang (2017) reported that the highest yield of the corn plant in dryland was obtained at an optimum biochar dosage 10.52 t ha^{-1}, compost 20.22 t ha^{-1}, and phonska 313.37 kg ha^{-1}.

Utilization of a balance in the use of biochar with compost and phonska fertilizer can improve efficiency, reduce the use of synthetic fertilizers, and improve crop yields of corn. Research on the benefits of biochar for soil quality improvement on dry land with a variety of plant commodities, especially corn crops is still very necessary. Improving soil quality in dry land is very important in the future to address various agricultural problems in dryland. Optimizing the utilization of dry land to increase production of corn needs to be done through the improvement of agricultural cultivation and make effective use of biochar. This study aims to determine the effectiveness of biochar combined with compost and phonska in increasing crop yields of corn in dryland. The proposed hypothesis is biochar 10.52 t ha^{-1} combined with compost and phonska can increase yield corn in dryland.

MATERIAL AND METHODS

Location, Time, and Research Materials

This research was conducted in Sulahan Village, District of Susut, Bangli Regency of Bali Province with height 762 m above sea level. The research was carried out from January to May 2016. The materials used in this research were biochar made from bamboo waste, cow manure compost, Bisi-2 hybrid corn seed, NPK phonska (15-15-15), urea, and insecticide.

Research Design

This research was conducted based on the optimum dosage of biochar (10.52 t ha^{-1}), compost (20.22 t ha^{-1}), and phonska (313.37 kg ha^{-1}) obtained from Situmeang research (2017). This research uses randomized block design (RBD) with a two-factor factorial pattern. The first factor is the biochar dosage (D), which consists of 4 levels, namely: D_0 = 0 t ha^{-1} (without biochar), D_1 = 5.26 t ha^{-1}, D_2 = 10.52 t ha^{-1}, D_3 = 15.78 t ha^{-1}. The second factor is the fertilizers types (P) which consists of four types, namely: P_0 = without fertilizer, P_1 = Compost, P_2 = Phonska, and P_3 = Compost+Phonska. Each treatment was repeated 3 times to obtain 48 units of the experiment.

Variable Observed

1. Plant height (cm). The measurement of plant height was started from the plant three weeks after planting. Subsequent observations were made weekly until the plant reached its maximum height (63 days after planting). Measurements were made by measuring plant canopy from the ground to the highest leaf tip.
2. A number of leaves per plant (strands). Observation on the number of leaves performed simultaneously at the time of measurement of plant height. The calculated leaves are leaves fully opened and still green. Observations are made once every week until the plants reach the maximum number of leaves.
3. The total oven-dry weight of plant (g). The total oven-dry weight of the plant is obtained by adding dry oven weight, root oven-dry weight, and dry weight of seed oven per plant.
4. Dry weight harvest seeds per ha (ton). Measurement of dry seed weight at harvest is done by converting seed weight per tile to a hectare. The equations used are: *Dry weight harvest seeds per ha (ton) =*$(10^4\ m^2 \times \textit{dry seed harvesting weight (g)} \times 10^6\ g) / (1.125\ m2 \times 10^6\ g)$.

Relative Agronomics Effectiveness
Relative Agronomics Effectiveness (RAE) is the ratio between the increase in yields due to the use of a fertilizer with an increase in yield with the use of 100 standard multiplied fertilizers (Machay *et al*., 1984), with the following calculations: *RAE (%) = (Result on tested fertilizer - Result on control) x 100 / (Result on standard fertilizer - Result on control).*

Scanning Electron Microscope Analysis
Scanning Electron Microscope (SEM) analysis to determine the morphology and surface microstructure of the observed sample (bamboo biochar, untreated soil, and soil after treatment). SEM analysis was conducted at the Metallurgical Laboratory of Mechanical Engineering Faculty of Engineering Udayana University.

Data Analysis Research
Variant analysis (ANOVA) was used to determine the effect of biochar combination with compost and phonska on the measured variable. The least significant difference test (LSD) and Duncans at the 5% level were used to determine the difference in the mean value of each variable. Data processing result of research done by using program of Microsoft Excel and Minitab 14.

RESULTS AND DISCUSSION

Effect of Biochar and Fertilizer Type on Growth and Yield of Maize Plant
The significance of the effect of biochar dosage and the type of fertilizer and its interaction on growth and crop yield can be seen in Table 1.
Based on Table 1 it can be seen that biochar interaction and fertilizer type (DP) have no significant effect ($P \geq 0.05$) on plant height and number of leaves. The interaction of DxP also had a very significant effect ($P < 0.01$) on total oven dry weight and significantly ($P < 0.05$) on the dry weight of corn harvest per ha. Treatment of biochar dosage (D) and type of fertilizer (P) had a significant effect ($P < 0.01$) on all observed variables.

Table 1. Significance of the effect of biochar dosage (D), type of fertilizer (P) and its interaction (DP) to growth and corn yield.

No	Variable	D	P	DxP
1	Plant height (cm)	**	**	ns
2	Number of leaves (strands)	**	**	ns
3	Dry weight of total oven per plant (g)	**	**	**
4	Dry harvesting weight of seed per ha (ton)	**	**	*

* = significant (P<0,05); ** = highly significant (P<0,01); ns = not significant (P≥0,05)

Plant Height
Statistical analysis showed that the interaction between dosages of biochar with fertilizers (DXP) do not affect significantly ($P \geq 0.05$) to the maximum plant height, while the dosage of biochar (D) and the treatment of types of fertilizers (P) was highly significant ($P < 0.01$) on plant height (Table 1). The maximum plant height on biochar dosage treatment and the type of fertilizer is presented in Table 2.
Based on Table 2 it can be explained that the highest plant height obtained at the treatment biochar dosage 10.52 t ha^{-1} (D_2) is 308.88 cm which is significantly different or increased by 6.58% compared to the lowest value of plant height and obtained at the treatment without biochar (D_0) 289.80 cm. Treatment types of compost+phonska (P_3) provides the highest value of 310.81 cm plant height were significantly different or the increase of 10.55% when compared to the lowest value of 281.15 cm at the treatment without fertilizers (P_0).

Table 2. Average plant height and number of leaves on biochar dosage and fertilizer type.

Treatment	Plant height (cm)	Number of leaves (Strands)
Dosage of Biochar		
0 t ha^{-1} (D_0)	289.80 b	15.74 b
5.26 t ha^{-1} (D_1)	295.15 b	16.08 a
10.52 t ha^{-1} (D_2)	308.88 a	16.22 a
15.78 t ha^{-1} (D_3)	306.86 a	16.14 a
LSD 5%	9.09	0.25
Type of fertilizer		
Without fertilizer (P_0)	281.15 c	15.49 d
Compost (P_1)	298.80 b	15.86 c
Phonska (P_2)	309.92 a	16.28 b
Compost+Phonska (P_3)	310.81 a	16.56 a
LSD 5%	9.09	0.25

Note: The numbers followed by the same letter in the same column are not significantly different in the 5% LSD test

Number of Leaves

The result of statistical analysis of an interaction between dosage of biochar and fertilizer type (DP) was not significant ($P \geq 0.05$) to maximum number of leaves, while treatment of biochar dosage (D) and treatment of fertilizer type (P) had significant effect ($P<0.01$) to the maximum number of leaves. The mean maximum number of leaves at the biochar dosage treatment and the type of fertilizer are presented in Table 2. From Table 2 it can be seen that the highest leaf number obtained in the treatment of biochar dosage 10.52 t ha^{-1} (D_2) is 16.22 strands that significantly different or increased by 3.09% when compared with the lowest value of leaf number obtained at the treatment without biochar (D_0) is 15.74 strands. The compost + phonska (P_3) compost treatment gave the highest value of the leaf number of 16.56 strands that was significantly different or increased by 6.91% compared to the lowest value of the leaf number of 15.49 strands in the fertilizer treatment (P_0) (Table 2).

Total Oven-Dry Weight of Plant

The result of statistic analysis on the total oven-dry weight of the plant was found that the interaction biochar dosage with fertilizer type (DP), biochar dosage (D), and fertilizer (P) were very significant ($P<0.01$). The average oven-dry weight of plant on the interaction biochar dosage with fertilizer type is presented in Table 3. Based on Table 3 it can be explained that the highest total oven-dry weight of plant was obtained at interaction biochar dosage 10.52 t ha^{-1} with compost+phonska (D_2P_3) of 485.36 g which was significantly different and increased by 110.53% when compared with the lowest yield of total oven-dry weight of the plant on interaction without biochar and fertilizer (D_0P_0) of 230.55 g.

Table 3. Average total oven-dry weight of plant on interaction biochar dosage with fertilizer type.

Treatment	Type of Fertilizer			
	Without Fertilizer (P_0)	Compost (P_1)	Phonska (P_2)	Compost+Phonska (P_3)
Dosage of Biochar	-------------------------------- g tan^{-1} --------------------------------			
0 t ha^{-1} (D_0)	230.55 g	300.95 fg	327.26 def	376.67 bcde
5.26 t ha^{-1} (D_1)	284.12 fg	322.68 ef	377.14 bcd	405.14 b
10.52 t ha^{-1} (D_2)	337.03 cdef	366.13 bcde	404.27 b	485.36 a
15.78 t ha^{-1} (D_3)	332.45 def	385.33 bc	374.60 bcde	357.64 bcde

Note: The numbers followed by the same letter in the same column are not significantly different in Duncan's 5% test.

Dry Weight Harvest Seeds per Hectare

Result of statistical analysis to yield of dry seed harvest per ha found that interaction between dosage of biochar with type of fertilizer (DP) have real effect (P<0.05), while treatment of biochar dosage (D) and treatment of fertilizer type (P) (P<0.01) to yield of dry harvested seeds per ha. The average yield of dry weight harvested seeds per ha on the interaction between biochar dosage and the type of fertilizer is presented in Table 4.

Table 4 shows that the highest yield of harvested seeds per hectare was obtained at interaction between biochar dosage 10,52 t ha^{-1} with compost and phonska (D_2P_3) of 13,71 ton which increased by 106,67% with the lowest yield of seed yield per hectare in treatment without biochar and fertilizer (D_0P_0) weighing 6.63 tons, or increased by 42.83% when compared to the interaction between biochar dosage of 10.52 t ha^{-1} with no fertilizer (D_2P_0) by 9.60 tons, or also increased by 33.91% when compared to the interaction between without biochar with compost and phonska (D_0P_3) of 10.24 tons.

Table 4. Average yield of dry seed harvest on interaction biochar dosage with the type of fertilizer.

Treatment	Type of Fertilizer			
	Without Fertilizer (P_0)	Compost (P_1)	Phonska (P_2)	Compost+Phonska (P_3)
<u>Dosage of Biochar</u>	---------------------------------- ton -------------------------------------			
0 t ha^{-1} (D_0)	6.63g	8.77 ef	9.53 cde	10.24 bcde
5.26 t ha^{-1} (D_1)	8.02 fg	9.10 def	10.69 bcd	11.20 bc
10.52 t ha^{-1} (D_2)	9.60 bcde	10.63 bcd	11.30 b	13.71 a
15.78 t ha^{-1} (D_3)	9.27 de	10.36 bcde	9.90 bcde	9.46 cde

Note: The numbers followed by the same letter in the same column are not significantly different in Duncan's 5% test.

The high yield of harvested maize on the interaction biochar dosage 10.52 t ha^{-1} with compost and phonska (D_2P_3) was caused by the improvement of soil properties on dry land due to biochar which was balanced with compost and phonska. This condition is characterized by the improved physical properties of the soil ie decreasing the weight of volume, increasing porosity, and soil moisture content. The improved physical properties of soil in D_2P_3 is also supported by the results SEM of a 2000x magnification showing its surface morphology with better pore micro distribution (Figure 1). The biochar formulation of 10.52 t ha^{-1} with compost+phonska (D_2P_3) compost can increase soil aggregation from micro-aggregate to larger aggregate, increase soil water and nutrient capacity, increase soil pH, increase N-total, C-organic, P-available, K-available, cation exchange capacity, base saturation, and total microbes (Situmeang, 2017). Biochar can improve soil properties such as aggregation and soil water holding capacity, pH and CEC and increase soil biological population and activity (Chan *et al*., 2007; Masulili *et al*., 2010). Biochar can improve soil carbon capability, increase soil fertility, maintain soil ecosystem balance, and can also act as fertilizer and increase crop yields, provide and maintain nutrients in the soil (Major *et al*., 2005; Steiner *et al*., 2007).

Agronomics Effectiveness of Biochar Combined with Compost and Phonska on Corn Crops

Analysis RAE of biochar combined with compost and phonska on corn plant growth can be seen in Table 5. The RAE biochar value at plant height ranges from 27.88% -116.55%. The plant height maximum with RAE biochar value of 5.26 t ha^{-1} was obtained at combination biochar with compost and phonska (D_1P_3) of 116.55% and the lowest on biochar interaction 10.52 t ha^{-1} with compost (D_2P_1) of 27.88 %. Furthermore, the value of RAE biochar on the number of leaves ranged 44.44% -200.00%. RAE value at maximum leaf number was obtained on biochar 5.26 t ha^{-1} with phonska (D_1P_2) equal to 200.00% and lowest at biochar interaction 15.78 t ha^{-1} with compost (D_3P_1) equal to 44.44%.

Analysis of biochar RAE combined with compost and phonska on corn yield (dry weight of plant oven and dry weight of seeds corn) can be seen in Table 3. The value of RAE biochar on a total oven dry weight of plants ranged from 17.24% 101.51%. The RAE on an oven-dry weight was obtained at 10.52 t ha^{-1} biochar with compost+phonska (D_2P_3) equal to 101.51% and lowest on biochar interaction 15.78 t ha^{-1} with compost+phonska (D_3P_3) amounted to 17.24%. The value of RAE biochar on a dry weight of seeds ranged from 5.23% -113.99%. The value of RAE on a dry weight of seed harvest was obtained on biochar dosage 10.52 t ha^{-1} with compost+phonska (D_2P_3) of 113.99% and lowest on biochar interaction 15.78 t ha^{-1} with compost+phonska (D_3P_3) equal to 5.23%.

The high value of RAE D_2P_3 on oven dry weight and total plant dry weight per ha grain harvest show that the agronomic effectiveness D_2P_3 very good and effective (useful) when applied on dry land. This condition is also supported by the results of the analysis of up to 2000x magnification SEM (Figure 1), which is the visible arrangement of micropores with a larger surface area on the morphology D_2P_3 treatment compared to untreated D_0P_0. The treatment surface of D_2P_3 in SEM 2000x enlargement is seen with the arrangement of micro and macro cavity spans scattered with a relatively large number of the soil surface. This large pore cavity causes the soil to be more porous and friable. With this condition, the formulations biochar dosage 10.52 t ha^{-1} with a type of compost+phonska (D_2P_3) into the soil to improve soil physical properties, through the retention of nutrients and water in soil pores. Soil quality improvement due to the provision of biochar, supported by the physical characteristics of biochar surface at 2000x magnification SEM obvious morphological biochar with a large surface area and micropore structure that spread over the surface of biochar (Situmeang, 2017). These porous biochar pores lead to improved aeration and drainage systems and increased soil ability to absorb ions and water in the soil. Biochar has the characteristics of a higher stability against decomposition and capable of absorbing ions and water better than other organic materials, due to the larger surface area, the negative surface, and the density (Liang *et al*., 2006; Lehmann, 2007).

Table 5. Relative Agronomic Effectiveness (RAE) analysis biochar combined with compost and phonska on plant height and number of leaves.

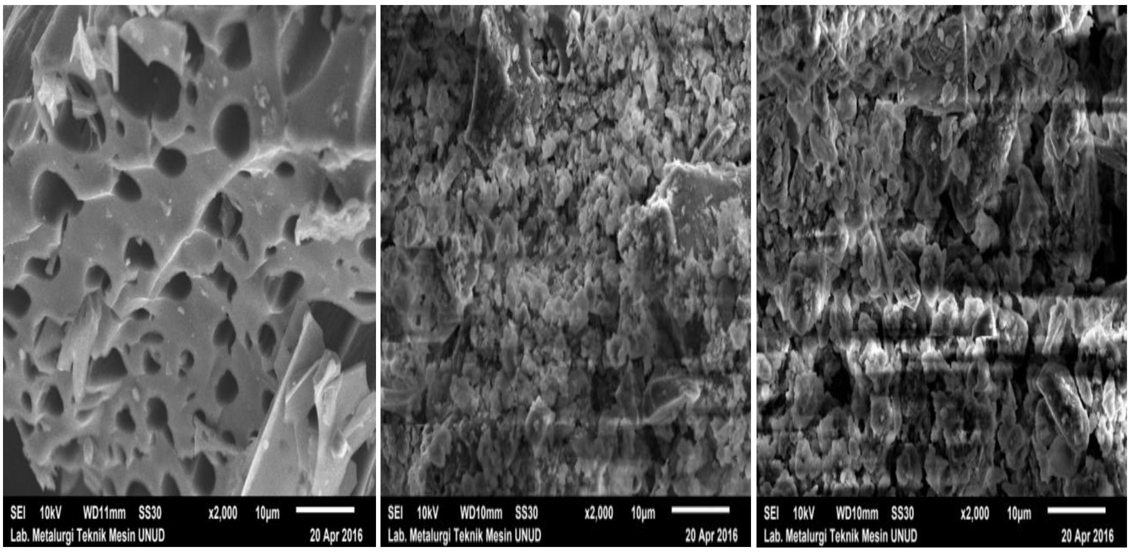
Treatment	Plant height		Number of leaves	
	(cm)	RAE (%)	(Strands)	RAE (%)
D_0P_0	262.11	-	15.17	-
D_0P_1	290.41	-	15.67	-
D_0P_2	305.11	-	15.89	-
D_0P_3	301.56	-	16.22	-
D_1P_0	268.17	-	15.28	-
D_1P_1	290.50	78.93	15.72	88.89
D_1P_2	307.78	92.12	16.72	200.00
D_1P_3	314.14	116.55	16.61	126.32
D_2P_0	298.78	-	15.72	-
D_2P_1	306.67	27.88	16.06	66.67
D_2P_2	311.17	28.81	16.22	69.23
D_2P_3	318.89	50.99	16.89	110.53
D_3P_0	295.56	-	15.78	-
D_3P_1	307.61	42.61	16.00	44.44
D_3P_2	315.61	46.64	16.28	69.23
D_3P_3	308.67	33.24	16.50	68.42

Note: D_0 (without Biochar), D_1 (Biochar 5 t ha^{-1}), D_2 (Biochar 10 t ha^{-1}), D_3 (Biochar 15 t ha^{-1}),
P_0 (without fertilizer), P_1 (Compost 20 t ha^{-1}), P_2 (Phonska 300 kg ha^{-1}), and P_3 (Compost + Phonska).

Table 6. Relative Agronomic Effectiveness (RAE) analysis biochar combined with compost and phonska on dry weight of plant oven and dry weight of harvest seed.

Treatment	Dry Weight Oven Total Plants		Dry Weight Seed Harvest	
	(g)	RAE (%)	(ton)	RAE (%)
D_0P_0	230.55	-	6.63	-
D_0P_1	300.95	-	8.77	-
D_0P_2	327.26	-	9.53	-
D_0P_3	376.67	-	10.24	-
D_1P_0	284.12	-	8.02	-
D_1P_1	322.68	54.76	9.10	50.41
D_1P_2	377.14	96.17	10.69	92.06
D_1P_3	405.14	82.81	11.20	88.28
D_2P_0	337.03	-	9.60	-
D_2P_1	366.13	41.34	10.63	48.00
D_2P_2	404.27	69.52	11.30	58.47
D_2P_3	485.36	101.51	13.71	113.99
D_3P_0	332.45	-	9.27	-
D_3P_1	385.33	75.12	10.36	50.66
D_3P_2	374.60	43.58	9.90	21.69
D_3P_3	357.64	17.24	9.46	5.23

Note: D_0 (without Biochar), D_1 (Biochar 5 t ha^{-1}), D_2 (Biochar 10 t ha^{-1}), D_3 (Biochar 15 t ha^{-1}), P_0 (without fertilizer), P_1 (Compost 20 t ha^{-1}), P_2 (Phonska 300 kg ha^{-1}), and P_3 (Compost+Phonska).



Bamboo Biochar **D_0P_0** **D_2P_3**

Figure 1. SEM of bamboo biochar, D_0P_0, and D_2P_3 at 2000x magnification

CONCLUSIONS

The interaction of biochar dosage with the type of fertilizer had no significant effect on the plant height and the number of leaves, very significant effect on the total oven-dry weight of plants, and significantly affect the dry weight of corn harvest per ha.

Treatment of biochar dosage and fertilizer type had the significant effect on all observed variables. The biochar dosage 10.52 t ha^{-1} combined with compost 20.22 t ha^{-1} and phonska 313.37 kg ha^{-1} gave the highest yield of dry corn seeds per ha of 13.71 tons, which iincreased by 106.67% when compared with without biochar, compost, and phonska.
The RAE value of a dry weight of seed harvest was obtained on biochar 10.52 t ha^{-1} with compost+ phonska of 113.99% and lowest on biochar interaction 15.78 t ha^{-1} with compost+phonska of 5.23%.
The agronomics effectiveness of combined biochar dosage 10.52 t ha^{-1} with compost 20.22 t ha^{-1} and phonska 313.37 kg ha^{-1} is very good and effective at the total oven-dry weight of the plant and the dry weight of corn harvest per hectare in dryland.

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