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INVESTIGATING THE EFFECTS OF BAMBOO BIOCHAR ON FERTILE SOIL FOR IMPROVING THE PRODUCTION OF *Brassica oleraceae*

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ABSTRACT

Cabbage (Brassica oleracea var capitate), broccoli (B. oleraceae L. var italica), carrots, and cauliflower (B. oleracea var botrytis) are the primary vegetable crops grown in Ngablak. The role of chemical fertilizers in crop enhancement cannot be avoided in the production of vegetables. Chemical fertilizers come in a variety of forms, including nitrogenous, phosphate, and potassium fertilizers. Fertilizer use not only boosts crop yield, but also modifies the physical, chemical, and biological aspects of the soil. However, the continual use of chemical fertilizers has led to a loss in soil organic matter (SOM) and a deterioration in the quality of agricultural soil. The excessive use of chemical fertilizers hardens the soil, diminishes soil fertility, pollutes the air, water, and soil, and depletes vital soil nutrients and minerals, consequently posing environmental risks. This research breakthrough is needed to reduce chemical fertilizers. Biochar, a pyrolyzed or anaerobically-grown biomass, could be used. This study examined the effects of biochar on disease suppression and yield in Brassica oleracea plants in rich soils in Magelang, Central Java. The treatment of this study was control, biochar, biochar+compost. The results of this study can be concluded that the maximum wet and dry weight of broccoli and cabbage plants was achieved in the biochar+compost treatment. Biochar and biochar+compost can enhance the nutrient content of the soil in broccoli, cauliflower, and cabbage. In addition, biochar has an effect (positive or negative influence) on disease in test plants. During June observations, the controls had the highest incidence and plant disease severity, whereas adding biochar and biochar+compost reduced disease incidence and plant disease severity. Increased potassium in conjunction with changes in the chemical characteristics i.e. increasing pH, total N, and C-organic of the soil results in the formation of resistance.

Keywords: bamboo biochar, Brassica oleraceae, fertile soil, investigating, production

INTRODUCTION

Ngablak District is one of Magelang Regency's subdistricts, situated in the highlands at an average elevation of 1,370 meters above sea level. Ngablak District having an extensive agricultural area and the highest vegetable production. Cabbage (*Brassica oleracea* var capitate), broccoli (*B. oleraceae* L. var *italica)*, carrots, and cauliflower (*B. oleracea* var *botrytis)* are the primary vegetable crops grown in Ngablak. Agriculture accounts for approximately two-thirds of the total area of the Ngablak sub-district, which has an area of 43,8 ha Farming groups can harvest four times within a calendar year, producing between 5-7 tons per crop per ha (BPS, 2021).

Vegetable production is constantly counterbalanced by increased fertilizer demand. However, farmers in Ngablak continue to rely on chemical fertilizers; the average amount of NPK chemical fertilizer used in the district is one quintal per 1000 m^2 of land before planting and following the generating phase, a further 30 percent fertilizer application (BPS, 2021). Chemical fertilizers are expected to be the essential nutrients for plants, such as nitrogen, phosphorus, potassium, sulfur, and magnesium. Chemical fertilizers likewise break down and are taken by plants more quickly. Nevertheless, using chemical fertilizers frequently can actually endanger the ecosystem, biological fertility, and physical soil conditions (Dewanto et al., 2017).

Biochar is a type of biomass that has been pyrolyzed or grown in anaerobic circumstances. Biochar contains a high concentration of aromatic carbon and possesses stable physical and chemical properties (Anderson et al., 2011; OK et al., 2015; Weber and Quicker, 2018). It has been reported that biochar improves soil quality, pH, organic matter, and nutrient availability. Numerous studies have demonstrated that biochar improves soil, increases plant output, simplifies fertilizer use, and creates inappropriate conditions for disease development (Lehmann et al., 2011; Berek et al., 2016)

Biochar is a porous substance with a wide surface area (Cornelissen et al., 2018; Sun et al., 2015). Biochar possesses a high potassium content that varies according to the raw material and fluctuates during the carbonization process, allowing it to retain potassium and slowly release it (Smider and Singh, 2014). Oram et al. (2014) demonstrated that legume plant sections collected significant potassium following biochar application. Biochar can be an essential source of chemical potassium for cabbage (*Brassica oleracea* var. *capitata*) production (Britzke et al., 2012). The application of biochar derived from rice husks at a rate of 2 to 5 t/ha enhanced the availability of N, P, K, and Ca nutrients in maize, resulting in a 45 percent reduction in the need for NPK fertilizer and a 12 percent rise in corn and cabbage production. (Verdiana et al., 2016; Mau et al., 2019).

The aim of this study was to determine the effect of biochar on known fertile soils in Magelang, Central Java. As a result, an

experiment was conducted to determine the effect of biochar in conjunction with organic and chemical fertilizers on disease suppression and yield increase in Brassica oleracea plants.

METHODS

Details on the field location and treatment

This research was conducted in Pendem, Ngablak, Center Java (-7.393581 S, 110.377241 E). The study site was naturally infections, and the field has a history of outbreaks due to pathogens. This research was conducted from April to June 2021. *B. oleraceae* L. var *italica* (broccoli), *B. oleracea* var *capitate* (cabbage), and *B. oleracea* var *botrytis* (cauliflower) were planted on the treatments presented in Table 1. The tests consisted of 27 plots 2,8 m × 1 m wide, organized into nine plots in three blocks with a 2 m discard between blocks and a 30 x 50 cm planting gap, 18 plant every plot. Before seedbed plots were put in, biochar and compost were combined. Compost was made from goat manure, and charcoal from Petung bamboo was employed.

Table 1 The treatment applied in the experiment

Treatment	Rate (ton/ha)	Note
Control		without treatment
Biochar	2,5	furrowed into 10 cm depth
Biochar + compost	2,5 + 2,5	furrowed into 10 cm depth

Measurements

Soil analyses were performed before and throughout the harvest. The soils were dried in the air to determine their physicochemical composition. A glass electrode was used to determine the pH in a 1:2.5 soil/water solution (CP-401 pH meter). C-organic compounds were examined using the Soil and Agricultural Chemistry Analysis method (Bao, 2000). Rhoades determined the cation exchange capacity (CEC). Bremner and Mulvaney (1982), John (1970), and Thomas (1982) conducted analyses on phosphorus (P), potassium (K), and nitrogen (N).

After nine weeks, nine plants of *B. oleraceae* was harvested and weighed for fresh and dry weight. Each month, the illness incidence and disease severity index (DSI) were recorded to assess the disease's relative severity (Tsuda et al., 2016): 0 indicates that there are no symptoms; 1 indicates that there are minor lesions on the outer leaves; 2 indicates that there is rot on the outer leaves; 3 indicates that there is rot on the outer leaves and a portion of the head, and four indicates that there is rot on the majority of the head. Disease incidence equals (the number of infected plants multiplied by 100/ the total number of plants), DSI equals (the scaled number of diseased plants multiplied by 100/the total number of plants).

Analytical Statistics

The data were analyzed using the F test to determine differences between the treatments used, followed by the LSD test to determine which treatment was the most statistically significant. The standard error of the means was used to illustrate the variety in the data.

RESULT AND DISCUSSION

The wet weight and dry weight calculations using biochar+compost indicated that the most significant yields were obtained for broccoli and cabbage; however, only practical effects were observed for cabbage (Fig. 1). It demonstrates that incorporating biochar into the soil can enhance the efficacy of inorganic fertilizers. Biochar can absorb nutrients and water, making them available to plants. Additionally, biochar can enhance and optimize plant growth and production and reduce the number of nutrients received by plants that are lost through leaching (Gao et al., 2016). According to Tomczyk et al. (2010), soil treated with biochar boosted microbial activity, increasing soil organic matter.

However, the highest wet weight was calculated for biochar in cauliflower plants, while the highest dry weight was calculated for untreated/control plants. The biochar treatment's low yield on the dry weight parameter is assumed to be attributable to a less optimum photosynthetic process. According to Rastiyanto et al. (2013), the fresh weight of plants is mainly determined by the water content of the plant body. Water is critical for cell turgidity, which causes plant cells to grow larger. The optimal fresh weight can be obtained if the plant receives sufficient energy and nutrients to increase the number and size of cells and the water content. Wasonowati (2009) states that the component of the plant that produces dry weight is the chlorophyll-containing portion.

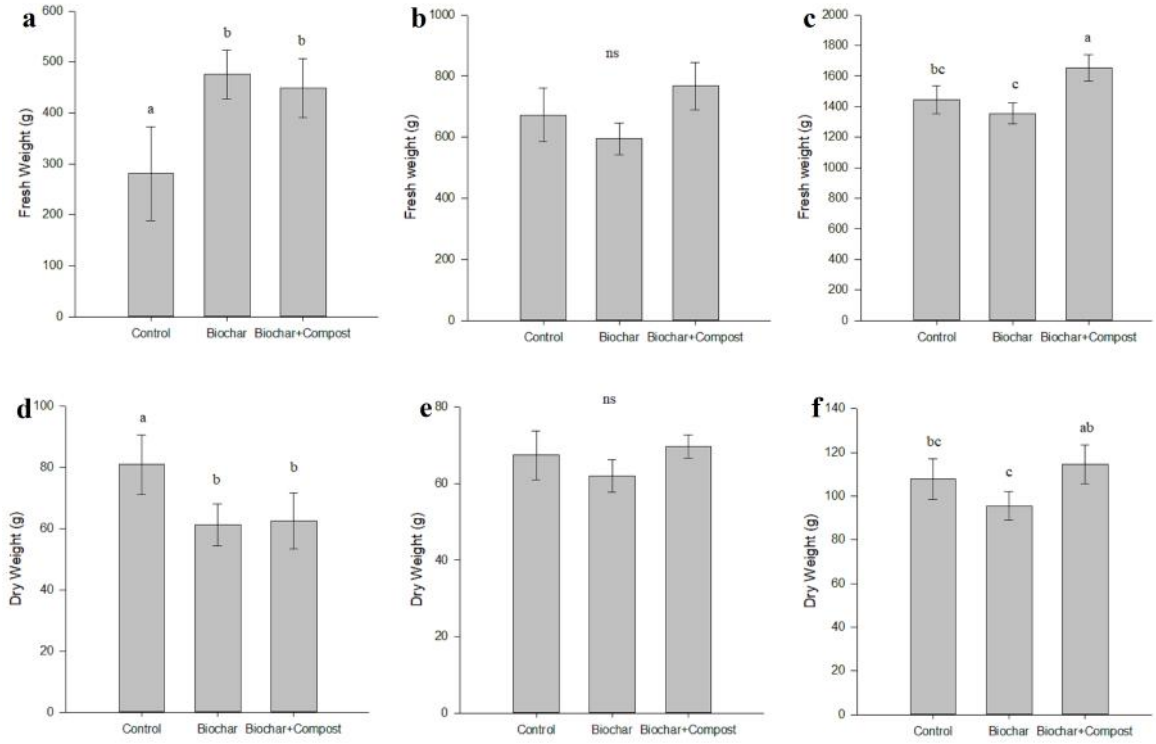


Figure 1 Plant growth (fresh and dry weight) of *B. oleraceae* under different treatments (control, biochar, biochar+compost). Different letters indicate a significant difference by LSD test at p≤0,05. The data for fresh and dry weight *B. oleracea* var *botrytis* (a,d) *B. oleraceae* L. var *italica* (b,e), *B. oleracea* var *capitate* (c,f).

Organic goat manure can help boost the availability of nitrogen, phosphorous, and other essential nutrients for plants (Rastiyanto et al., 2013). According to Situmeang et al. (2015), incorporating biochar into the soil with organic matter such as manure will improve soil fertility. Plants truly require the nutrients N, P, and K to flourish. Sufficient NPK availability enables plants to obtain the nutrients necessary for optimal growth (Purnomo et al., 2018).

The addition of biochar affects growth and affects the incidence of disease in the field. In observing the disease on the test plant, namely *B. oleraceae*, it was found that black rot was caused by *Xanthomonas campestris* pv. *campestris*, while clubroot disease caused by *Plasmodiophora brassicae* was not found (Table 2). The highest incidence and severity of disease were in the controls during observations in June, while adding biochar and biochar+compost showed a decrease in infection (Table 2). Resistance is formed due to increased potassium when associated with changes in soil chemical properties. Giving biochar and biochar+ compost can help root development, support the process of protein and carbohydrate formation, and increase plant resistance to disease and drought (Marsono and Sigit, 2001).

The condition of plants that lack potassium causes their resistance components to be disrupted to facilitate the penetration of pathogens into the leaves. Plants that have a high K nutrient status have better disease resistance. Nutrient K affects the movement of opening and closing of stomata so that sufficient K status can reduce the penetration of disease through stomata (Mpelasoka et al., 2003). Elemental K can strengthen the plant tissue's structure and thicken the epidermis and cuticle cells cell walls to block the penetration of pathogens. According to Mpelasoka et al. (2003), potassium significantly increases lignin levels in the sclerenchyma tissue under the epidermis and cells around the bundle vessels, increasing plant resistance to pathogen attack.

The soil analysis found that the soil treated with biochar and biochar+compost cauliflower could be fertile because it had higher pH, total N, and C-organic values

Table 2 Black rot incidence and severity among the treatment

Date of observation	Treatment	Black rot incidence (%)			Black rot severity (DSI)		
		B. oleracea var. *botrytis*	*B. oleracea* var. *italica*	*B. oleracea* var. *capitata*	*B. oleracea* var. *botrytis*	*B. oleracea* var. *italica*	*B. oleracea* var. *capitata*
28-Apr	Control	0	0	0	0	0	0
	Biochar	10	0	0	6	0	0
	Biochar+compost	0	0	0	0	0	0
28-May	Control	50	60	30	32	36	12
	Biochar	16	20	20	46	10	4
	Biochar+compost	20	10	10	68	16	20
28-Jun	Control	100	100	100	90	95	92
	Biochar	100	95	100	85	82,5	90
	Biochar+compost	95	80	85	80	82,5	80

than the control. Meanwhile, the biochar treatment had higher P and CEC values than the control (Fig. 2). According to Situmeang et al. (2016), bamboo biochar applied to the soil will increase pH, N, P, C-organic, CEC, reduce N leaching, and increase soil microbial activity. So it is suspected that the treatment of biochar and biochar+compost was able to increase the nutrients in the soil but could not increase the yield of flower cabbage. In addition, it is suspected that the dose used has not been able to support the growth of flower cabbage plants. According to Mau and Eduardus (2019), the administration of biochar at a dose of 5 tons/ha and chicken manure compost at a quantity of 5 tons/ha gave higher growth of cauliflower plants in the parameters of plant height, the number of leaves, leaf area, and flower diameter.

Soil analysis was carried out before planting and after harvesting. The soil analysis found that the soil pH had no significant difference between the control and the treatment with biochar and biochar+compost. However, it can be seen that in some treatments, the application of biochar+compost had a higher soil pH value than other treatments (Fig. 2a). It is because soils with high clay content and organic matter can better buffer pH (Dvoøáèková et al., 2022).

The total N element of broccoli plants decreased in each treatment, where the biochar+compost treatment had the lowest total N compared to the other two treatments. Meanwhile, biochar treatment increased total soil N after harvest in cabbage and cauliflower. The total K element before planting in the soil is deficient. However, broccoli plants showed a significant increase in total K compared to each treatment after harvesting. The cauliflower plant increased in total K in control and decreased in the biochar and biochar+compost treatments. Meanwhile, each treatment slightly increased in total K in cabbage (Fig.2b).

Several studies have shown that biochar can increase macronutrient bioavailability and substantially increase K (Purnomo et al., 2018; Gonzaga et al., 2017), which will increase soil fertility and maintain optimal growth. Biochar is enriched with mineral nutrients (Park et al., 2011; Alburquerque et al., 2014; Mukherjee et al., 2014). Biochar, a nutrient-rich material, has increased plant nutrient uptake (Lehmann et al., 2003). In our study, biochar caused an increase in some nutrients but decreased other nutrients in *B. oleraceae*.

Biochar increased K but decreased N content in *B. olearaceae* plants (Fig.2). Lehmann et al. (2011) reported, a decrease in plant N with the addition of biochar to the soil, indicating an increase in ammonia volatilization with an increase in soil pH. The increase in carbon by biochar affects N mineralization, fixation, and immobilization (Dempster et al., 2012).

The increase in K content can be related to the structure of biochar because K is the most abundant nutrient available in biochar. In this study, the K content of the plant increased significantly, but the P content decreased (Fig.2f). In our study, we found that biochar can significantly replace potash

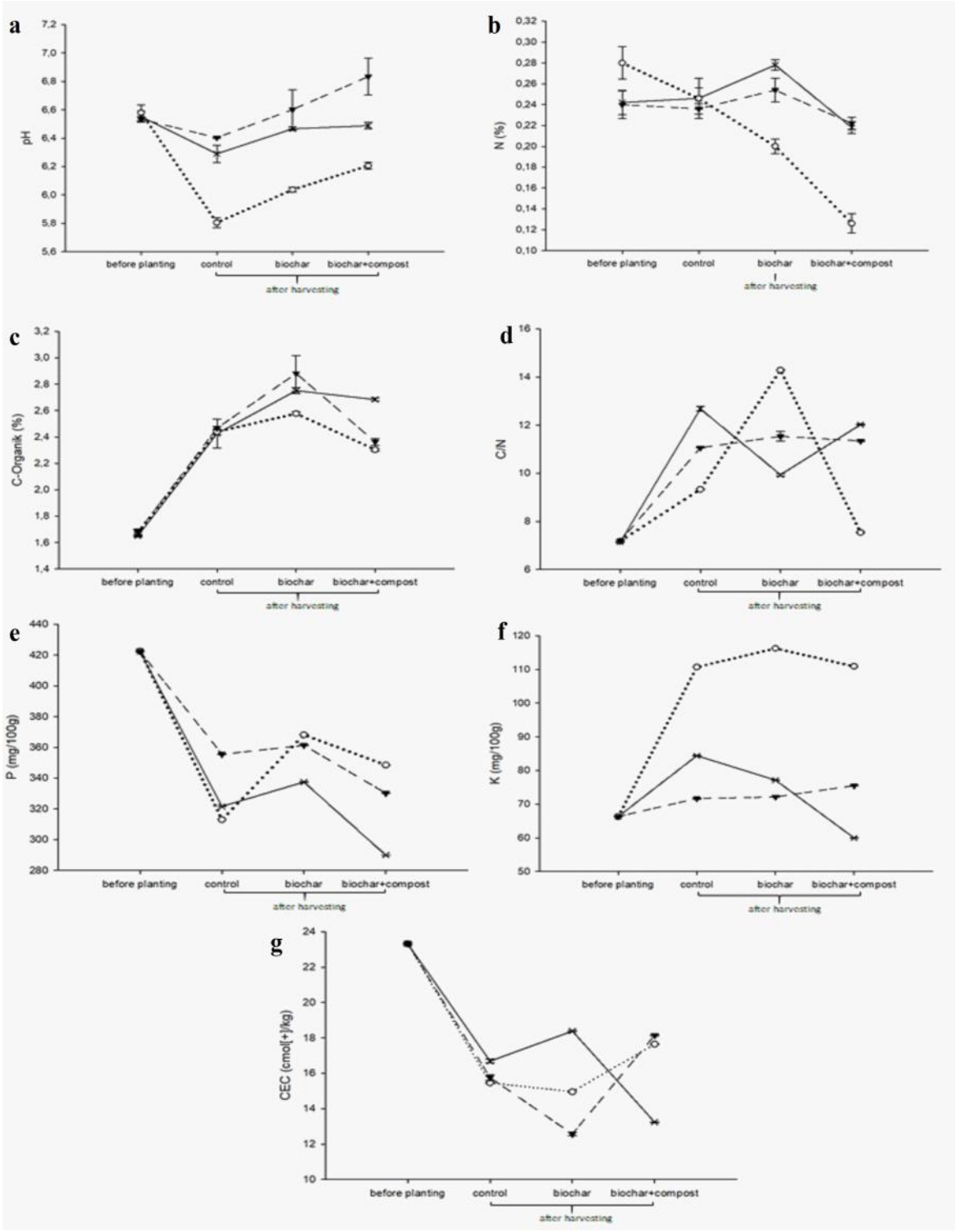


Figure 2. The relationship between selected soil chemical properties changes before planting and after planting with various compost. *B. oleraceae* L. var *italica* : ·····○····· , *B. oleracea* var *capitate* : −− −▼ −− , and *B. oleracea* var *botrytis* : ——×——

fertilizers. It may be because biochar has large porosity and specific area (Gonzaga et al., 2017) and can convert water-soluble and exchangeable K to non-exchangeable K.

However, the effect of K on biochar was not seen when mixed with compost on cauliflower plants. This may be due to the high content of exchangeable K and water-soluble K in cauliflower cultivation. Other potassium forms are converted to non-exchangeable K (Black et al., 1995). Another possible reason is that soil (pH, moisture content) affects nutrient release from biochar (Biederman and Harpole, 2013).

Before planting in the soil, the total P element was very high, but the total P decreased in the three test plants after harvesting. In the biochar+compost treatment, the three plants had the lowest total P compared to other treatments (Fig.2e). It is in contrast to Bai et al. (2015) statement that soil P availability increased significantly after adding poultry manure biochar. This decrease in P may be due to P being absorbed by allophane. In addition, it is also caused by P being adsorbed by Fe to form Fe-P. So to prove it is necessary to test the availability of Fe in the soil.

The C-organic content of the soil before planting is shallow. However, organic C-organic for broccoli, cauliflower, and cabbage plants increased following harvest. In contrast, the biochar treatment on the three plants had the highest concentration of organic carbon compared to the other treatments (Fig.2c). It is consistent with Nuryani and Handayani's (2003) assertion that organic matter added to the soil during decomposition can enhance the soil's carbon content and organic acids formed during weathering of organic matter. Pane et al. (2014) show that composting can improve soil quality.

The C/N ratio was meagre before sowing in all three plants. Following harvest, the C/N ratio increased in all test and treatment plants. The C/N ratio was significantly impacted by the incubation and corn-planted soil's C and N contents (Fig 2d). According to Roesmarkam and Yuwono (2002), the amount of nitrogen mineralized and the total nitrogen content in the soil due to organic matter decomposition will grow proportionately to the amount of organic C in the soil. According to Rusdiana and Lubis (2012), if the C content of the soil is greater than the total N content, the C/N ratio will be greater; conversely, if the C and N contents of the soil are relatively high, the C/N ratio will be more excellent. The ground level in the north will be below.

CEC in the soil before planting revealed a high concentration. However, after the harvest time in broccoli, cauliflower, and cabbage, the three treatments showed a significant decline in yield. As a result, additional research on CEC lowering following treatment is required (Fig. 2g). As is widely known, the CEC is critical for absorbing cations exchanged in the soil solution. In general, the value of CEC reflects the level of soil fertility. It is feasible to describe soil as having a high fertility level if it has a high capacity for cation exchange (Indranada, 1986). CEC quantifies the soil ability to store and exchange cations derived

from plant nutrients. The fertility of the soil is dependent on CEC.

CONCLUSIONS

Calculating wet and dry weight using biochar+compost gave broccoli and cabbage plants the highest yields. Biochar and biochar+compost can increase soil nutrients in broccoli, cauliflower, and cabbage crops. In addition, giving biochar affects disease in the test plants. The highest incidence and severity of disease were in the controls during observations in June, while adding biochar and biochar+compost showed a decrease in disease. Resistance is formed due to increased potassium when associated with changes in soil chemical properties i.e. increasing pH, total N, and C-organic.

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