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Agronomic effectiveness of biochar and fertilizer type in increasing the results of sweet corn

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Abstract. This study aims to examine the effectiveness of biochar from bamboo and coconut shell combined with compost and NPK fertilizer on the growth and yield of sweet corn. In this study, we used a randomized block design with factorial patterns consisting of two factors and 3 replications. The first factor is the treatment of biochar types (3 types), namely: without biochar, bamboo biochar, and coconut shell biochar. The second factor is the treatment of fertilizer types (4 types), namely: without fertilizer, compost, NPK, and compost+NPK. The results showed that the interaction of bamboo biochar with compost+NPK significantly increased the total fresh weight of the highest plant 297.97 g when compared to without biochar, compost, and NPK 184.63 g or increased by 61.38% with an agronomic effectiveness of 132.10%. Likewise, the coconut shell biochar interaction with compost+NPK significantly increased the highest total fresh weight of 295.83 g when compared to the lowest yield without biochar, compost and NPK 184.63 g with an increase of 60.23% and agronomic effectiveness of 103.76 %. The application of compost+NPK fertilizer treatment significantly gives the highest fresh weight of cob without husk 79.26 g increased by 51.54% when compared with the lowest yield on 52.30 g fertilizer without fertilizer. From the results of this study, biochar from bamboo and biochar from coconut shell combined with compost+NPK can be used to improve the yield of sweet corn.

Introduction

Sweet corn (*Zea mays saccharata* Sturt.) has an important role in fulfilling food for some Indonesian people. Sweet corn plants can adapt to extreme temperatures, are easy to cultivate, and can be harvested in a short time, so that this plant has the potential to be developed, especially on dry land. To achieve the maximum yield of sweet corn on dry land, balanced fertilization can be done using biochar, compost, and NPK fertilizer.

Biochar is made with pyrolysis technology, namely by incomplete combustion of biomass or agricultural waste in anaerobic conditions that produce stable biological charcoal. Biochar is difficult to decompose in the soil so that a single application of biochar can provide beneficial effects for several growing seasons on the land. Biochar can maintain a long balance of carbon and nitrogen in the soil, adding biochar soil enhancers can also increase P and N absorption, and increase CEC and soil pH [1]. The using of biochar to agricultural land can improve carbon content in the soil, water and nutrient retention ability in the soil, and increase soil quality [2]. Biochar can increase nutrient availability of N, P, K, and cation exchange capacity (CEC) in the soil, as well as yields, and can reduce the risk of leaching nutrients in the soil, especially nutrients N and K [3].

The effectiveness of biochar in improving soil quality is highly dependent on the chemical and



physical properties of biochar which are determined by the type of raw material and the method of carbonization, and form [4]. Biochar is more effective at holding nutrients to their availability for plants than other organic materials. Biochar has many pores because of its large surface area so that it has a high water holding capacity. Biochar from bamboo has a very micropore structure with a wide surface, which causes the adsorption efficiency of bamboo biochar to reach 10 times greater than that of wood biochar [5].

Compost is an organic fertilizer derived from agricultural waste which has undergone weathering processes and has a large contribution to increasing soil fertility. Biochar can be added to the composting process, which functions as a bulking agent that increases the humification process and the final quality of compost in producing humic acid and fulvic acid. Biochar is also useful as an important ingredient in the compost to help absorb nutrients and form humus and accelerate many processes that occur on the ground. Biochar can be decomposed by microbes at least ten times longer in most soils. Biochar has an important role when added to compost, making compost richer in nutrients, more biologically diverse, more moist, and stable [6].

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The results of the study [7], the application of 15 tons ha⁻¹ of coconut shell biochar gave a positive response to the yield of corn crops, obtained corn seed yield in the three cycles of the growing season reached 5.54 tons ha⁻¹. The application of 10 tons ha⁻¹ of bamboo biochar has a significant effect on the growth and yield of corn plants [8]. The results [9,10, 11], the application of bamboo biochar (10 tons ha⁻¹), Compost from cow dung (20 tons ha⁻¹), and NPK phonska fertilizer (300 kg ha⁻¹) could increase growth and corn yield on dry land. Based on the description above, a research is conducted that aims to obtain the agronomic effectiveness of various types of biochar and fertilizer types and their interactions in increasing the growth and yield of sweet corn crops.

2. Materials and Methods

This research was carried out at the Experimental Station of the Agriculture Faculty, Warmadewa University, Denpasar, Bali. Soil analysis was carried out in the Land Laboratory of the Faculty of Agriculture, Udayana University, Denpasar, Bali. This research has been going on from March to July 2018. The materials used are sweet corn seeds, compost from cow manure, biochar from coconut shell waste, and biochar from bamboo waste, and pearl NPK fertilizer (16 % N, 16 % P₂O₅, 16% K₂O).

This study used a Randomized Block Design (RBD) factorial pattern. The first factor is the type of biochar treatment (3 types), namely: Bo (control / without biochar), Bb (Biochar bamboo), Bs (Biochar coconut shell). The second factor is the treatment of various types of fertilizers (F) consisting of 4 levels, namely: Fo (without fertilizer), Fc (compost), Fn (NPK fertilizer), and Fcn (compost+NPK). Of the two factors above obtained 12 treatment combinations. This treatment combination was repeated 3 times to obtain 36 experimental pots. Variables observed in pots (per plant) in this study include plant height of 49 days after planting, number of leaves 49 days after planting, fresh weight of plant roots, the total fresh weight of plants, oven dry weight total plants, fresh weight of corn without cob skin, and dry weight of seeds.

The Relative Agronomic Effectiveness Analysis (RAE) was carried out to obtain a percentage value from achieving an increase in the yield of bamboo biochar compared to the increase in the yield of standard fertilizers. Variance analysis was used to test the effect of various types of biochar on fertilizer types on the observed variables. Furthermore, if the results of the analysis of variance are obtained real results, then proceed with the Least Significant Difference test and Duncan's test level 5%.

3. Results

3.1 Soil characteristics, compost, biochar bamboo, and biochar coconut shell

The results of the laboratory analysis of soil characteristics before research, compost, and biochar made from bamboo and coconut shell as shown in Table 1.

Table 1. Results Soil analysis, compost, bamboo biochar*[9], and coconut shell biochar

Type of Analysis	Soil Research	Compost	Biochar* Bamboo	Biochar Coconut Shell
pH H ₂ O	6.90 (N)	7.11 (N)	7.48 (N)	7.40 (N)
C-organic (%)	0.39 (VL)	11.32 (VH)	3.08 (M)	8.51 (VH)
N-total (%)	0.06 (VL)	0.78 (VH)	0.06 (VL)	0.05 (VL)
C/N ratio	6.50	14.51	51.33	170.20
P-available (ppm)	75.59 (VH)	5300 (VH)	451.78 (VH)	251.99 (VH)
K-available (ppm)	1086.75 (VH)	8900 (VH)	36.07 (VL)	4258.68 (VH)
Water content:				
Dry Air (%)	17.41	27.19	5.48	9.19
Field Capacity (%)	44.70	-	-	-
Tekstur (Loam)				
Sand (%)	39.77			
Dust (%)	47.51			
Clay (%)	12.72			

Description: N= Neutral, VL=Very Low, M=Moderato, VH=Very High

Nutrients needed for growth and development of sweet corn plants are strongly influenced by nutrient availability or soil nutrient status. The results of the soil characteristics analysis at the study site (Table 1) showed that organic C and total N were very low, while P and K were available at very high status. With such nutrient status, the land where the research was conducted was unable to provide enough C and N nutrients for corn plants to grow properly, therefore it needed the addition of organic matter or soil enhancers such as compost and biochar and inorganic materials such as pearl NPK fertilizer to improve soil fertility. From such soil conditions after research shows that the administration of biochar, compost and NPK (Table 1) can significantly and effectively improve the growth and yield of sweet corn compared to no treatment (Tables 2, 3, 4, 5, 6).

3.2 Significance of the influence of biochar type and fertilizer type on all observed variables.

The importance of the effects of various types of biochar (B) and fertilizer (F) and their interactions (BxF) as in Table 2.

Table 2. The significance of the effects of various types of biochar (B), type of fertilizer (F), and their interaction (BxF) on all variables observed.

Variable	Treatment		
	Biochar Type (B)	Fertilizer Type (F)	Interaction (BxF)
1 The height of the corn plant (cm)	ns	**	ns
2 Number of plant leaves (strands)	ns	**	ns
3 Fresh weight of plant roots (g)	**	ns	ns
4 The total fresh weight of plants (g)	**	**	**
5 The total dry weight of plants (g)	*	**	ns
6 Fresh weight of cob without husk (g)	ns	**	ns
7 Harvested dry seed weight (g)	ns	**	ns

ns (no significant), * (significant), ** (very significant)

Table 2 shows that (1) the interaction the type of biochar and the type of fertilizer (BxF) does not have a real effect ($P \geq 0.05$) for all variables observed, except for total fresh weight of plants, (2) significant ($P \geq 0.05$) in most plants except for fresh root weight, total weight of fresh plants, and total weight of dry oven plants, (3) treatment of fertilizer types had a very real effect for all variables of plant observed, except for fresh weight from the root.

3.3 The height of the corn plant

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The interaction between biochar and fertilizer (BxF) and biochar (B) treatment did not have a real effect ($P \geq 0.05$) on plant height (Table 2), but the application of various types of fertilizer (F), was very significant ($P < 0.01$) effect on the height of corn plants. Bamboo biochar (Bb) application gives a maximum plant height of 110.70 cm, which is not significantly different from the treatment biochar of coconut shell (Bs) and without biochar (Bo). The treatment of compost + NPK (Fcn) gives maximum plant height as high as 117.13 cm, which is real increased 16.08% compared treatment without fertilizer (Fo), which has a height of 100.91 cm (Table 3).

Table 3. The average plant height, number of leaves, and fresh weight of roots of sweet corn plants on biochar dose treatment and type of fertilizer

Treatment	Plant Height (cm)	Number of leaves (strands)	Fresh root weight (g)
Biochar Type (B):			
Without Biochar (Bo)	104.26 a	8.00 a	32.69 b
Biochar Bamboo (Bb)	110.70 a	8.50 a	33.33 b
Biochar Coconut Shell (Bs)	110.59 a	8.58 a	35.01 a
LSD 5%	-	-	1.81
Fertilizer Type (F):			
Without Fertilizer (Fo)	100.91 b	7.56 b	32.61 a
Compost Fertilizer (Fc)	105.53 b	8.22 b	33.49 a
NPK Fertilizer (Fn)	110.49 ab	8.67 ab	34.18 a
Compost+NPK Fertilizer (Fcn)	117.13 a	9.00 a	34.43 a
LSD 5%	11.89	1.03	-

3.4 Number of leaves

The biochar of coconut shell application (Bs) gives the maximum number of leaves is 8.58 strands (Table 3) which are not significantly different from the treatment of bamboo biochar (Bb) and without biochar (Bo) with 8.50 leaves and 8.00 strands. The treatment of the type of compost + NPK (Fcn) gave the highest value of leaves of 9.00 strands the real increase was 19.12% compared to treatment without fertilizer (Fo) with a leaf number of 7.56 strands.

3.5 Fresh weight of root

The highest weight of root fresh (Table 3) was obtained in coconut shell biochar (Bs) which was 35.01 g which differed significantly from bamboo biochar (Bb) and without biochar (Bo) treatment with fresh root weight 33.33 g and 32.69 g. In the treatment of compost + NPK (Fcn), the highest fresh root weight was obtained 34.43 g, which was not a real difference when compared to NPK (Fn), compost (Fc), and without fertilizer (Fo) treatment with fresh root weights of 34.18 g, 33.49 g, and 32.61 g.

3.6 Total fresh weight of corn plant

The total fresh weight highest (Table 4) was obtained from the interaction between bamboo biochar and compost + NPK (BbFcn) 297.97 g the real increase was 61.38% compared to the interaction without the application of biochar and fertilizer (BoFo) with the total weight of fresh plants 184.63 g. Likewise in

5 the interaction between coconut shell biochar and compost + NPK (BsFcn), the highest value of the total fresh weight was 295.83 g (an increase of 60.23%) if compared to the interaction without biochar and fertilizer (BoFo) with a total fresh weight of 184.63 g.

Table 4. Effect of interaction of various types of biochar and types of fertilizers on the total fresh weight of corn plants

Treatment	Fo	Fc	Fn	Fcn
Bo	184.63 i	235.87 of	253.80 def	262.67 cd
Bb	191.77 hi	227.10 fg	262.60 cd	297.97 a
Bs 1	214.87 gh	259.53 cde	286.00 abc	295.83 ab

The numbers followed by the same letters in the same column show no significant difference in the 5% level of the Duncan test.

3.7 Total dry weight of corn plants

The application of coconut shell biochar (Bs) gives the highest of a total dry weight of corn plants 46.68 g, which is significantly increased 10.69% compared to treatment without biochar (Bo) 42.17 g. The application of compost + NPK (Fcn) gave the highest total oven dry weight of corn plants 52.97 g which significantly increased 56.30% when compared without fertilizer (Fo) with a total oven dry weight of 33.89 g (Table 5).

3.8 Fresh weight of corn cob without husk

Biochar application of bamboo (Bb) obtained the fresh weight of cob without husk that is 68.87 which is not really different from coconut shells biochar treatment (Bs) or without biochar (Bo). The application of compost + NPK (FCN) gave a fresh weight of corn cob without husk of 79.26 g (increased 51.54%) compared to the treatment without fertilizer (Fo) (Table 5).

3.9 Weight of seeds dry harvest

The results of statistical tests of the weight of dried seeds harvested showed that the interaction between biochar and fertilizer (BxF) and the treatment of single biochar (B) did not have a significant effect, while fertilizer application (F) is very real effect to a weight of dried seeds harvested (Table 2). In Table 5, we can see the average weight of dried seeds harvested in the treatment of biochar types and types of fertilizers.

Table 5. Application effects of various types of biochar and types of fertilizers on the yield of corn plants

Treatment	Total dry weight oven plant (g)	Fresh weight of cob without husk (g)	Seed weight dry harvest (g)
Biochar Type (B):			
Without Biochar (Bo)	42.17 b	63.38 a	50.68 a
Biochar Bamboo (Bb)	41.58 b	68.87 a	52.04 a
Biochar Coconut Shell (Bs)	46.68 a	65.59 a	53.16 a
LSD 5%	5.51	-	-
Fertilizer Type (F):			
Without Fertilizer (Fo)	33.89 d	52.30 b	41.78 b
Compost Fertilizer (Fc)	39.96 c	62.10 b	49.02 b
NPK Fertilizer (Fn)	47.08 b	70.13 ab	57.07 ab
Compost+NPK Fertilizer (Fcn)	52.97 a	79.26 a	59.98 a
LSD 5%	6.36	18.01	11.41

3
The highest dry weight of seeds harvested (Table 5) obtained in bamboo biochar (Bb) 53.16 g was not really different from the application of coconut shell biochar (B) or without biochar (Bo) with dry seed weight 52.04 g and 50.68 g. The treatment of compost + NPK (Fcn) gave the highest dry weight of seeds harvested at 59.98 g which real increased by 43.58% when compared with no fertilizer with dry seed weight 41.78 g.

3.10 Relative agronomic effectiveness of the combination of biochar with compost and NPK

The results of the analysis of relative agronomic effectiveness (RAE) combination of biochar types with the type of fertilizer on all observed variables such as Table 6. The best average RAE values for all plant variables observed (103.76% -166.67%) were obtained in bamboo biochar and coconut shell biochar combined with compost+NPK (BbFcn and BsFcn) compared to other combination treatments. Bamboo biochar application combined with compost+NPK (BbFcn) on all observed plant variables gave the highest RAE value with a range of 106% -167%. Likewise, coconut shell biochar combined with compost+NPK (BsFcn) on all observed variables gave the highest RAE value with a range of 103.76% -166.67%.

2
Table 6. The average RAE percentage of all variables observed due to the influence of biochar combination with fertilizer type

Treatment	Relative Agronomic Effectiveness (RAE)						
	Plant Height	Number of leaves	Fresh root weight	Total dry weight oven plant	Total dry weight oven plant	Fresh weight of cob without husk	Seed weight dry harvest
----- % -----							
BbFc	87.66	100.00	41.46	68.97	56.12	47.47	61.80
BbFn	86.77	100.00	61.40	102.41	80.94	82.29	133.77
BbFcn	110.25	166.67	124.44	136.10	105.69	120.05	151.87
BsFc	82.47	100.00	51.22	87.18	74.26	24.12	82.40
BsFn	91.29	133.33	85.96	102.84	112.87	104.83	126.44
BsFcn	122.32	166.67	140.00	103.76	120.11	110.91	156.61

4. Discussion

The interaction between bamboo biochar and compost+NPK (BbFcn) gave the highest total fresh weight of plants, namely 297.97 g (Table 4) which increased by 61.38% with RAE 136.10% (Table 6) if compared with the interaction without biochar and fertilizer (BoFo) 184.63 g. Likewise, the interaction between coconut shell biochar and compost+NPK (BsFcn) gave the highest total fresh weight of plants 295.83 g or an increase of 60.23% (Table 4) with RAE value of 103.76% (Table 6) when compared with interactions without biochar and fertilizer (BoFo) 184.63 g.

The high total fresh weight of plants was also supported by a positive, strong and very real correlation on all observed variables (Table 7), namely plant height ($r = 0.91^{**}$), number of leaves ($r = 0.96^{**}$), fresh weight of roots ($r = 0.82^{**}$), total oven dry weight of plants ($r = 0.95^{**}$), fresh weight of cob without cornhusk ($r = 0.90^{**}$), and dry weight of seed ($r = 0.95^{**}$). The strong and very real relationship between the total fresh weight of plants and all observed variables is in line with the yield of fresh cob without weight in the application of compost + NPK which gave the highest value of 79.26 g, increased 51.54% when compared with treatment without fertilizer 52.30 g.

RAE assessment or relative agronomic effectiveness of biochar made from bamboo and coconut shell combined with compost+NPK on all observed plant variables gave the best RAE value or agronomic effectiveness with a range of 103.76% -166.67%. The treatment combination from bamboo biochar, compost, and NPK phonska provides the highest RAE of 113.99% which was classified as very effective [12], also produced very good soil quality with Soil Quality Rating (SQR) 18 on plants corn cultivation in the dryland [13].

Table 7. Correlation coefficient value (r) between plant variables due to the influence of interactions between biochar types and fertilizer types

	Plant Height	Number of leaves	Fresh root weight	Total fresh weight of plant	Total dry weight oven plant	Fresh weight of cob without husk
Number of leaves	0.96**					
Fresh root weight	0.75**	0.80**				
The total fresh weight of plants	0.91**	0.96**	0.82**			
Total dry weight oven plant	0.90**	0.91**	0.78**	0.95**		
Fresh weight of cob without husk	0.92**	0.93**	0.60**	0.90**	0.90**	
Seed weight dry harvest	0.89**	0.93**	0.68**	0.95**	0.95**	0.94**
r (0.05, 34, 1) = 0.329			r (0.01, 34, 1) = 0.424			

Increased percentage of RAE or very effective interactions between biochar made from bamboo and coconut shell with compost+NPK (BpFcn and BsFcn) on the total fresh weight of plants is due to the improvement of soil characteristics due to biochar application added with compost and NPK on plant growth media. The very low C-organic and N-total contents in the soil media used were able to respond well to compost and biochar which had very high C-organic content (Table 1) and NPK nutrients needed by corn plants. The high C-organic in biochar and compost has encouraged improvements in soil physical properties, increasing soil aggregation from micro aggregation to larger aggregates, more porous and loose, increase water and nutrient absorption in the soil, increase soil pH, nitrogen, phosphorus, potassium, cation exchange capacity, base saturation, and total soil microorganisms [14]. Furthermore [15, 16], This states that biochar can increase soil fertility such as aggregation, groundwater capacity, pH, CEC, and soil biological activity. The application of biochar can increase the ability of the soil to store carbon, increase soil fertility, maintain the balance of soil ecosystems, provide and maintain nutrients in the soil and increase crop yields [17, 18].

5. Conclusions

The application of various types of biochar does not have a significant effect on most plants except on fresh root weight, total plant weight, and oven dry weight total of corn plants. However, the application of fertilizers type has a very real effect on all variables except the root weight is not significant. While the interaction of biochar and fertilizer on the observed variables was not significant, except for the total fresh weight of plants.

The application of bamboo biochar with compost + NPK obtained the highest value of 297.97 g from the total fresh weight of the plant which increased 61.38% compared to the application without biochar and fertilizer (184.63 g). From the results of this study obtained the highest agronomic effectiveness on the total fresh weight of corn plants with RAE values of 136.10%.

Biochar application made from bamboo and coconut shell combined with compost + NPK on all plant variables observed gave the best RAE value with agronomic effectiveness 103.76% -166.67%. The interaction between coconut shell biochar and compost + NPK obtained the highest percentage increase of 60.23% from the total fresh weight of corn plants with an RAE value of 103.76%.

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