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COMBINED EFFECT OF BIOCHAR RESIDUE AND FERTILIZER APPLICATION ON MAIZE GROWTH AND PRODUCTION IN LAMPUNG ULTISOL

PENGARUH KOMBINASI PERLAKUAN RESIDU BIOCHAR DAN PEMUPUKAN TERHADAP PERTUMBUHAN DAN HASIL TANAMAN JAGUNG DI TANAH ULTISOL LAMPUNG

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ABSTRACT

This study aimed to evaluate the combined effect of biochar residue and fertilizer application on the growth and yield of maize (Zea mays L.) in Lampung Ultisol. The research was conducted at the Integrated Field Laboratory, Faculty of Agriculture, University of Lampung. A factorial experiment was arranged in a Randomized Complete Block Design (RCBD) with two factors. The first factor were soil amendment residue treatments (B), consisting of B0: no soil amendment residue, B1: 5 tons ha^{-1} rice husk biochar residue + 5 tons ha^{-1} cattle manure residue, B2: 5 tons ha^{-1} maize cob biochar residue + 5 tons ha^{-1}cattle manure residue, and B3: 5 tons ha^{-1} cassava stem biochar residue + 5 tons ha^{-1}cattle manure residue. The second factor were the application of N, P, and K fertilizers, consisted of P0: no fertilizer, P1: ½ recommended fertilizer dose (Urea 225 kg ha^{-1}, TSP 112.5 kg ha^{-1}, and KCl 100 kg ha^{-1}), and P2: full recommended fertilizer dose (Urea 450 kg ha^{-1}, TSP 112.5 kg ha^{-1}, and KCl 100 kg ha^{-1}). A total of 12 treatment combinations were replicated three times. This study showed that fertilization with a full dose of 450 kg ha^{-1} Urea , 25 kg ha^{-1} TSP, and 200 kg ha^{-1} KCl (P2) had a significant effect on almost all parameters of maize plant growth and yield, such as plant height, stem diameter, number of leaves, biomass weight, cob length and diameter, and yield. Meanwhile, applying biochar residue increased plant vegetative growth (number of leaves and biomass dry weight. There was no significant interaction between biochar residue and fertilization treatment on most of the parameters observed. These results confirm that to increase maize productivity on Ultisol soil, fertilization plays an important role, while biochar residue has the potential to increase vegetative growth and long term soil quality.

ABSTRAK

Penelitian ini bertujuan untuk mengevaluasi pengaruh gabungan residu biochar dan aplikasi pemupukan terhadap pertumbuhan dan produksi tanaman jagung (*Zea mays* L.) pada tanah Ultisol di Lampung. Penelitian dilaksanakan di Laboratorium Percobaan Lapang Terpadu (LTPD), Fakultas Pertanian, Universitas Lampung. Percobaan disusun dalam Rancangan Acak Kelompok (RAK) secara faktorial dengan dua faktor perlakuan. Faktor pertama adalah perlakuan residu bahan pembenah tanah (B) yang terdiri atas B0: tanpa residu bahan pembenah tanah, B1: residu biochar sekam padi 5 ton ha^{-1} + residu pupuk kandang sapi 5 ton ha^{-1}, B2: residu biochar tongkol jagung 5 ton ha^{-1} + residu pupuk kandang sapi 5 ton ha^{-1}, dan B3: residu biochar batang singkong 5 ton ha^{-1} + residu pupuk kandang sapi 5 ton ha^{-1}. Faktor kedua adalah dosis pemupukan N, P, dan K, yaitu P0: tanpa pemupukan, P1: ½ dosis anjuran (Urea 225 kg ha^{-1}, TSP 112,5 kg ha^{-1}, dan KCl 100 kg ha^{-1}), dan P2: 1 dosis anjuran (Urea 450 kg ha^{-1}, TSP 112,5 kg ha^{-1}, dan KCl 100 kg ha^{-1}). Sebanyak 12 kombinasi perlakuan diuji dan masing-masing diulang sebanyak tiga kali. Penelitian ini menunjukkan bahwa pemupukan dengan dosis penuh Urea 450 kg ha^{-1}, TSP 25 kg ha^{-1}, dan KCl 200 kg ha^{-1} (P2) berpengaruh nyata terhadap hampir semua parameter pertumbuhan dan hasil tanaman jagung, seperti tinggi tanaman, diameter batang, jumlah daun, berat biomassa, panjang dan diameter tongkol, serta hasil. Sementara itu, pemberian residu biochar meningkatkan pertumbuhan vegetatif tanaman (jumlah daun dan bobot kering brangkasan). Tidak terjadi interaksi yang nyata antara residu biochar dengan perlakuan pemupukan pada sebagian besar parameter yang diamati. Hasil ini menegaskan bahwa untuk meningkatkan produktivitas jagung pada tanah Ultisol, pemupukan memegang peranan penting, sedangkan residu biochar berpotensi meningkatkan pertumbuhan vegetatif dan perbaikan kualitas tanah jangka panjang.

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the crops that has an important role in Indonesia, both as the main food source, raw material for animal feed, and industrial purposes (Suryandari, 2021). Maize kernels contain nutrients that are very beneficial for the body, including macronutrients, minerals, and vitamins. According to the United States Department of Agriculture (2016), the basic chemical composition of maize kernels consists of carbohydrates, fat, protein (about 9.42 g per 100 g of maize kernels), vitamins, and minerals. Demand for maize continues to increase along with the increase in population and the development of the agricultural industry sector. To keep up with this demand, intensification and extensification strategies for maize cultivation need to be implemented, including utilizing suboptimal land such as Ultisol soil. Ultisols are known for low productivity due to adverse soil physical and chemical properties, such as high soil acidity, low organic matter. and cation exchange ability (CEC), and limited nutrient content (Saragih et al., 2021).

In Lampung province, ultisols are quite widespread, requiring the application of proper soil management technology to increase soil productivity. A technique that has the ability to be applied is the use of biochar as an acidic material. In addition to biochar is shown to improve various soil properties, such as supporting the activity of pH, water holding capacity, CEC, and soil microorganisms (Tisa et al., 2019; Shao et al., 2024). In permanent agricultural practices, it is also necessary to consider the use of biochar residues occurring in soil for one or more growing seasons. These remains have different characteristics from fresh biochar due to weathering, microbial activity, numerous regeneration and other soil reactions due to chemical and physical changes. Current knowledge on the effect of residual biochar on plant growth is limited, especially about its interaction with fertilizer application. However, biochar remains have the ability to maintain or increase the benefits of initial biochar, which reduces the requirement of additional soil modifications and improves fertilizer use efficiency.

Meanwhile, inorganic fertilizers still require the main nutrients for maize plants, such as nitrogen (N), phosphorus (P) and potassium (K). However, in ultisols, fertilizer efficiency is reduced due to run-off and leaching (Sargih et al., 2021). Therefore, the combination of biochar residue with proper fertilization is considered to be able to increase the efficiency of nutrient retention in the soil, reduce nutrient loss, improve the root environment, and support the growth and yield of corn plants (Uzoma et al., 2011; Shao et al., 2024).

Previous studies have shown that fresh biochar can have a positive impact on plant growth and yield. However, information on the effectiveness of biochar residue, especially when combined with fertilization on Ultisol soil is still limited (Taisa et al., 2019; Baquy et al., 2020). Therefore, further research is needed to evaluate the extent to which biochar residue could maintain or increase plant productivity, as well as formulate optimal and sustainable Ultisol land management strategies. Based on this background, this study aims to examine the effect of interactions between biochar residue and fertilization on the growth and yield of maize on Ultisol soil in Lampung, and to identify the most effective treatment combinations in increasing maize productivity.

2. MATERIALS AND METHODS

2.1 Time and Place

The research was conducted from March to August 2024. Maize planting was carried out at the Integrated Field Experimental Laboratory, Faculty of Agriculture, University of Lampung.

2.2 Research Design

This study was arranged using a Randomized Complete Block Design (RCBD) in a factorial pattern consisting of two treatment factors. The first factor was the residual effect of soil amendment materials in the experimental plots, which included various combinations of biochar and cow manure. These treatments were: B0 (no residual soil amendment), B1 (residue of rice husk biochar at 5 tons ha^{-1} combined with cow manure residue at 5 tons ha^{-1}), B2 (residue of maize cob biochar at 5 tons ha^{-1} combined with cow manure residue at 5 tons ha^{-1}), and B3 (residue of cassava stem biochar at 5 tons ha^{-1} combined with cow manure residue at 5 tons ha^{-1}). The second factor was the dose of N, P, and K fertilizers, consisting of three levels: P0 (0% of the recommended dose—Urea 0 kg ha^{-1}, TSP 0 kg ha^{-1}, KCl 0 kg ha^{-1}), P1 (½ of the recommended dose—Urea 225 kg ha^{-1}, TSP 112.5 kg ha^{-1}, KCl 100 kg ha^{-1}), and P2 (the full recommended dose—Urea 450 kg ha^{-1}, TSP 225 kg ha^{-1}, KCl 200 kg ha^{-1}).

2.3 Implementation of Research

Prior to planting, the research field was first cleared from weeds to facilitate the plotting of experimental plots. Weed removal was necessary to minimize competition for nutrients and ensure similar soil conditions across treatments. After clearing, soil tillage was done using the complete tillage method to loosen the soil structure. This step was essential to improve soil aeration and water infiltration, thereby enhancing root development and nutrient uptake by maize. The field was then divided into plots according to the experimental layout, with each plot measuring 4 × 2 meters. The spacing between treatment plots was 0.25 meters, while the spacing between replication blocks was 1 meter to prevent treatment interference.

Maize seeds were sown using the dibble method, with two seeds placed in each planting hole to ensure good stand establishment. Approximately 50 plants were maintained per plot. If any seeds failed to germinate, replanting was carried out to maintain plant density. At one week after sowing, thinning was performed to retain the more vigorous seedling in each planting hole, ensuring equal plant growth.

Fertilizer application followed the designated treatment levels outlined in Table 1. Phosphorus (TSP) and potassium (KCl) fertilizers were applied once at 7 days after planting (DAP). Nitrogen (urea) was applied in two times: the first at 7 DAP and the second during the vegetative maximum phase to fulfill the plant’s nutrient demands. All fertilizers were applied by dibbling at a depth of 5 cm and a horizontal distance of 10 cm from the plant base, then covered with soil to minimize nutrient loss.

Harvesting was conducted when most of the maize husks had turned dry and yellow, which occurred at around 110 days after planting. Maize cob were manually harvested and grouped according to treatment plots for further analysis. Growth parameters observed included plant height (cm), number of leaves, stem diameter (cm), fresh and dry weight of maize cob (g), 100-grain weight (g), cob diameter and length (cm), and biomass fresh and dry weight (g per plant). Yield-related variables measured included grain yield per hectare (tons ha^{-1}).

Table 1. Treatment doses of N, P, and K fertilizers

Treatment	N (Urea) (kg ha^{-1})	K (KCl) (kg ha^{-1})	(P) (TSP) (kg ha^{-1})
P0	0	0	0
P1	225	100	112,5
P2	450	200	225

To assess the treatment effects, data obtained from the observations were statistically analyzed. Homogeneity of variances was tested using Bartlett's test, and additivity was examined using Tukey's test. After the data is homogeneous and additive, analysis of variance (ANOVA) was conducted, and significant differences among treatments were further tested using the Least Significant Difference (LSD) test at the 5% significance level, masukkan PCA untuk mengetahui korekasi (Pustaka,…).

3. RESULTS AND DISCUSSION

The variance analysis of the effect of biochar residue and fertilizer application on the growth and production of maize is presented in Table 2. Based on the results of the study, it is known that biochar residue factor (B) has a significant effect on the number of leaves and dry weight of maize biomass. This shows that the provision of biochar can improve the physical, chemical, and biological properties of soil which have an impact on the vegetative growth of plants, especially in terms of leaf formation and biomass accumulation. According to Lehmann & Joseph (2024), the addition of biochar to the soil is known to increase the cation exchange capacity (CEC), improve soil structure, and increase water retention and nutrient availability. In addition, the biochar pore structure is also a place for the growth of soil microbes that support the nutrient mineralization process. Another study by Jeni et al. (2024) also supports that biochar residue can significantly increase maize growth.

The fertilization factor (P) significantly influenced most of the observation variables, namely the number of leaves, stem diameter, plant height, wet weight and dry weight of biomass, wet weight of maize without husk, cob length, cob diameter, and yield (tons.ha^{-1}), while the interaction between biochar residue and fertilization (B x P) showed no significant effect on all observation variables. These results indicate that fertilizer application more consistently influenced the growth and production variables of maize than biochar residue.

The effect of biochar residue and fertilizer application on maize growth can be seen in Table 3. The fertilization treatment showed a significant effect on stem diameter, where P2 produced wider stem diameter (2.40 cm) compared to P0 and P1, while the P1 treatment produced a wider stem diameter compared to P0. This shows that the availability of macronutrients such as Nitrogen (N), Phosphorus (P), and Potassium (K) in optimal amounts is very important in supporting the growth of stem tissue.

Table 2. Analysis of Variance of Biochar Residue and Fertilizer Application Effect on Maize Growth and Yield

Variable	Treatment		
	Biochar Residue (B)	Fertilization (P)	B x P
Number of Leaf	*	*	ns
Stem Diameter (cm)	ns	*	ns
Plant Height (cm)	ns	*	ns
Biomass Wet Weight (g)	ns	*	ns
Biomass Dry Weight (g)	*	*	ns
Wet Weight of Maize with Husk (g)	ns	ns	ns
Wet Weight of Maize without Husk (g)	ns	*	ns
Cob lenght (cm)	ns	*	ns
Cob Diameter (cm)	ns	*	ns
100 Grain Wet Weight (g)	ns	ns	ns
100 Grain Dry Weight (g)	ns	ns	ns
Yield (tons.ha^{-1})	ns	*	ns

Note: *= Significant at 5% level; ns= not siginificance at 5% level.

Table 3. The Effect of Biochar Residue and Fertilizer Application on Maize Growth

Treatment	Stem Diameter (cm)		Plant Height (cm)		Number of Leaf		Biomass Wet Weight (g)		Biomass Dry Weight (g)	
B0	2,15	a	171,69	a	11,11	c	705,11		258,56	b
B1	2,26	a	187,79	a	12,24	ab	817,11		320,11	a
B2	2,33	a	186,43	a	12,49	a	838,11		330,78	a
B3	2,28	a	184,26	a	11,84	b	839,56		328,78	a
LSD 5%					0,43				36,14	
P0	2,08	c	167,75	b	11,40	b	635,58	c	268,50	c
P1	2,28	b	179,68	b	12,02	a	816,83	b	302,42	b
P2	2,40	a	200,20	a	12,35	a	947,50	a	357,75	a
LSD 5%	0,09		12,36		0,37		99,51		31,29	

Note : Means with the same letters are not significantly different at the LSD 5%. B0: without soil conditioner residue, B1: rice husk biochar residue 5 tons ha^{-1} + cow manure residue 5 tons ha^{-1}, B2: maize cob biochar residue 5 tons ha^{-1} + cow manure residue 5 tons ha^{-1}, and B3: cassava stem biochar residue 5 tons ha^{-1} + cow manure residue 5 tons ha^{-1}, P0: 0 fertilization dose (0 kg ha^{-1} Urea, 0 kg ha^{-1} TSP, and 0 kg ha^{-1} KCl), P1: ½ fertilization dose (225 kg ha^{-1} Urea, 112.5 kg ha^{-1} TSP, and 100 kg ha^{-1} KCL), and P2: 1 fertilization dose (450 kg ha^{-1} Urea, 225 kg ha^{-1} TSP, and 200 kg ha^{-1} KCl).

Nitrogen plays a role in the formation of chlorophyll, amino acids, and proteins that are essential in the formation of vegetative tissues such as stems and leaves. Phosphorus helps in cell division and enlargement, and supports the development of a good root system (Havlin et al., 2014). Meanwhile, potassium plays a role in the transportation of photosynthetic products, strengthening cell walls, and increasing plant resistance to stress (Tisdale et al., 1993). The combination of these three nutrients will increase plant physiological activities, including the formation of vigorous and larger stem tissues. This is in line with the results of research by Hardiayanti et al. (2022) which stated that the application of NPK fertilizer can increase the growth of plants.

Plant height variable was also significantly affected by fertilization. Full fertilization (P2) produced the highest plant height (200.20 cm), while no fertilization (P0) produced plants with the same height as the half dose fertilization treatment (P1). This increase in plant height is closely related to the function of Nitrogen which encourages active growth of meristematic tissues, lengthens stem internodes and increases crown formation (Mitchell et al., 1991). In contrast, the P0 and P1 treatments develop plant heights that were not significantly different, which may be due to the limited availability of essential nutrients to support optimal growth.

The number of leaves was influenced by biochar residue and fertilization. Biochar residues B2 (maize cob biochar + manure) and B1 (rice husk + cow manure) produced the highest number of leaves (12.49 leaves), while biochar residue B1 and no biochar residue (B0) produced the lowest number of leaves (11.11 leaves). Fertilization treatment also significantly affected the number of leaves of maize plants. P1 (½ doses of fertilizer) and P2 (1 dose of fertilizer) treatments produced plants with the same number of leaves and higher than P0 (0 dose of fertilizer). Kumar & Bhattacharya (2021) stated that biochar not only increases water retention but also increases the availability of nutrients in the soil, which is important for plant growth. On the other hand, fertilization also plays an important role in increasing the number of leaves. Proper fertilization can increase the availability of nutrients needed for vegetative growth thus significantly increasing the number of leaves of plants (Barker & Pilbeam, 2015; Hardiyanti et al., 2022).

Biochar residue significantly affected the dry weight of maize biomass. All residues from biochar combinations, namely B1, B2, and B3, produced the same and higher dry weight of stover compared to those without biochar residues (Table 3). These results are in line with the research of Mardiyan et al. (2024), Rohaniatun et al. (2021), and Elpira et al. (2021) which stated that the application of palm kernel shell and rice husk biochar can significantly increase the growth and yield of maize.

In addition, Medyńska-Juraszek et al. (2021) reported that the application of biochar for three years consistently increased the growth of maize plants, although its effect on soil properties was limited. This suggests that biochar may play a role in directly enhancing plant growth, possibly through increasing nutrient availability or improving soil structure.

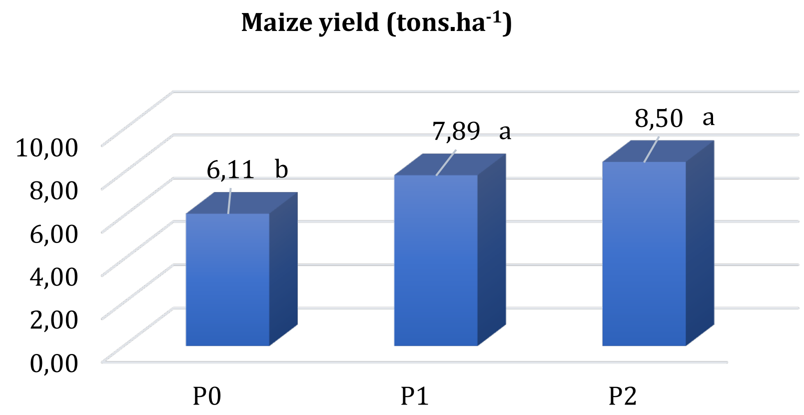
Fertilization treatment gave a significant effect on the wet weight and dry weight of biomass. P2 treatment produced the highest wet weight and dry weight of maize biomass, followed by P1 (½ fertilizer dose), while the P0 treatment produced the lowest wet weight and dry weight of maize biomass (Table 3). Based on the results of research by Mustadir et al. (2023), the growth and production of sweet maize are influenced by fertilizer treatments with different doses. Phospor (P) affects the fresh cob weight of sweet maize plants. The function of P nutrients for plants is cell division, albumin formation, flower, fruit, and seed formation. In addition, P also used to accelerate fruit ripening, strengthen stems, root development and increase disease resistance.

The effect of biochar residue and fertilizer application on maize yield is shown in Table 4. The results showed that the application of biochar residue did not have a significant effect on all maize yield parameters, such as maize wet weight (with and without husks), cob length, and cob diameter. Meanwhile, inorganic fertilizer treatment showed a significant effect on maize yield parameters. The application of a full fertilizer dose (P2: Urea 450 kg/ha, TSP 112.5 kg/ha, and KCl 100 kg/ha) gave significantly better results compared to the half-dose fertilizer treatment (P1) and 0 fertilizer dose (P0). In the P2 treatment, wet weight of maize without husks reached 179.90 g, cob length was 14.07 cm, and the cob diameter was 45.37 mm. In contrast, the P0 treatment produced the lowest values for all parameters, namely the wet weight without husks of 123.90 g, cob length of 11.30 cm, and the diameter of 42.44 mm. A study by Badu et al. (2019) stated that biochar can retain nitrogen in the soil, but to increase maize yields, inorganic fertilizers are still needed as a source of nitrogen on soil. Babalola et al. (2022) highlighted that biochar contributes more to the efficiency of water use and increasing soil aggregates, rather than directly increasing yields. A study by Yang et al. (2023) found that the residual effect of biochar on maize yields was only significant in the long term and with full support from chemical fertilization. A single application biochar or without a combination of fertilizers is not enough to significantly increase yields in the next planting season.

Tabel 4. The Effect of Biochar Residue and Fertilizer Application on Maize Yield

Treatment	Wet Weight of Maize with Husk (g)	Wet Weight of Maize without Husk (g)	Cob Length	Cob Diameter
B0	154,89	140,87	12,18	43,35
B1	172,18	156,04	13,13	43,97
B2	174,00	159,33	13,04	44,62
B3	174,20	161,51	12,98	44,33
LSD 5%				
P0	135,45 b	123,90 c	11,30 c	42,44 b
P1	176,02 a	159,52 b	13,13 b	44,39 a
P2	194,98 a	179,90 a	14,07 a	45,37 a
LSD 5%		20,21	0,91	1,14

Note : Means with the same letters are not significantly different at the LSD 5%. B0: without soil conditioner residue, B1: rice husk biochar residue 5 tons ha^{-1} + cow manure residue 5 tons ha^{-1}, B2: maize cob biochar residue 5 tons ha^{-1} + cow manure residue 5 tons ha^{-1}, and B3: cassava stem biochar residue 5 tons ha^{-1} + cow manure residue 5 tons ha^{-1}, P0: 0 fertilization dose (0 kg ha^{-1} Urea, 0 kg ha^{-1} TSP, and 0 kg ha^{-1} KCl), P1: ½ fertilization dose (225 kg ha^{-1} Urea, 112.5 kg ha^{-1} TSP, and 100 kg ha^{-1} KCL), and P2: 1 fertilization dose (450 kg ha^{-1} Urea, 225 kg ha^{-1} TSP, and 200 kg ha^{-1} KCl).

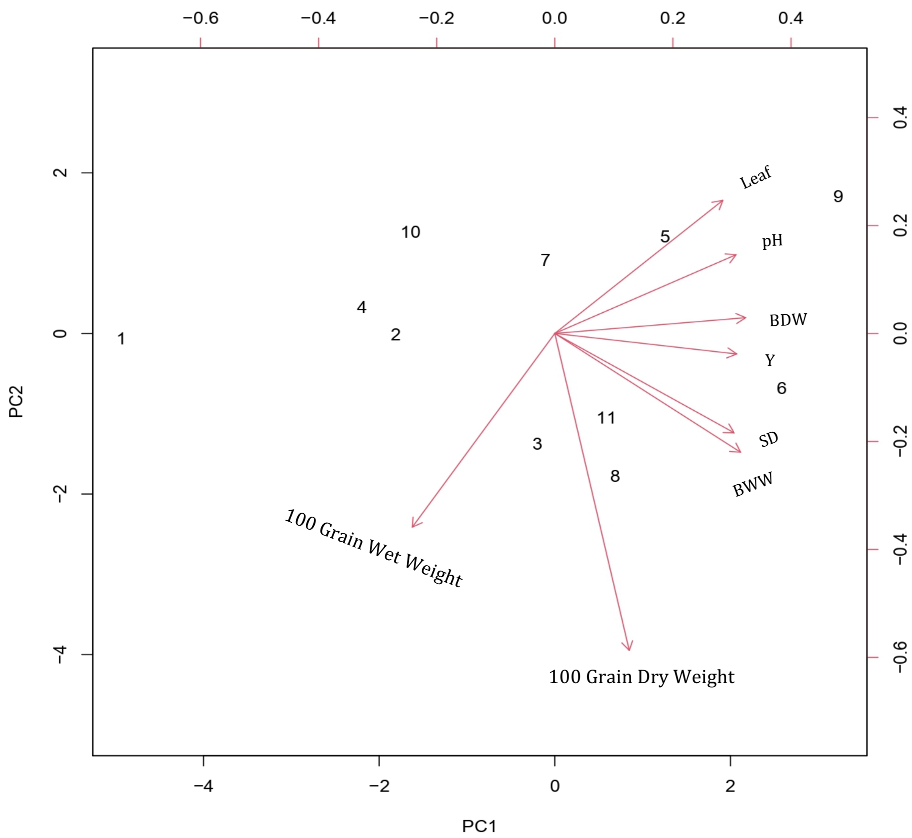


Note : Means with the same letters are not significantly different at the LSD 5%. P0: 0 fertilization dose (0 kg ha^{-1} Urea, 0 kg ha^{-1} TSP, and 0 kg ha^{-1} KCl), P1: ½ fertilization dose (225 kg ha^{-1} Urea, 112.5 kg ha^{-1} TSP, and 100 kg ha^{-1} KCL), and P2: 1 fertilization dose (450 kg ha^{-1} Urea, 225 kg ha^{-1} TSP, and 200 kg ha^{-1} KCl).

Figure 1. The effect of biochar residue and fertilizer application on maize yield

The results of the BNT test showed that the fertilization treatment gave a significant difference in results on maize production. Soil reated with P1 (½ fertilization dose) and P2 (1 fertilization dose) produced maize with the same production but higher than the P0 treatment (0 fertilization dose). This shows that the dose of inorganic N, P, and K fertilizers, both half dose and full dose, significantly increased maize production compared to no fertilization (Figure 1).

The results of this study indicate that only fertilization treatment has a significant effect on maize production. This finding aligns with Ishaq et al. (2024), who discovered that the optimal application of phosphate-based inorganic fertilizers significantly increased nutrient absorption and maize production. Additionally, Pusparini et al. (2018) noted that the optimal dose of NPK (nitrogen, phosphorus, potassium) fertilizer, particularly nitrogen, greatly influenced the vegetative growth and yield of maize plants. Harini et al. (2023) also emphasized that higher doses of fertilizer resulted in greater cob yields compared to other treatments. Furthermore, Yuliani et al. (2020) highlighted the importance of combining inorganic fertilizers with the appropriate doses to enhance biomass and yields, reinforcing the relevance of this study's results in the context of efficient fertilization practices. Research by Nurdin et al. (2023) further supports these findings by stating that balanced fertilization is crucial, especially for hybrid maize varieties that have high nutrient requirements. Therefore, this study emphasizes the importance of using optimal fertilizer doses to achieve maximum maize productivity.



Note : BWW = Biomass Wet Weight, SD = Stem Diameter, Y= Yield, BDW = Biomass Dry Weight

Figure 2. Principal Component Analysis (PCA) of maize plant growth and yield variables influenced by biochar residue and fertilization.

Principal Component Analysis (PCA) of the growth and yield variables of maize plants affected by biochar residue and fertilization is presented in Figure 2. The relationship between two variables is said to be close if the angle formed by the two variable lines is less than 90o, conversely the relationship between two variables is said to be less close if the angle formed is more than 90o. Based on the PCA analysis that has been carried out, maize plant yields have a close relationship with almost all variables, namely the number of leaves, plant height, stem diameter, dry weight and wet weight of the stover, and dry weight of 100 grains. These results indicate that maize plant growth variables (plant height, number of leaves, and plant diameter) affect plant yields. An increase in plant height, number of leaves, stem diameter, can be said to cause an increase in maize plant yields. Leaves are where photosynthesis occurs, so the more leaves are formed, the more photosynthate produced will be distributed throughout the plant body, resulting in better plant growth and also having an impact on optimal maize plant yields. These results are in line with the research of Adimihardja (2012) and Sari et al. (2019) which showed that the number of leaves and plant height contributed significantly to crop yields. In addition, the dry weight of the stalk and the dry weight of grain had a significant positive correlation that affected crop production.

4. CONCLUSION

This study demonstrated that applying a full dose of 450 kg/ha of urea, 225 kg/ha of TSP, and 200 kg/ha of KCl (treatment P2) significantly affected nearly all parameters of maize plant growth and yield. These parameters included plant height, stem diameter, number of leaves, biomass weight, cob length, cob diameter, and overall yield. Additionally, the use of biochar residue was found to enhance vegetative growth, specifically increasing the number of leaves and the biomass dry weight. However, there was no significant interaction between the biochar residue and the fertilization treatment for most of the observed parameters. These findings confirm that fertilization plays a crucial role in enhancing maize productivity on Ultisol soil, while biochar residue has potential benefits for improving vegetative growth and long-term soil quality.

5. REFERENCES

Adimihardja, S. A. 2012. Analisis korelasi dan sidik lintas peubah pertumbuhan terhadap produksi cabai merah (*Capsicum annuum* L.). *Jurnal Pertanian*. 3 (2): 111-121.

Babalola, T. E., B.A. Adabembe, & O.T. Faloye. 2022. Water use-yield relationship of maize as influenced by biochar and inorganic fertilizer applications in a tropical sandy clay loam soil. *Agricultural water management*. 271: 107801.

Badu, E., J.S. Kaba, A.A. Abunyewa, E.K. Dawoe, O. Agbenyega, & R.V. Barnes. 2019. Biochar and inorganic nitrogen fertilizer effects on maize (*Zea mays* L.) nitrogen use and yield in moist semi-deciduous forest zone of Ghana. *Journal of Plant Nutrition*. 42 (19): 2407-2422.

Baquy, M. A. A., J. Jiang, & R. Xu. 2020. Biochars derived from crop straws increased the availability of applied phosphorus fertilizer for maize in Ultisol and Oxisol. *Environmental Science and Pollution Research*. 27 (5): 5511-5522.

Barker, A. V., & Pilbeam, D. J. 2015. Handbook of Plant Nutrition. CRC Press.

Elpira, E., D. Okalia, & G. Marlina. 2022. Pengaruh pemberian biochar sekam padi dan pupuk npk phonska (15: 15: 15) terhadap pertumbuhan dan produksi tanaman jagung (*Zea mays* L.) di tanah ultisol. *Green Swarnadwipa: Jurnal Pengembangan Ilmu Pertanian*. 11 (2): 202-208.

Hardiyanti, R. A., H. Hamzah, & A. Andriani. 2022. Pengaruh pemberian pupuk npk terhadap pertambahan bibit merbau darat (*Intsia palembanica*) di pembibitan: the effect of npk fertilizer on the growth of merbau land (*Intsia palembanica*) seedlings in nursery. *Jurnal Silva Tropika*. 6 (1): 15-22.

Harini, N. V. A., Y. Ilmiasari, R. Sanjaya, E.A. Novrimansyah, & S. Febrianti. 2023. Pengaruh Pupuk Npk Terhadap Pertumbuhan Dan Hasil Produksi Jagung Manis (*Zea mays* Saccharata Sturt.) Di Lampung Utara. *Agroradix: Jurnal Ilmu Pertanian*. 7 (1): 31-37.

Havlin, J.L., J.D. Beaton, S.L. Tisdale, & W.L. Nelson. 2014. *Soil Fertility and Fertilizers* (8th ed.). Pearson Education.

Ishaq, R. M., M. Hilmi, S. Kurniawan, M.T. Hidayat, W.W. Katili, & T. Utami. 2024. Efektivitas pupuk anorganik berbasis fosfat dalam meningkatkan serapan hara dan produksi tanaman jagung (*Zea mays*). *Agrika: Jurnal Ilmu-Ilmu Pertanian*. 18 (1): 123-137.

Jeni, M., & W. Fikrinda. 2024. Effectiveness of biochar residue composition and organic fertilizer on cauliflower crops. *Agrisaintifika: Jurnal Ilmu-Ilmu Pertanian*. 8 (2): 292-299.

Kumar, A., & T. Bhattacharya. 2021. Biochar: a sustainable solution. *Environment, Development and Sustainability*. 23: 6642-6680.

Lehmann, J., & S. Joseph. (Eds.). 2024. *Biochar for environmental management: science, technology and implementation*. Taylor & Francis.

Mardiyan, K., B. Nasrul, & N. Nelvia. 2024. Pengaruh biochar cangkang kelapa sawit dan pupuk npk terhadap pertumbuhan dan hasil tanaman jagung manis (*Zea mays* saccharata Sturt.). *Innovative: Journal Of Social Science Research*. 4 (3): 16840-16854.

Medyńska-Juraszek, A., A. Latawiec, J. Królczyk, A. Bogacz, D. Kawałko, M. Bednik, & M. Dudek. 2021. Biochar improves maize growth but has a limited effect on soil properties: Evidence from a three-year field experiment. *Sustainability*. 13 (7): 3617

Mustadir, M., & B. Ibrahim. 2023. Pengaruh pemberian pupuk organik cair dan pupuk npk terhadap pertumbuhan dan produksi tanaman jagung manis (*Zea mays* L. Saccaharata Sturt). *AGrotekMAS Jurnal Indonesia: Jurnal Ilmu Peranian*. 4 (2): 258-264.

Nurdin, L., H. Rukka, & K. Kaharuddin. 2023. Aplikasi beberapa rekomendasi pemupukan dan dampaknya terhadap pertumbuhan dan produksi jagung pulut (*Zea mays* ceratina l.): application of some fertilization recommendations and its impact on growth and production of waxy maize (*Zea mays* ceratina L.). *Jurnal Agrisistem*. 19 (2): 95-101.

Pusparini, P. G., A. Yunus, & D. Harjoko. 2018. Dosis pupuk NPK terhadap pertumbuhan dan hasil jagung hibrida. *Agrosains: Jurnal Penelitian Agronomi*. 20 (2): 28-33.

Rohaniatun, R., A.M. Oklima, & I.W. Ayu. 2021. Pengaruh biochar sekam padi dan pupuk silikat cair terhadap tanaman jagung manis (*Zea mays* Saccharata Sturt. L) di lahan kering. *Jurnal Agroteknologi*. 1 (1): 39-46.

Saragih, M. I., & S.T. Fauzi. 2019. Aplikasi biochar dan pupuk kandang sebagai amelioran dan sp-36 terhadap peningkatan P-tersedia, serapan P dan pertumbuhan jagung (*Zea mays* L.) di Tanah Ultisol. *Jurnal Online Agroekoteknologi*. 1 (3): 532-541.

Sari, P., Y.I. Intara, & A.P.D. Nazari. 2019. Pengaruh jumlah daun dan konsentrasi Rootone-F terhadap pertumbuhan bibit jeruk nipis lemon (*Citrus limon* L.) asal stek pucuk. *Ziraa'ah Majalah Ilmiah Pertanian*. 44 (3): 365-376.

Shao, Z., X. Zhang, J. Nasar, & H. Gitari. 2024. Synergetic effect of potassium, biochar and cattle manure on the growth and yield of maize, and soil physio-chemical characteristics. *Plants*. 13 (23): 3345.

Suryandari, K.C. 2021. Seri produk Olahan : Jagung. PT. Bumi Aksara. Jakarta

Taisa, R., D. Maulida, A.K. Salam, M. Kamal, & A. Niswati. 2019. Improvement of soil chemical properties and growth of maize due to biochar application on ultisol. *Journal of Tropical Soils*. 24 (3): 101-107.

Tisdale, S.L., W.L. Nelson, J.D. Beaton, & J.L. Havlin. 1993. *Soil Fertility and Fertilizers*. Macmillan Publishing Company.

United States Department of Agriculture. (2016). *USDA National Nutrient Database for Standard Reference*. U.S. Department of Agriculture, Agricultural Research Service. Retrieved from https://www.nal.usda.gov/human-nutrition-and-food-safety/nutrient-lists-standard-reference-legacy-2018.

Uzoma, K. C., M. Inoue, H. Andry, H. Fujimaki, A. Zahoor, & E. Nishihara. 2011. Effect of cow manure biochar on maize productivity under sandy soil condition. *Soil use and management*. 27 (2): 205-212.

Yang, W., Y. Jia, G. Feng, C. Ma, & Z. Qu. 2023. Residual effect of single biochar application on soil nutrients availability and fertilizer productivity in a mulched drip-irrigated maize field. *Archives of Agronomy and Soil Science*. 69 (6): 905-919.

Yuliani, D., N. Sasmita, & R. Hidayat. 2020. Respons Tanaman Jagung terhadap Variasi Dosis Pupuk Organik dan Anorganik. *Jurnal Tanaman Pangan*. 5 (1): 50–57.

Zhang, M., C. Tao, H. Latifmanesh, X.M. Feng, T.H. Cao, C.R. Qian, ... & W.J. Zhang. 2018. How plant density affects maize spike differentiation, kernel set, and grain yield formation in Northeast China?. *Journal of Integrative Agriculture*. 17 (8): 1745-1757.