GROWTH AND YIELD PERFORMANCE OF POTTED BELL PEPPER APPLIED WITH BIOCHAR

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ABSTRACT

Biochar is a charcoal used as a soil amendment. It is a stable solid, rich in carbon, and can endure in the ground for thousands of years. The process of producing biochar is the same when making charcoal, but with the aid of a modified burner. This study was conducted to determine the growth and yield performance of potted bell pepper using Biochar as soil amendment. The growth parameters were plant height (cm.) and leaf growth while the yield parameters were fruit weight (grams) and fruit diameter (cm.). The research design was Complete Randomized Design. There was no significant difference in the growth performance during the first data gathering, but the number of leaves showed a significant difference, wherein bell pepper planted on a soil media added with different levels of Biochar showed better performance than those with no Biochar. Furthermore, a significant difference was observed during the second to fourth data gathering for both plant height, and leaves. The potted bell pepper applied with different levels of Biochar showed better performance than those with no Biochar applications. As to yield performance of bell pepper, the fruit diameter and weight showed a significant difference when because some bell peppers without biochar additive did not bear fruits. Therefore, the different levels of Biochar application as soil amendment significantly resulted in better yield performance of bell pepper up to the fourth harvest. The Biochar applications of up to 3.0kgs significantly resulted in better growth and yield performance of the potted bell pepper.

Keywords: biochar, bell pepper, growth, yield

INTRODUCTION

Background of the Study

Black carbon produced through pyrolysis of organic materials is known as 'biochar' (Lehmann, Gaunt & Rondon, 2006). Biochars are carbon-rich materials that were produced through heating under high temperature in the absence of oxygen (pyrolysis) of biomass (Lehmann, 2007; Laird, Brown, Amonette & Lehmann, 2009). Pyrolysis of organic residues is perceived to be an alternative to produce energy as well as return carbon and nutrients to the soil (Laird, 2008). The process produces gases, bio-oil and biochar that can be used as fuel sources (Ioannidou & Zabaniotou, 2007). Biochar has highly condensed aromatic structures that are resistant to decomposition in soil (Baldock & Smernik, 2002; Lehmann, et al., 2006) and has the ability to sequester some of the applied carbon for even hundred years (Lehmann, et al., 2006). This can be produced from a wide range of biomass materials under different conditions resulting to different soil amendment values (Baldock & Smernik, 2002; Nguyen, Brown & Ball, 2004; Guerrero, Ruiz, Alzueta, Bilbao, & Millera, 2005).

There has been an increasing interest on the use of biochars in agriculture as soil amendments to improve and maintain soil fertility and to increase soil carbon sequestration (Chan et al., 2008). Its use offers an opportunity to reduce the potential negative impacts of biomass removal for energy production on soil quality (Lehmann, 2007; Laird, 2008). Application in soils has the potential to increase soil waterholding capacity. Biochar could retain more water increasing crop production in non-irrigated dryland regions (Jeffery, et al., 2011), and decreasing the required volume of irrigation water to grow crops in irrigated regions (Basso, Miguez, Laird, Horton & Westgate, 2013). Biochar is thought to resist microbial degradation (Sombroek, et al., 1993; Schmidt & Noack, 2000; Baldock & Smernik, 2002; Lehmann et al., 2006). Therefore, the N content of biochar may not be available for plant use (Gaskin et al., 2010).

Studies reported that application of high amount of carbon (C) could cause nitrogen (N) immobilization (Gaskin, et al., 2010). A decrease in plant tissue N in cowpea treated with biochar was observed in the study of Lehmann, et al. (2003). In the study of Rondon, Lehmann, Ramírez & Hurtado (2007), they also observed that high application rates of biochar (90 g kg–1) decrease biomass and N uptake of common beans. Biochar is similar to charcoal and hence may pose similar effects (Gaskin, et al., 2010). Researches on charcoal in soils indicates that charcoal has important effects on application exchange capacity (Liang et al., 2006), soil water retention (Glaser, Lehmann & Zech, 2002; Jeffery, et al., 2011), soil fertility (Steiner et al., 2007), and soil biology (Pietikäinen, et al., 2003; Warnock, Lehmann, Kuyper & Rillig, 2007).

Biochar exhibits various potentials based on some studies conducted in other countries. However, little had been known about the effects of biochar on plant growth and yield particularly in tropical countries like the Philippines. Hence, the study focused on the growth and yield performance of bell pepper as test crop applied with different levels of biochar. We hypothesized that the application of biochar made from carbonized rice hulls will positively affect the growth and yield of potted bell pepper due to changes in soil fertility and plant nutrient status.

Objectives of the Study

Generally, this study aims to determine the growth and yield performance of potted bell pepper applied with different levels of biochar. Specifically, it aimed to determine the: (a) Growth performance of potted bell pepper applied with different levels of biochar in terms of plant height (centimeters), number of leaves, planting to flower initiation (days), flowering to fruiting (days), fruiting to maturity (days); and (2) Yield performance of potted bell pepper applied with different levels of biochar in terms of weight of fruit (grams), average diameter of fruits (centimeters), average number of fruits per plant and yield per plant.

MATERIALS AND METHODS

Materials

The materials used in the study were bell pepper (OPV), biochar (carbonized rice hull), plastic plots, foot bath, disinfectant, bamboo sticks, twine straw, spades, shovels, seed trays, sprinkling cans, pruning shears, meter stick, tape measure, weighing scale, pen and record book.

Methods

The first thing done was to collect and do laboratory analysis of the soil samples. The soil samples were collected from the site where the soils will be taken. Five (5) representative soil samples were taken to form one (1) composite soil sample. After processing the soil sample, it was sent Soils Laboratory for analysis for determination of Nitrogen-Phosphorous and Potassium (NPK) contents of the soil.

The study used Complete Randomized Design (CRD) with four (4) treatments replicated five (5) times. Each treatment had five (10) potted bell pepper plants with five (5) plant samples. The treatments used were: Treatment A – 1 kg biochar, Treatment B - 2 kgs biochar, Treatment C – 3 kgs biochar, and Treatment D – Control.

The garden soil was collected from the site where the soil samples were taken for laboratory analysis. The soil was then sterilized by heating the soil to eliminate the harmful microorganisms or soil born organisms that can affect the seed germination.

Soil media used for sowing was a combination of 1/3 garden soil, 1/3 carbonized ricehull and 1/3 compost. The materials were cleaned of plant residues and stones, or other impurities, and were mixed and pulverized thoroughly before placing inside the seedbox. The soil media was then watered and sown with seeds.

The greenhouse was disinfected by applying chemical disinfectant. This was done prior to the placement of pots filled with garden soil inside the greenhouse. A foot bath was placed at the entrance of the greenhouse to avoid pests and diseases from entering the place that might be carried by the researchers or other people visiting the area.

Polyethene pots measuring 12 x 12 x 15 inches were used in the study. They were placed inside the greenhouse and were filled with biochar according to their assigned treatments. The seedlings were transplanted the moment they had 4-5 true leaves. There were two (2) seedlings per pot. The plants were thinned to have one seedling per pot. The potted plants were arranged in the area at a distance of 30 cm between rows and 30 cm between hills. A walkway of 60 cm was provided for easier movement inside the greenhouse. It was done in the afternoon where the sun is not too hot to avoid seedling shock. It was watered immediately to promote good root-soil contact and to maintain good texture and condition.

Bamboo stick was placed beside the plants to serve as support. The plants were tied to the sticks using plastic twine. Since bell pepper is less tolerant to drought, it was watered every day early in the morning and late in the afternoon with the aid of sprinkler. Pruning was conducted when dead branches and dried leaves were observed. It was done from the vegetative stage until maturity with the use of pruning shear. The weeds are controlled by just cutting them. This is to avoid the plants from being disturbed when the weeds are pulled near the base of the plant. The bell pepper was harvested 60-80 days after transplanting. The fruits were harvested when they have deep green color turning dull or red. Harvesting was done early in the morning with 3-4 days harvest interval.

The following growth and yield parameters were gathered for the whole duration of the study:(a) Plant height (cm); (b) Number of leaves; (c) Days from planting to first flowering; (d) Days from flowering to first fruiting; (e)Days from first fruiting to maturity; (f) Weight of fruit (g) Diameter of Fruits (cm); and (h) Number of fruits per plant.

All data gathered were subjected to analyses of variance using One-Way Analysis of Variance at 1% and 5% level of probability. Comparison of treatment means was done using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSIONS

Initial chemical properties of the soil

Initial chemical analysis of the soil used as the potting medium is shown in Table 1. Chemical analysis showed that the soil used was slightly acidic (pH = 4.8.1) with low total N (0.10%), P (0.01%) and K (1%).

Table 1. Initial chemical properties of the soil before the experiment.

Property	Amount
pH	4.81
Total (%)	
N	0.10
P	0.01
K	1.00

Chemical properties of biochar (CRH)

The chemical properties of biochar (CRH) are shown in Table 2. The biochar derived from carbonized rice hull (CRH) had a strongly alkaline pH (8.89). It had very high organic carbon (OC) (28.03%), low total N (0.55%), P (0.07%) and K (0.48%) with low concentrations of Ca, Mg and Na.

Table 2. Chemical properties of biochar (carbonized ricehull) (Rollon, Galleros, Galos, Villasica & Garcia, 2017).

Property	Amount
pH	8
OC (%)	28.03
Total (%)	
N	0.55
P	0.07
K	0.48
Ca	Trace
Mg	0.01
Na	0.03

Plant height and number of leaves

The effect of the application of biochar (0, 1, 2, and 3 kg) on plant height is presented in Table 1 (2nd to 5th column). Biochar application did not affect plant heights at 10 DAT but did affect plant heights at 20, 30 and 40 DAT. At 20 DAT, plant heights of biochar treatments (1, 2 and 3 kg) were significantly higher over control (0 kg), with no difference among biochar treatments. At 30 and 40 DAT, biochar treatments (1, 2 and 3 kgs) were significantly higher than control (0 kg). Among biochar treatments, application of 3 kgs produced the tallest plant. The result confirms the findings of Graber, et al. (2010) where he found out that tomato plant heights were significantly greater in biochar treatments (1 and 3%) than in control plots (0%). On one hand, this was contrary to the findings of Rondon et al., (2007) where they also observed that high application rates of biochar (90 g kg-1) decrease biomass and N uptake of common beans. On the other hand, this was supported by the study of Carter, et al., (2013) who found out that there was an increase in plant height in all the cropping cycles compared to no biochar applications.

Biochar application was found to increase nitrogen (N) retention (G”uere”na et al., 2013) by reducing N leaching (Zheng, et al., 2013), and increased plant uptake (Steiner et al., 2008). Moreover, French & Iyer-Pascuzzi (2018) believed that biochar affects Gibberellic acid-related traits. Gibberellic acid (GA) is a plant hormone that stimulates growth and development that include triggering of transitions from meristem to shoot growth (Gupta, et al., 2013). Hence, increases plant height.

Table 3 (6th column) reflects the number of leaves of bell pepper at 40 days after transplanting. Results show that there was no significant difference among treatment means in terms of the number of leaves. This implies that biochar application did not affect the number of leaves of bell pepper plants.

Days from transplanting to flowering, flowering to fruiting, and fruiting to maturity

Biochar did not show a significant effect on the number of days from transplanting to flowering (Table 4). However, when it comes to the development of flowers to fruit set, a significant effect was observed where biochar treated (1, 2 and 3 kg) plants have faster fruit development over control (0 kg).

This confirms the findings of French & Iyer-Pascuzzi (2018) in their study under greenhouse condition that they observed that biochar treatments decreased the days to flowering and increased the number of flowers of tomato at eight weeks after planting. As previously mentioned, biochar affects Gibberellic acid-related traits. Apart from its contribution mentioned in the earlier section, GA stimulates growth and development that includes vegetative to flowering (Gupta, R., & Chakrabarty, S.K., 2013).

Table 3. Plant height of bell pepper at 10, 20, 30 and 40 DAT, and number of leaves at 40 DAT.

Treatment		Days After Transplanting (DAT)			No. of leaves at 40
	10	20	30	40	DAT
A	16.53	27.36[a]	39.08[b]	47.67[b]	36.50
B	15.87	28.09[a]	39.45[b]	48.35[ab]	38.00
C	16.42	28.66[a]	42.17[a]	53.15[a]	37.4
D	15.58	21.83[b]	30.27[c]	38.30[c]	34.2
f-test	Ns	**	**	**	Ns
CV	4.2%	7.6%	12.4%	8.2%	3.9%

Conversely, fruits under control treatment did not reach maturity as there was an observed fruit abortion under this treatment. Only the biochar treatments were determined, where the levels of biochar application significantly affect the number of days from fruiting to maturity. Plants treated with biochar at 1 and 3 kg mature faster than those treated with 2 kg biochar. According to Stephenson (1981) abortions of undamaged fruits seems to result from limited resources. Once these are limited, competition among fruits and subsequent abortion would expectedly increase. In treatments without biochar application, the nutrient resources and moisture are limited than those with biochar application. This is supported by the statements from different researchers that biochar improves soil water retention (Glaser, et al., 2002; Jeffery, et al., 2011), and soil fertility (Steiner, et al., 2007). Hence, the soil could not provide the required amount of nutrients the plants need for growth and fruit retention.

Table 4. Number of days flower initiation to flowering, flowering to fruiting and fruiting to maturity

Treatment	Planting to Flowering	Number of days Flowering to Fruiting	Fruiting to Maturity
A	24.99	12.2[a]	12.5[ab]
B	23.52	11.4[a]	23.5[b]
C	23.94	12.8[a]	20.5[a]
D	27.93	22.4[c]	0[c]
f-test	ns	**	**
CV	10.5%	15.9%	15.7%

Average diameter of fruits, weight of fruits, and number of fruits per plant

Biochar significantly affected the average diameter of fruits (Table 5, 1st column). Control (0 kg) plants were not able to retain its fruits because of early fruit abortion. Hence, the value was zero (0) in terms of diameter. Plants treated with biochar at 3 kg per plant had significantly wider fruit diameter than plants treated with lower levels of biochar (1 and 2 kg). The increase in fruit diameter could be attributed to the increased available nutrients in the presence of biochar, which stimulates plant growth and development (Amin & Eissa, 2017). Result was contrary to the findings of Ke, et al., (2018) where an increased level of biochar application did not significantly affect the length and width index of cherry radish fruit. The result may be different because cherry radish and bell pepper came from different botanical families thus, exhibited different responses to biochar application.

The same with the diameter of fruits, biochar significantly affected the weight of fruits (Table 5, 2nd column). Since control (0 kg) plants were not able to retain its fruits because of early fruit abortion, the weight per fruit was zero. The result showed that plants treated with biochar at 2 and 3 kg per plant were significantly heavier than plants treated with a lower level of biochar (1 kg). This agreed with the findings of Amin & Eissa (2017) where they found out that fresh and dry weights of zucchini fruits significantly increased with the increased level of biochar application calcareous sandy soil. The increase could be attributed to the increased available nutrients in the presence of biochar, which stimulates plant growth and development.

The average number of fruits per plant differed significantly from biochar treated plants and control (Table 5, 4th column). Since control (0 kg) plants were not able to retain its fruits because of early fruit abortion, the number of fruits per plant is zero. The result showed that plants treated with biochar at 2 and 3 kg per plant were significantly higher in number than plants treated with a lower level of biochar (1 kg).

Table 5. Yield performance of bell pepper applied with different levels of biochar based on average diameter of fruit, average weight of fruit and number of fruits per plant.

Treatment	Average diameter of fruit (cm)	Fruit yield Average weight per fruit (g)	Number of fruits per plant
A	5.64^{b}	61.89^{b}	12.3^{a}
B	5.64^{b}	78.67^{a}	13.1^{a}
C	5.87^{a}	79.26^{a}	12.2^{a}
D	0.00^{c}	0.00^{c}	0.00^{b}
f-test	**	**	**
CV	5.1%	11.5%	5.2

CONCLUSIONS

The biochar treated plants had faster fruit development than control plants. Moreover, plants treated with biochar at 3 kg per plant matured faster and had better performance than those applied with lower levels of biochar. Thus, biochar application generally improved the growth and yield performance of bell pepper.

REFERENCES

Amin, A.E.B., & Eissa, M. (2017).Biochar effects on nitrogen and phosphorus use efficiencies of zucchini plants grown in a calcareous sandy soil. Journal of Soil Science and Plant Nutrition, 17(4), 912921.

Baldock, J., & Smernik, R. (2002).Chemical composition and bioavailability of thermally altered Pinusresinosa(Red pine) wood. Organic Geochemistry, 33, 1093–1109.

Basso, A., Miguez, F., Laird, D., Horton, R. & Westgate, M. (2013).Assessing potential of biochar for increasing waterholding capacity of sandy soils.Global Change Biology Bioenergy,5, 132-143.

Carter, S., Shackley, S., Sohi, S., Suy, T., &Haefele, S. (2013).The Impact of biochar application on soil properties and plant growth of pot grown lettuce (Lactuca sativa) and cabbage (Brassica chinensis).Agronomy,3, 404–418.

Chan, K., Van Zwieten, L., Meszaros, I., Downie, A. and Joseph, S. (2008). Agronomic Values of Green waste Biochar as a Soil Amendment.Soil Research,45, 629-634.

French, F., & Iyer-Pascuzzi (2018).A role for the gibberellin pathway in biochar-mediated growth promotion. Scientific Reports,8(5389).

G”uere”na, D., Lehmann, J., Hanley, K., Enders, A., Hyland, C., &Riha, S. (2013). Nitrogen dynamics following field application of biochar in a temperate North American maize-based production system.Plant Soil,365, 239–254.

Gaskin, J., Speir, R., Harris, K., Das, K., Lee, K., Morris, L., & Fisher, D. (2010).Effect of peanut hull and pine chip biochar on soil nutrients, corn nutrient status, and yield. Agronomy Journal,102(2), 623-633.

Glaser, B., Lehmann, J., &Zech, W. (2002).Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal – a review.Biology Fertility Soils,35, 219-230.

Guerrero, M., Ruiz, M.P., Alzueta, M., Bilbao, R.,illera, A., (2005). Pyrolysis of Eucalyptus at Different Heating Rate: Studies of Char Characterization and Oxidatove Reactivity. Journal of Analytical and Applied Pyrolysis,74, 307-314

Gupta, R., and Chakrabarty, SK. (2013). Gibberellic acid in plant: still a mystery unresolved. Plant Signal Behaviour 8 (9), DOI: 10.4161/psb.25504

Ioannidou, O. and Zabaniotou, A. (2007). Agricultural Residues as Precursors for Activated Carbon Production–A Review. Renewable & Sustainable Energy Reviews,11, 1966-2005. https://doi.org/10.1016/j.rser.2006.03.013

Jeffery, S., Verheijen, F., van der Velde, M., Bastos, A.C. (2011). A Quantitative Review of the Effects of Biochar Application to Soils on Crop Productivity Using Meta-Analysis. Agriculture Ecosystem and Environment,144(1): 175-187, DOI: 10.1016/j.agee.2011.08.015

Ke, H., Zhang, Q., Liu, G. (2018). Effects of wood biochar addition on growth of cherry radish (Raphanus sativus L. var. radculus pers). IOP Conference Series Earth and Environment Science 128 (1): 012182 DOI:10.1088/1755-1315/128/1/012182

Laird, D.A. 2008. The charcoal vision: A win-win-win solution for simultaneously producing bioenergy, permanently sequestering carbon, while improving soil and water quality. Agronomy Journal 100:178-181

Laird, D.A., Brown, R.C., Amonette, J.E., Lehmann, J. (2009). Review of the pyrolysis platform for coproducing bio-oil and biochar. Biofuels Bioproducts and Biorefining 3:547-562.

Lehmann, J. 2007. Bio-energy in the black. Frontiers in Ecology and the Environment 5:381-387.

Lehmann, J., Gaunt, J., Rondon, M. (2006). Biochar Sequestration in Terrestrial Ecosystem – A Review. Mitigation and Adaptation Strategies for Global Change,11: 403-427, DOI: 10.1007/s11027005-9006-5

Liang, B.; Lehmann, J.; Solomon, D.; Kinyangi, J.; Grossman, J.; O'Neill, B.; Skjemstad, J.O.; Thies, J.; Luizão, F.J.; Petersen, J.; Neves, E.G. 2006. Black carbon increases cation exchange capacity in soils. Soil Science Society of America Journal 70:1719- 1730

Pietikäinen, J., Kiikkilä, O., & Fritze, H., (2003). Charcoal as a habitat for microbes and its effect on the microbial community of the underlying humus, Oikus,89 (2): 231-242, DOI: 10.1034/j.16000706.2000.890203.x

Rondon, M.A.; Lehmann, J.; Ramirez, J.; Hurtado, M. 2007. Biological nitrogen fixation by common beans

(Phaseolus vulgaris L.) increases with bio-char additions. Biology and Fertility of Soils 43:699708.

Schmidt, M., Noack, A. (2000).Black carbon in soils and sediments: Analysis, distribution, implications, and current challenges. Global Biogeochemical Cycles, 14 (3), 777-793

Steiner, et al., (2007).Long Term Effects of Manure, Charcoal and Mineral Fertilization on Crop Production and Fertility on a Highly Weathered Central Amazonian Upland Soil. Plant and Soil 291 (1): 275-290, DOI: 10.1007/s11104-007-9193-9

Stephenson, A. (2003). Flower and Fruit Abortion: Proximate Causes and Ultimate Functions. Annual Review of Ecology and Systematics 12 (1): 253-279, DOI: 10/1146/annurev.es.12.110181.001345 Warnock, D., Lehmann, J., Kuper, T., Rillig, M. (2007).Mycorrhizal Responses to Biochar in Soil – Concepts and Mechanisms. Palnt and Soil 300 (1-2):9-20, DOI: 10.1007/s11104-007-9193-9

Zheng, H., Wang, Z., Luo, Y., Deng, X., Herbert, S., and Xing, B., (2013). Environmental Pollution, 174: 289-296, doi: 10.1016/j.envpol.2012.12.003