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The effect of corncob biochar application and dose reduction of N, P, K fertilizer on growth and yield of soybean (*Glycine max* L.) in regosol soil, Bantul, Yogyakarta

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Abstract

During the period of growth and development, soybeans need loose soil that is rich in organic matter. Biochar is a soil amendment with high porosity and large surface area, resulting in nutrients and water to be well absorbed and retained. Intensive agricultural cultivation requires a supply of nutrients by the application of inorganic fertilizers such as N, P, and K. Organic matter needs to be applied to maintain soil fertility and balancing the dose of inorganic fertilizers. The study aimed to determine the effect of corncob biochar application and the dose reduction of N, P, K fertilizer on the growth and yield of soybean. The research was conducted from November 2020 to March 2021, located at Tridharma Farm, Yogyakarta. Randomized complete block design was used with the application of 10 t/ha of biochar and without biochar as the first factor. The second factor was the use of N, P, K fertilizers in 100%, 75%, 50%, and 0% of recommended doses. The application of biochar 10 t/ha on soybeans was able to increase physiological components which include stomatal opening, stomatal density, and N, P, K uptake; growth components which include root length density, root area density, leaf area, leaf area index, net assimilation rate, crop growth rate, plant dry weight, harvest index, and yield components which include number of nodes and pods per plant, 100 seed weight, grain weight per plant and grain yield. Dose reduction of fertilizers did not lead to decreasing the physiological activity, growth, and yield of soybeans.

INTRODUCTION

Soybean (*Glycine max* L.) is one of the most important food crop commodities and has great potential to be developed in Indonesia and the world. Soybeans are legumes having a symbiotic relationship with the bacterium *Rhizobium japonicum* (Kumalasari, et al., 2013). In addition to rice and corn, soybeans have been on the list Indonesia's three major food commodities. National soybean consumption, which is growing, is currently unable to keep up with growth in production. The average soybean demand in Indonesia is ±2.3 million tons of grain yield per year, but the domestic production capacity for example in 2018 according to the Ministry of Agriculture (2018) was only around 982.598 thousand tons of grain yield, so that the rest has been met through importing activities.

Factors causing the low productivity of soybean are varieties, planting time, level of plant maintenance, availability of irrigation water, and soil fertility. Another obstacle is the limitation of production technologies to support sustainability, and the decrease of land resources. The land destruction caused by traditional farming methods is currently due to the high input of inorganic fertilizers and pesticides. In addition to balancing the dose of inorganic fertilizers, organic matter needs to be applied to maintain soil fertility, so that the results will be optimal.

As a source of organic matter, biochar helps to improve soil fertility. Biochar is a soil amendment in

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agriculture that functions to increase the soil productivity. Agricultural and plantation waste is the raw material used for biochar production. There is still a big amount of agricultural biomass waste that is not reused yet for agriculture, including the use of corncobs into biochar. Hence, in this study, corncobs were used as raw materials for biochar. Biomass waste is considered less efficient to be used directly to plants so it is used as biochar.

Biochar is produced from organic materials that are difficult to decompose, incompletely burned (pyrolysis) with minimal oxygen condition and high temperature (Lehmann and Joseph, 2009). The temperature used in the production of biochar is about 400–450°C. Biochar has different benefits and content depending on the materials used. Raw materials and pyrolysis conditions (temperature and time) affect the stability and nutrient content of the biochar. The temperature and type of biomass in the manufacture of biochar affect the properties of biochar including surface area, pH, quality, and quantity. The use of higher temperatures produces higher surface area of corncob biochar (Hao et al., 2013), but pyrolysis at higher temperatures will reduce functional groups in biochar and lead to higher energy consumption and costs. Biochar properties are strongly affected by the pyrolysis conditions and the materials used.

Biochar is considered to be more effective than the direct use of biomass waste which is due to being produced at the high temperature of <700°C and in limited oxygen combustion. Compared with other soil amendments, its surface area and porosity are higher, which can absorb and retain nutrients and air, and provide a suitable environment for beneficial microorganisms. According to Lehman and Joseph (2009), biochar is basically more effective than other soil amendments because of its high degree of stability in the soil and ability to increase the availability of nutrients.

Intensive agricultural cultivation basically requires adequate supply of nutrients in every growing season. Application of inorganic nutrients in the form of fertilizers such as N, P, and K usually fulfil plant nutrient needs quickly. Abdelhafez et al. (2012) stated that inorganic fertilizers are generally used in agriculture to quickly meet the nutritional needs of plants. Fertilization method by applying fertilizers on the soil has several disadvantages and leads to nutrient leaching. The use of inorganic fertilizers affects soil microflora and soil physical properties (Wei et al., 2016). Furthermore, the overdose application of inorganic fertilizers leads to loss of microbial diversity, and reduced soil fertility and soil structure.

Currently, in order to increase yields, farmers are still adding overdose inorganic fertilizers to soybean. One of the properties of biochar that affects nutrient availability is its high cation exchange capacity, so that it is able to improve cation binding in soil which can be utilized for plant growth. Biochar is able to control the use of N, P, K fertilizers while maintaining soil quality when applied to the soil (Agegnehu et al., 2017). Sukartono and Sudantha (2016) stated that the application 10 t/ha of coconut shell biochar was able to increase soybean yields due to changes in soil fertility status for better availability of water and soil nutrients. Mete et al., (2015) appended, the total of biomass and seed yield was higher in sawdust biochar and NPK fertilizer was applied in combination rather than in the single treatment of biochar or NPK fertilizer. Therefore, this study was conducted to provide information regarding the effect of corncob biochar application and dose reduction of N, P, K fertilizer on growth and yield of soybean.

MATERIALS AND METHODS

The research was carried out in regosols conducted from November 2020 to March 2021, located at Tridharma Farm, Banguntapan, Faculty of Agriculture, Gadjah Mada University, on Banguntapan District, Bantul Regency, Yogyakarta, Indonesia. This study applied a factorial Randomized Block Design of three replications. The first factor was the application of biochar, including without biochar application and 10 t/ha biochar application. The second factor was a dose reduction of N P K fertilizers namely 100% recommendation: 50 kg/ha urea, 75 kg/ha SP36, 100 kg/ha KCl; 75% recommendation: 37.5 kg/ha urea, 56.25 kg/ha SP36, 75 kg/ha KCl; 50% recommendation: 25 kg/ha urea, 37.5 kg/ha SP36, 50 kg/ha KCl and 0%: without fertilization.

The size of each plot was 2.6 m × 2.1 m, where there was eight combinations with three replications, resulting in total of 24 experimental units. Plant spacing was 40×15 cm. Plant maintenance began with preparation of land, biochar and seeds. The soil tillage was done mechanically using a hand tractor followed by the making of experiment plots. The corncobs biochar were produced by Tribhuwana Tunggadewi University, Malang and soybean seeds of the Anjasmoro variety from the Research Institute for Various Nuts and Tubers, Malang. The application of corncob biochar was once in two weeks before planting. The application of N, P, K fertilizers were once right at the time of planting seeds. Biochar was applied to the soil and the soil was overturned by hoe. Before planting, seeds holes and fertilizer holes were made with a distance of 15 cm from the seed holes. Planting was carried out on the same day as the application of N, P, K fertilizer.

Plant maintenance was conducted by replacing dying plants with fresh seeds 1 week after planting (WAP). Weed control management was carried out mechanically by clearing weeds in the field at 3 WAP and 7 WAP. Pest and disease control was done depending on the intensity of the attack using pesticides, insecticides, and fungicides. Harvesting was done when >85% of the plant population was mature enough, indicated by the plants, the color of the pods which turned brown, and the leaves starting to fall.

The variables observed were the chemical properties of corncobs biochar, physiological components, growth, and yield of soybean. The observation of chemical properties of corncobs biochar included pH, c-organic, and total N, P, and K before being applied to the field. Observations of physiological components were carried out at 7 WAP including relative water content (Jensen method), stomatal density and stomatal opening (Haryanti method), N levels (Kjeldahl method), N, P, K uptake (Juhaeti method), and total chlorophyll (Arnon method). Observation of growth components consist of root area and root length density using a soil drill (7 WAP), leaf area using leaf area meter (12 WAP), leaf area index (12 WAP), net assimilation rate, crop growth rate, and plant dry weight (12 WAP). The yield components observed at 12 WAP consist of the number of nodes and pods per plant, weight of 100 grains (g), grains weight per plant, grain yield (t/ha), and harvest index. The grain yield in tonnes per ha was obtained from grain yield in harvested plots (2 m × 1.05 m) which was weighed at a moisture content of 14%, which was then converted into ton per ha. The data analysis applied analysis of variance (ANOVA), and DMRT α= 5% was then carried out.

RESULTS AND DISCUSSION

Corncob biochar

The application of biochar showed that the availability of plant nutrients was affected by the cation exchange capacity and soil pH. Biochar can function as soil mix materials to increase pH and nutrient availability in various soil types (Lehmann et al., 2006). The application of biochar reduces nutrient leaching thereby improving the availability of soil nutrients for plants.

Table 1 presents the biochar analysis of corncobs. Corncob is one type of biomass that can be recommended as a biomass material for biochar. Biochar is produced from corncobs at a temperature of 400–450°C. Biochar has a slightly acidic pH value. Iskandar and Rofiatin (2017) stated that the temperature of 400–500°C produced corncob biochar on the highest calorific value. The calorific value is closely related to biochar carbon. The high calorific value in biochar shows the high carbon content in biochar. Biochar generally functions as a carbon storage and soil fertilizer (Sohi et al., 2010).

According to Lehmann and Joseph (2009), biochar is able to provide nutrients indirectly through the ability to improve soil properties to retain nutrients. Based on the results, the corncob biochar content of c-organic was quite high at 44.24%. The high value content of c-organic in biochar given to the soil directly affects the process of absorption of plant nutrients. Soils with a high C-organic content are generally loose

Table 1. Analysis of corn cobs biochar content

Parameter	Chemical	Method
pH (H_2O)	10.04	(Electrometry)
C-organic	44.24%	(Ashing 600°C)
N-Total	0.56%	(Kjeldahl)
P Total	0.65%	(Walkley and Black)
K Total	2.75 %	(Walkley and Black)

Remarks: The analysis was conducted at the Laboratory of Soil, Plants, Fertilizer and Water, Assessment Institute for Agricultural Technology, Yogyakarta.

soils. The effect of biochar on the physical properties of the soil can directly affect the plant growth. Biochar can be provide a suitable environment for beneficial microorganisms. Biochar facilitates the depth of root penetration, and availability of air and water in the root zone due to improved tillage. Plant productivity and sustainable land use are determined by the presence of organic matter which plays an important role in maintaining and increasing the chemical, physical and biological fertility of the soil.

Table 1 shows that corncob biochar has low N, P, and K content. Raw materials and pyrolysis conditions (temperature and time) affect the stability and nutrient content of biochar. Biochar is unable to provide nutrients directly to plants because of its low content of nutrient. Biochar is a soil amendment that improves soil properties to optimize the ability of the soil to provide nutrients. Chan et al (2007) suggested that biochar applied to the soil was able to reduce nutrient leaching so as to increase the availability of nutrients in the soil.

Soil chemical properties

Environmental conditions are a limit factor in soybean cultivation. Soil is one of the factors to be considered in soybean cultivation. The environment that is unable to fit the requirements for growing soybeans disrupts the growth and development of soybeans. Soil is a growth medium that acts as a provider and storage of water, air, nutrients, and as medium for growing organisms to support the growth and development of soybean plants. Most of lands in Indonesia for soybean cultivation have shallow tillage layer. This affects the growing environment that is susceptible to drought and the development of soybean roots is less than optimal so that it interferes with nutrient absorption and then has an impact on soybean crop yields.

Soybean requires good soil drainage, aeration, and the ability to hold water. In addition, the presence of soil organic matter is also essential as the sufficient amount of which becomes a source of food for micro-organisms and improves tillage which will increase soil fertility. There are several soil chemical parameters that are commonly observed as references to determine soil fertility, such as pH, organic matter content, soil nutrient content, and cation exchange capacity.

The soil in the research area was measured before the application of biochar and dose reduction treatments. Based on Table 2, the soil has suitable pH for soybean growing requirements, which is 6.28 so that pH is not a limiting factor in the growth and development of soybean plants. In the soil, pH is used as a determinant of the activity and dominance of microorganisms which is closely related to the nutrient cycle and decomposition. Uguru et al. (2012) suggested that soybeans will grow well in soil with a pH range of 5.8 to 7.0. It is important that pH level be discovered to determine the ability of plants to absorb nutrients. This is related to the presence of chemical elements from the soil-plant system which are closely related to the acidity and alkalinity of the soil. One of them, soil acidity, can accelerate the loss of some essential nutrients in the soil such as K, Ca, Mg, and reduce the cation exchange capacity of the soil.

The type of soil at the research site is regosol, coarse-grained texture mixed with sand having low fertility level. The next indicator of soil fertility is the content of soil organic matter. pH and organic matter are interrelated factors which can directly affect the process of absorption of plant nutrients that affect soybean yields. The value of c-organic indicates the content of organic matter in the soil. Table 2 shows the

Table 2. Analysis of initial soil chemical properties at Tridharma Farm, Banguntapan before application of biochar and N, P, K fertilizers

Parameter	Chemical	Method
pH (H_2O)	6.28	(Electrometry)
C-organic	1.04%	(Walkley and Black)
N-Total	0.05%	(Kjeldahl)
P_2O_5	2201 mg/100 g	(25% HCl Extraction)
K_2O	16 mg/100 g	(25% HCl Extraction)
KTK	4.73 cmol(+)/kg	

Remarks: The analysis was conducted at the Laboratory of Soil, Plants, Fertilizer and Water, Assessment Institute for Agricultural Technology, Yogyakarta.

soil c-organic content of 1.04%. According to Eviati and Sulaeman (2009), this value belongs to the low c-organic category. Plant productivity and sustainable land use are largely determined by the presence of organic matter which plays an important role in maintaining and increasing the chemical, physical and biological fertility of the soil (Muzaiyanah and Subandi, 2016). The lower availability of organic matter in the soil becomes one of the limiting factors that affect the growth and development of soybean.

Soil fertility is also determined by the ability of the soil to provide adequate amount of nutrients in a balanced and available forms in order to optimize the growth and development of plants. Nutrients needed by soybean plants in large quantities are N, P, and K. According to Eviati and Sulaeman (2009), Table 2 shows that the total N value was very low, the P content was very high, the K content was low, and the CEC was quite low. The results of the analysis indicate that the value of the content of some soil chemical indicators was quite low. The degradation in soil fertility is the main factor that can affect the growth and yield of soybeans.

Physiological component

Water is the main need for plants. Water has an important role in the life cycle of a plant as it can dissolve and carry nutrients from the soil for plants to grow. Water deficiency disrupts the growth and development of plants, especially on the balance of plant metabolism. Drought stress was estimated physiologically by measuring the relative water content of leaves to control plants against air deficit. Fertilization is one of the farming management methods to increase soybean yields. The content of macro fertilizers, especially N, P, and K at the precise dose increases the efficiency of fertilization if the fertilization method, fertilizer dose, equipment, and time of application are carried out correctly according to the needs of plants.

Physiological components of soybean affected by biochar application and dose reduction of fertilizer are present in Table 3. There was no interaction between the application of biochar and dose reduction of N, P, K fertilizer on relative water content, stomatal density, stomatal opening, total chlorophyll, N content, and N, P, K uptake. Biochar application and dose reduction of fertilizers had the same effect on relative water content, total chlorophyll, and N content. Relative water content is the important indicator against the tolerance towards plant water deficits (Salvador et al., 2012). Relative water content describes the average water content in plant organs such as leaves. When the plant is not affected by water deficit, the plant will have relative water content that does not affect growth and development of the plant. Nitrogen content did not increase significantly, but the application of 10 t/ha biochar caused an increase in nutrient status from low to moderate.

The efforts to improve land conditions also affected

Table 3. Physiological components of soybean affected by biochar application and dose reduction of N, P, K fertilizer

Treatment	RWC	Stomatal density (/mm^2)	Stomatal opening (µm)	Total chlorophyll	N content (%)	N uptake (g/tan)	P uptake (g/tan)	K uptake (g/tan)
Biochar								
0 t/ha	89.332 a	331.580 b	2.667 b	0.519 a	3.903 a	12.337 b	1.222 b	7.459 b
10 t/ha	89.239 a	384.510 a	3.733 a	0.564 a	4.120 a	23.756 a	2.271 a	13.508 a
Fertilizer								
100%	90.180 a	373.620 a	3.467 a	0.539 a	3.635 b	14.085 a	1.327 a	9.141 a
75%	89.445 a	379.840 a	2.883 a	0.536 a	4.020 ab	19.286 a	1.786 a	11.084 a
50%	88.370 a	333.140 a	3.717 a	0.552 a	4.227 a	19.694 a	1.867 a	11.054 a
0%	89.148 a	345.590 a	2.733 a	0.539 a	4.163 a	19.122 a	2.006 a	10.656 a
Mean	89.313	358.047	3.200	0.542	4.011	18.047	1.747	10.484
CV (%)	2.992	11.805	12.826	12.237	9.222	21.723	20.308	21.502
Interaction	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)

Remarks: Means followed by the same letters in one column indicate no significant difference based on DMRT α= 5%; 0 t/ha: without biochar; 0%: without N, P, K fertilizer; RWC: relative water content.

the increase of soybean productivity, one which was by adding soil amendment materials such as biochar. A study conducted by Kleiner (2009) showed that when applied to soil, biochar reduces soil density and increases the content of organic matter, water, nutrients, and soil porosity. Afterwards, biochar creates healthy environment for the existing microorganisms and promotes their growth in the soil. Nutrients retained by biochar are easily released and available for absorption by plant roots (Rens et al., 2018). Hence, good land quality allows plants to optimally absorb water and nutrients to optimize their growth and development.

The application of 10 t/ha biochar significantly increased stomatal density and stomatal opening of soybean leaves. The plant leaves primarily function on its relation to the photosynthesis process. Stomata are microscopic pores formed from pairs of guard cells located in the leaf epidermis and function as a medium for exchanging CO_2 with the environment and controlling water loss (Zeng et al., 2010). Stomata density ranges from 330–380 mm^2, and this value is included in the medium stomatal density (Juairiah, 2014). Sakoda et al. (2019) stated that stomata density is a reference to increase photosynthesis in soybean leaves. Stomata are the main route for CO_2 to enter the leaves, which will affect the photosynthetic capacity of plants. The CO_2 diffusion of leaves stomatal with small openings was lower than the leaves with larger stomatal openings. Wider stomata openings have a good effect on the photosynthetic capacity of plants.

Furthermore, the uptake of N, P, K nutrients increased significantly at the application of 10 t/ha biochar. The increase in N uptake did not increase the total chlorophyll of soybean leaves. When K uptake was increasing, the density and stomatal opening also increased. The number of stomata leads to increasing transpiration to maintain cell turgidity, stabilize leaf temperature, and accelerate the rate of nutrient transport through the xylem. According to Mohammadi et al. (2014), the increase in the number of stomata is also influenced by the level of potassium absorbed by plants to help stomata to prevent water loss during transpiration and to increase photosynthetic efficiency. Kleiner (2009) stated that biochar applied to the soil can reduce soil density and increase the content of organic matter, air, nutrients, and soil porosity. Furthermore, biochar creates a suitable environment for the presence of microorganisms and promotes their growth in the soil. Soil fertility allows plants to optimally absorb air and nutrients to improve their growth and development.

The dose reduction of N, P, K fertilizers to 0% (without fertilizer) did not reduce the physiological components of soybean plants and tended to have the same values for relative moisture content, stomata density, stomata opening, total chlorophyll, N content, and N, P, K uptake. This is presumably caused by infertile soil conditions. The application of fertilizer without biochar caused the low ability of the soil to provide nutrients. Soybeans need nutrients to grow and develop optimally, but adequate nutritional needs must be balanced with soil conditions that maintain fertility.

The nitrogen (N) content of the tissue increased in application of biochar 10 t/ha although it was not significantly different. It improved nutrient level from low to moderate conditions. Increasing the percentage of fertilization did not increase the N content of the plant. This relates to the ability of the soil to provide and absorb nutrients. Biochar creates the right environment for the presence of microorganisms and promotes their growth in the soil. Nutrients retained by biochar are easily released and will be absorbed by plant roots (Rens et al., 2018 in Lebrun et al., 2022). Therefore, good soil quality allows plants to optimally absorb water and nutrients to meet their growth and development needs.

Nutrient uptake describes the ability of plant to absorb levels of N, P, K based on the application of biochar and reduced dose of N, P, K fertilizer. Soybean applied with 10 t/ha biochar significantly increased N, P and K uptake of plant tissue, however, decreasing the dose of N, P, K fertilizer did not decrease the uptake. The absorption of nutrients in plant tissues is influenced by the availability of nutrients in the soil and the ability of plants to use the nutrients. Nitrogen has an efficiency level of use in most plants of only 30% to 50%, so 50% to 70% which is lost through leaching, denitrification and evaporation (Sharma et al., 2017). The loss of N that is not absorbed by plants poses a serious threat to the ecological environment including global warming, particularly groundwater pollution which possibly damages human health. Phosphorus (P) is a source of macronutrients needed by plants in large quantities after nitrogen. Thoyyibah et al. (2014) proved that by the application of sufficient P at the early growth phase, normal germination and high vigor index were obtained. Management of P nutrients is quite important to optimize crop yields.

Table 4. Growth components of soybean affected by biochar application and dose reduction of N, P, K fertilizer

Treatment	Root length density (cm/cm^3)	Root area density (cm^2/cm^3)	Leaf area (cm^2)	Leaf area index	NAR (g/cm^2/ weeks)	CGR (g/m^2/ weeks)	Plant dry weight (g/plant)	Harvest index
Biochar								
0 t/ha	0.185 b	0.290 b	945.100 b	1.575 b	0.012 a	0.137 b	9.939 b	0.317 b
10 t/ha	0.247 a	0.388 a	1261.500 a	2.102 a	0.017 b	0.269 a	14.867 a	0.356 a
Fertilizer								
100%	0.178 a	0.280 a	1079.800 a	1.800 a	0.013 a	0.175 a	11.255 a	0.330 a
75%	0.197 a	0.309 a	1009.400 a	1.682 a	0.015 a	0.213 a	12.355 a	0.332 a
50%	0.227 a	0.356 a	1098.500 a	1.831 a	0.015 a	0.213 a	12.391 a	0.342 a
0%	0.261 a	0.410 a	1225.300 a	2.042 a	0.016 a	0.209 a	13.611 a	0.341 a
Mean	0.216	0.339	1103.267	1.839	0.015	0.203	12.403	0.336
CV (%)	13.625	13.603	13.813	13.806	22.771	7.334	19.123	12.507
Interaction	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)

Remarks: Means followed by the same letters in one column indicate no significant difference based on DMRT α= 5%; 0 t/ha: without biochar; 0%: without N, P, K fertilizer; RNAR: Net Assimilation Rate; CGR: Crop Growth Rate.

P deficiency in soybeans will also affect the number of seeds. A study conducted by Thoyyibah, et al., (2014) showed that soybeans without phosphorus fertilization caused lower number of seeds per plant than the soybean with phosphorus fertilization.

An equally important macronutrient of N and P is K. Most of the soil potassium is in unavailable form to plants, only 2–10% is slowly available and only 1–2% is in readily-available form. Potassium has properties such as N which is easily lost through leaching, because potassium is not bound by soil colloids. The composition of cations in the soil plays a role in determining the amount of potassium absorbed in plant tissues. This is in accordance with the results of this research, showing that soybeans applied with 10 t/ha biochar were able to increase the K uptake to soybean plant tissue, however, reducing the dose of fertilization did not reduce the K uptake to plants.

Growth component

Good soil quality enables plants to absorb optimal water and nutrients to improve their growth and development. The efforts to improve land conditions can also affect the success of soybean productivity. In this study, soil amendment added was biochar. Growth components of soybean affected by biochar application and dose reduction of fertilizer are present in Table 4. There was no interaction between the application of biochar and dose reduction of fertilizer on root length and root area density, leaf area, leaf area index, net assimilation rate (NAR), crop growth rate (CGR), plant dry weight and harvest index (HI). Growth and yield response related to root spread determined the uptake and utilization for growth and development of soybean plants. According to Faye et al., (2019) total length of roots per unit of soil volume can be expressed as root length density. Root length density is important to describe the absorption of water and nutrients by plants, while the root surface area density describes the reach of roots in the soil. The application of 10 t/ha was able to improve the density of the surface area and root length of soybeans, affecting the improvement of soil properties. Biochar as a soil amendment has a high microstructure, which is able to increase porosity and soil organic matter content, to reduce soil density, and to optimize soybean root development.

Leaves are important organs in plants, where are parts and places for photosynthesis and transpiration related to plant growth. Leaf area is a vital parameter in the analysis of plant growth. The development of the leaves was observed; when the shape of the leaves changed, it reflected the changes in the photosynthetic active part of the leaf. The application of 10 t/ha biochar was able to widen the soybean leaf area. Root distribution and optimal nutrient uptake directly affected soybean growth and yield. Suminarti and Nagano (2015) stated that leaf area is a description of the plant's capacity to produce assimilate. The wider the leaves, the more sunlight the plants can absorb, resulting in greater assimilation for growth and development. The leaf area value is an illustration of the area of the leaf where photosynthesis takes place, while the leaf area index (LAI) is a description of the amount of sunlight that can be absorbed by plants. Leaf area index is a growth variable that is directly related to light interception by the canopy (Mubarak et al., 2018).

Net assimilation rate is a measure of the average photosynthetic efficiency of plant leaves based on the accumulation of plant dry weight (g/cm²/weeks). The application of 10 t/ha biochar increased the net assimilation rate and crop growth rate. Soybeans in the vegetative phase of plants are still actively growing and are effective in carrying out photosynthesis.

Application of 10 t/ha resulted in heavier plant dry weight. The dry weight of the plant is the accumulation of photosynthetic products. Dry weight is to determine plant metabolism because the value of dry weight of plants represents the results of metabolites in plant organs. The amount of nutrients absorbed by plants contributes to the increase in the value of dry weight of plant. Nurdin (2011) stated that the increase in the photosynthesis process leads to increasing results of photosynthesis in the form of organic compounds that are translocated to all parts of the plant, affecting the dry weight of the plant.

The ability of plants to distribute assimilated grains is the main focus of soybeans. In this study, the application of 10 t/ha biochar produced higher harvest index than without biochar. It was stated that soybean plants fed with biochar were better at distributing assimilate to the pods, resulting in higher soybean grain yields.

The dose reduction of N, P, K fertilizers to 0% (without fertilizer) did not reduce the physiological components of soybean plants and tended to have the same values as root length and root area density, leaf area, leaf area index, net assimilation rat (NAR), crop growth rate (CGR), plant dry weight and harvest index. Reducing the dose of N, P, K fertilizers did not

Table 5. Yield components of soybean affected by biochar application and dose reduction of N, P, K fertilizer

Treatment	Number of nodes per plant	Number of pods per plant	Grain weight per plant (g/plant)	Grain yield (t/ha)
Biochar				
0 t/ha	17.958 b	59.750 b	16.470 b	1.682 b
10 t/ha	21.771 a	78.750 a	21.507 a	2.075 a
Fertilizer				
100%	19.583 a	65.580 a	17.579 a	1.802 a
75%	20.917 a	73.790 a	20.010 a	1.755 a
50%	18.958 a	70.880 a	18.405 a	1.917 a
0%	20.000 a	66.750 a	19.962 a	2.038 a
Mean	19.865	69.250	18.988	1.878
Interaction	(-)	(-)	(-)	(-)

Remarks: Means followed by the same letters in one column indicate no significant difference based on DMRT α= 5%.

Table 6. 100 seed weight (g) of soybean in biochar and N, P, K fertilizers application

Biochar	N, P, K Fertilizers				Mean
	100%	75%	50%	0%	
Without biochar	17.130 ab	17.480 a	17.133 ab	16.460 b	17.051
10 t/ha biochar	17.740 a	17.017 ab	17.093 ab	17.853 a	17.426
Mean	17.435	17.248	17.113	17.157	+
CV (%)	2.956				

Remarks: Means followed by the same letters in one row indicate no significant difference based on DMRT α= 5%. Sign (+) shows interaction between biochar and N, P, K fertilization.

have any different effect on the length density and surface area of soybean roots. Furthermore, the absorption of N, P, K did not increase. As the total chlorophyll, stomatal opening and stomatal density did not increase, the process of photosynthesis was as large as the reduction in N, P, K fertilizer dose. There was no increasing value of net assimilation rate and crop growth rate on any dose reduction of N, P, K fertilizers. Hence, the dry weight of soybean plants was low. Soybeans tend to have the same harvest index value for all percentages of dose reductions of N, P, K fertilizer. It indicates that there is no decreasing value of the yield of dry seed weight due to the dose reduction of N, P, K fertilizers.

Yield component

Seeds are the most influential component of soybean yields. The high or low weight of the seeds depends on the amount of dry matter in the seeds. Yield components of soybean affected by biochar application and dose reduction of fertilizer are present in Table 5. There was no interaction between the application of biochar and dose reduction of fertilizers to the number of nodes and pods per plant, grain weight per plant, and grain yield. The number of nodes and pods per plant is an important agronomic character to be observed. The number of nodes and pods per plant is a parameter that contributes to soybean yield (Ngalamu et al., 2012). The results present that the application of 10 t/ha biochar to soybean plants was able to increase the number of nodes and pods per plant, grain weight per plant, and grain yield. Soybeans that were applied with 10 t/ha of biochar significantly produced more nodes and pods per plant, heavier grain weight per plant, and more grain yield.

The dose reduction of fertilizers did not reduce the yield components of soybeans, including the number of nodes and pods per plant, seed weight per plant, and seed yield. The ability of the soil did not optimally affect the absorption of N, P, K in soybean plants, so dose reduction of N, P, K fertilizer had no different effect on the absorption of N, P, K. There was no interaction between the application of corncob biochar and dose reduction of fertilizers on yield components, including the number of nodes and pods per plant, seed weight per plant, and seed yield.

Based on this research, it is known that the first growing season with the application of 10 tons/ha of biochar has not been able to increase the efficiency of the use of N, P, K fertilizers on soybean plants, regardless of its ability to increase the physiological activity, growth, and yield of soybeans. Salvador et al., (2012), stated the slow rate of photosynthesis has an impact on sub-optimal yields. Furthermore, Cornelissen et al., (2018) suggested that biochar application achieved optimal results in the second season.

Table 6 presents the 100-seed weight of soybean. The 100-seed weight of soybean was influenced by the interaction between biochar application and dose reduction of fertilizers. Reducing the dose of fertilizer up to 50% and the application of biochar did not significantly affect the weight of 100 seeds. While the treatment was not fertilized, the application of biochar could increase the weight of 100 seeds of soybean seeds. On the soybean without biochar application, the recommended 75% fertilizer dose resulted in higher weight of 100 seeds. Afterwards, on soybeans applied with biochar, there was no effect of fertilization.

The weight of 100 seeds was used to classify the size of soybean seeds. In Indonesia, there are three sizes of soybean seeds based on weight; large size >14 g/100 seeds, medium size 11–12 g/100 seeds, and small size 6–10 g/100 seeds. The weight of 100 soybean seeds ranges from 17 g/100 seeds which are included in the large seed size (Yustina et al., 2020). In the generative growth phase, water availability is an important factor, and grain weight is determined by the amount of air supplied in the growing season. The application of biochar can improve soil properties which affect the water holding capacity. The application of biochar affects the growth and yield of soybeans through changes in better soil properties. The characteristics of biochar that has large surface area, porous structure, and high cation exchange capacity affect the transformation process of nutrients in the soil. The condition of the soil becomes more friable due to the application of biochar. The penetration of roots in absorbing air and nutrients can be balanced to obtain optimal results.

CONCLUSIONS

The above description revealed that application of biochar 10 t/ha on soybeans was able to increase physiological components which include stomatal opening, stomatal density, N uptake, P uptake and K uptake; increase growth components which include root area density, root length density, leaf area, leaf area index, net assimilation rate, crop growth rate, plant dry weight and harvest index; and increase yield components which include number of nodes per plant, number of pods per plant, 100-seed weight, grain weight per plant and grain yield. Dose reduction of fertilizers did not lead to decreasing the physiological activity, growth, and yield of soybeans. This research benefits the researchers and farmers in a way of increasing the growth and yield of soybean.

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