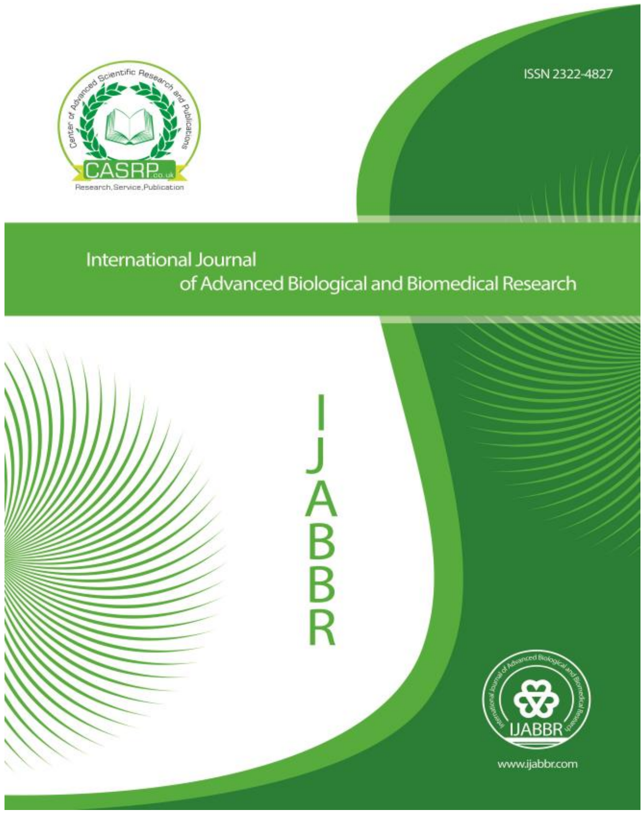
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Determination of bio-char rate for improved production of Lemmon grass (Cymbopogon citratuc L.)

K. Jemal*, A. Abebe

Wondo Genet Agricultural Research Center P.O. Box 198 Shashemene, Ethiopia.

Abstract

The impact and cost of synthetic fertilizers as well as their associated risks on the environmental safety was becoming unaffordable. To alleviate these problems, integrating this synthetic fertilizers with easily available and an environment friendly compound like bio-char is of very high significance towards meeting our goal of increasing agricultural production and ensuring food security. The present field experiment was therefore conducted to investigate the effect of biochar rate application on the selected properties of soils and yield and yield components of Lemon Grass (Cymbopogon citratuc L.) during 2013/2015 in W/Genet. Biochar produced from coffee husk and biogas was applied at rates of 0, 5, 10, 15 and 20 tone ha^{-1} for both coffee husk and biogas which was giving a total of nine treatments, where arranged in Randomized Complete Blocked Design with three replications. The over years result showed that the application of biochar have an increasing effects on soil properties like PH, OC, total N, available P, CEC and exchangeable cations and significant ($p<0.05$) increase in fresh biomass and number of leaf per hill. The highest fresh biomass, number of leaf per hill and moisture content was obtained by the application of 15ton/hectare biochar rate from coffee husk followed by the application of 15ton/hectare biochar rate from sugar factory and the highest essential oil yield was obtained by the application of 15ton/hectare biochar rate from sugar factory followed by the application of 15ton/hectare biochar rate from coffee husk. The best treatment recommended would be 15 tone ha^{-1} biochar from coffee husk and followed by 15 tone ha^{-1} biochar from biogas in order to achieve optimum Lemmon Grass production in W/Genet soil. Therefore, application biochar is very imperative to increase soil fertility, enhance nutrient uptake, ameliorate polluted soils and reduce the amount of carbon produced due to biomass burning.

***Corresponding author:** Wondo Genet Agricultural Research Center P.O. Box 198 Shashemene, Ethiopia.

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1. Introduction

Lemongrass (Cymbopogon citratuc L.) belongs to the family of Poaceae (Graminae). The perennial plants grow in clumps of up to two meters in diameter, while the leaves are up to one meter in length. Lemon grasses grow well in a variety of soils with good drainage under sunny, warm and humid conditions. The oil yield is correlated to the rainfall; a well distributed rainfall of about 2,500 to 3,000 mm a year is said to give optimal oil yields, which is native to southern India and ceylon, indonesia and Malaysia (Tashi Delek, 2008). Lemongrass oil has a wide range of applications in the cosmetic, perfume, pharmaceutical and food industry. Local people use lemon grass oil to subdue toothache; a drop of oil is put on a cotton-bud and put on the exact place where the toothache occurs. It is said that lemon grass oil can help to accelerate the healing of scratches and cuts. However, when pure lemon grass oil comes into direct contact with the skin, it causes a burning sensation. In other countries in Asia such as Thailand, Indonesia and Vietnam, lemon grass is frequently used as a spice to flavor meat dishes and soups (Tashi Delek, 2008). Farmers need better technologies, more sustainable practices, and fertilizers to improve and sustain their crop productivity and to prevent further degradation of agricultural lands. Fertilizers have played a vital role in raising the agricultural productivity in Ethiopia over a period of time (Samuel, 1981). Thus, agricultural institutions were making continues follow-up and encouraging efforts for the installation of chemical fertilizer units across the country. However, the cost of chemical fertilizers and their associated risks on the environmental safety was becoming unaffordable (Mahajan et al., 2008). To alleviate these problems, easily available and an environment friendly compound like bio-char is of very high significance towards meeting our goal of increasing agricultural production and ensuring food security. Bio-char is a fine- grained highly porous charcoal (carbon) that can be formed as a result of the pyrolysis (heating) of biomass, in a complete or near absence of oxygen and it is different from other charcoals for intended use as a soil amendment(Gaunt and Lehmann, 2008).

Today, in many countries bio-char has widely been accepted and given great attention not only due to its contribution in lowering climate change but also as a desirable soil conditioning. Material that can enhance fertility and biochar serves as a catalyst that enhances plant uptake of nutrients and water. Compared to other soil amendments, the high surface area and porosity of biochar enable it to adsorb or retain nutrients and water and also provide a habitat for beneficial microorganisms to flourish (Warnock et al., 2007). Biochar have agronomic as well as environmental impact for example it is a good soil conditioner meaning water holding capacity and aggregate stability, cat ion exchange capacity and PH improved. The ability of biochar to retain nutrient and moisture will hopefully improve the soil physical and chemical properties and consequently improve crop yield (Abebe et al., 2012). This study intended to assess the effect of different rates of biochar amendment on growth and yield of lemon grass and enhancing soil fertility.

2. Materials and methods

2.1. Description of the experimental area

The experiment was conducted during the main season of 2013 and 2014/15 at Wondo Genet Agricultural Research Center. Wondo Genet Agricultural Research Center is geographically located at 07° 03' 19.1'' to 07° 04' 00.2'' North latitude and from 38° 30' 08.4'' to 38° 31' 01.8'' East longitude. The site receives mean annual rain fall of 1128 mm with minimum and maximum temperature of 11 and 26°c, respectively. The soil textural class of the experimental area is clay loam with pH of 6.4(). The biochar used in this study was crushed into particles of different sizes ranging between 2 mm to 2.5 mm. biochar was amended a week before planting by manually mixing them into the soil within the 20 cm depth.

2.2. Treatments and experimental design

There were 9 different rates of biochar (0, 5,10,15,20 tone ha^{-1} for both coffee husk and biogas) giving a total of nine treatments (Table 4).The experimental design used was Randomized Complete Blocked Design (RCBD).

Nine different treatments were established in three replications. Each treatment was applied on the $9m^2$ plots (3m length and 3m width) a respective spacing of 2m and 1m were maintained between replications and plots.

2.3. Cultural practices

Planting for better quality and yield of oil, it was recommended to grow lemongrass by slips obtained by dividing well-grown clumps, which were grown at Wondo Genet Agricultural Research Center planting materials multiplication site. Top of clumps was cut off within 20 to 25 cm of the root and the latter should be divided into slips and panting was done manually with panting distance 60cm between plant and 60cm between rows. Proper hoeing, weeding and irrigation of the experimental field were carried out uniformly whenever required.

2.4. Soil sampling, growth and yield parameters

Soil samples were collected from the experimental site at the depth of 0-15 cm once before biochar amendment and another on the one year after biochar amendment. Data collection for yield and growth data was carried out by taking five random samples from central rows of each plot. Data on plant height, fresh biomass, and number of leave per hill, essential oil content, and essential oil yield were collected and analyzed.

2.5. Samples analysis

The collected soil samples were air dried and sieved through a 2mm sieve. The sieved samples were analyzed for necessary soil physico chemical properties by using respective methods (Book Martin R. Carter, 1993). Essential oil content was determined by taking 300 g fresh leaves of composite samples using hydro-distilled in a Clevenger apparatus according to (Guenther, 1972). The oils were collected, dehydrated, measured and expressed in w/w dry basis.

2.6. Data analysis

Mean values of all data for all characters measured were subjected to analysis of variance by using SAS (version 9) computer software programs (SAS inst., 2002). Least Significant Difference (LSD) was used to compare significant means at 5% probability level.

Table 1
The selected physicochemical properties of the experimental soil and biochars used.

Parameters soil	
Textural class	Clay loam
PH-H_2O	6.4
OC (%)	1.81
TN (%)	0.20
AVP(ppm)	9
CEC (meq/100g)	19.78
Exchangeable Cations K (Cmol/kg)	-
Exchangeable Cations Na (Cmol/kg)	0.08
Exchangeable Cations Ca (Cmol/kg)	9.15
Exchangeable Cations Mg (Cmol/kg)	2.51
Biochar from coffee husk	
OC (%)	44.95
TN (%)	0.59
AVP(ppm)	36
CEC (meq/100g)	15
Exchangeable Cations K (Cmol/kg)	-
Exchangeable Cations Na (Cmol/kg)	0.77
Exchangeable Cations Ca (Cmol/kg)	6.47
Exchangeable Cations Mg (Cmol/kg)	2.37
Boichar from biogas	
OC (%)	29.58

TN (%)	0.25
AVP(ppm)	50
CEC (meq/100g)	33.15
Exchangeable Cations K (Cmol/kg)	-
Exchangeable Cations Na (Cmol/kg)	8.49
Exchangeable Cations Ca (Cmol/kg)	3.82
Exchangeable Cations Mg (Cmol/kg)	0.62

OC = organic carbon; TN= total nitrogen; AVP = available phosphorous; CEC = cation exchange capacity.

3. Results and descusion

3.1. Biochar chemical properties

The results of boichar characteristics are presented in Table l. referring to the table, the value of C content is high as expected from charred materials and also the value of available P and total N are high. Exchangeable cations (K, Ca and Mg) values from biochar are also medium to high. The CEC of the biochars used is in the medium range. Based on these values we understand that there are nutrients in boichar rather than it acts as soil conditioner but it is better to be applied together with additional nutrients in order to maximize its' functions. As reported in previous study, it needs to be combined together with organic matter (O.M) or fertilizer to work better (Steiner et al., 2008). Furthermore, by (Major et al., 2010) and (Novak et al.) report biochar has been shown to retain nutrients against leaching, potentially improving the efficiency of nutrients applied alongside biochar. However, chemical properties of biochar varied base on several circumstances such as type of organic matter used for charring, the charring environment (e.g. temperature, air) and additions during charring process (Glaser et al., 2002). The source of biochar material strongly affects content and availability of nutrients in the soil after amendment. The soil chemical properties after amendment will strongly be affected by source of biochar amended.

Table2
Chemical properties of soil samples before and after one year amendment (2013-2014).

Soil properties	Before amendment	After 1 year amendment
Textural class	Clay loam	Clay
PH-H2	6.40	6.80
OC (%)	1.81	2.00
TN (%)	0.20	0.27
AVP(ppm)	9.00	24.74
CEC (meq/100g)	19.78	29.90
K (Cmol/kg)	-	1.32
Na (Cmol/kg)	0.08	0.63
Ca (Cmol/kg	9.15	9.53
Mg (Cmol/kg)	2.51	6.60

3.2. Soil properties

Soil chemical properties before and after biochar amendment: The data presented in Table 2show that there was an increased on organic C and pH value on soil sampled 1 year after planting. Similar trends were observed on values of total N, available P, CEC and exchangeable bases as well and the texture of the soil was changed to clay, which denoted for belter CEC value of this soil. The value of available P showed most obvious increment, which is 24.74 ppm. The increased in available P value and others is due to charcoal amendment.

The increase in soil pH due to application of biochar could be because of high surface area and porous nature of biochar that increases the cation exchange capacity (CEC) of the soil. Thus, there could be a chance for Al and Fe to bind with the exchange site of the soil. The decrease in exchangeable Al and soluble Fe in biochar amended soils was also reported by (Agusalim et al., 2010). According to (Lehmann et al., 2006) and (Agusalim et al., 2010), Al and soluble Fe was decrease in biochar amended soil is due to the increase in CEC.

The increase in organic carbon and total nitrogen due to addition of biochar could be resulted from the presence of high amount of carbon and nitrogen in the source of biochar. The highest values of organic carbon at biochar treated soils indicate the recalcitrance of C-organic in biochar. High organic carbon in soils treated with biochar has been also reported by (Lehmann, 2007).

The increase in available phosphorus due to application of biochar could be due to the presence of high phosphorous in the source of biochar and the increase in soil pH and CEC, that reduce the activity of Fe and Al, could also contribute for the highest values of available phosphorous in soils treated with biochar. (Van Zwieten et al., 2010) and (Chan et al., 2008) also reported the increase in available phosphorous after the application of biochar. The increase in CEC due to application of biochar could be resulted from the inherent characteristics of biochar. Biochar has high surface area, highly porous, variable charge organic material that has the potential to increase soil cation exchange capacity (CEC), surface sorption capacity and base saturation when added to soil (Glaser et al., 2002). Therefore, it is quite logical that soil applied with biochar had the highest CEC. (Agusalim et al., 2010) and (Chan et al., 2008) also revealed the increase in soil cation exchange capacity after the application of biochar.

The observed highest values of exchangeable bases at biochar treated soils might be attributed to the presence of ash in the biochar. The ash content of biochar helps for the immediate release of the occluded mineral nutrients like Ca, K and N for crop use (Scheuner et al., 2004). The results of the present study also agree with (Lehmann et al., 2003) who reported the highest exchangeable bases in biochar applied soils.

3.3. Yield and yield components

The results of the study in 2013 showed that application of biochar did not show statistically significant difference in all parameters (Table 3). even if significant effect is not obtained in 2013, the highest Lemongrass number of leaf per hill (111.7 kg/hr) and fresh biomass (5694.6 kg/hr) was obtained by the application of 15ton/hectare biochar rate from coffee husk and moisture content (73.32%) and essential oil yield (28.2 kg/hr) was obtained by the application of 15ton/hectare biochar rate from sugar factory, where as in 2014 cropping season application of different biochar rates had a significant effect ($p<0.001$) on Lemongrass fresh biomass, significant effect ($p<0.01$) on lemon grass number of leaf per hill and significant effect ($p<0.05$) on lemongrass essential oil yield, but not for moisture content.

The highest Lemongrass number of leaf per hill (207.22kg/hr) was obtained by the application of 15ton/hectare biochar rate from coffee husk and essential oil yield (72.2kg/hr) and fresh biomass (10844.8 kg/hr) was obtained by the application of 15ton/hectare biochar rate from sugar factory.

The absence of statistical difference in the first growing season and the presence of statistical difference in the second growing season might be because of the residual effect of biochar increase thorough time and some unusual observations might be created because of factors related to the flatness of the experimental area and the fertility status of the soil.

This result is similar to study conducted by (Stephanie et al., 2005), stating that bichar amendment increases production of shoots and pod of yard-long been cultivated on different soil. The ability of biochar to retain nutrient and moisture would hopefully improve the soil physical and chemical properties and consequently improve yield. (Steiner et al., 2008) also reported that biochart plus fertilizer improved plant growth and doubled grain production in comparison to the fertilizer without boichar and also the result was in agreement with the works of (Chan et al., 2008; Major et al., 2010) indicating that positive effects of biochar application on crop yields with rates of 5-50 tonnes of biochar per hectare, with appropriate nutrient management.

Another report lining with the results were due to its recalcitrance to decomposition in soil, single applications of biochar can provide beneficial effects over several growing seasons in the field (Steiner et al., 2008; Major et al., 2010).

Table 4
Effect of biochar application on yield and yield components of lemon grass at W/Genet (2013-2015).

		2013		
Treatments	**FBM kg ha^{-1}**	**NLPH**	**MC (%)**	**EOY kg ha^{-1}**
0 (control)	4674.2	90.90	76.90	21.9
5tha $^{-1}$ CH	4944.2	100.90	77.30	24.7
10tha $^{-1}$ CH	5058.9	98.00	77.70	25.5
15tha $^{-1}$ CH	**5694.6**	**111.7**	77.80	26.0
20tha $^{-1}$ CH	5459.3	97.20	78.00	27.0
5tha $^{-1}$ SF	5236.4	96.60	77.90	26.0
10tha $^{-1}$ SF	5093.3	92.00	78.00	23.7
15tha $^{-1}$ SF	4950.9	95.20	**78.32**	**28.2**
20tha $^{-1}$ SF	4610.9	99.00	78.31	23.0
CV (%)	19	18.9	2.2	22
$LSD_{0.05}$	NS	NS	NS	NS
		2014/15		
Treatments	**FBM kg ha^{-1}*****	**NLPH****	**MC (%)**	**EOY kg ha^{-1}***
0 (control)	8564.3^{d}	190.5^{bc}	71.3	57.0^{c}
5tha $^{-1}$ CH	8975.1^{cd}	188.8^{bc}	72.0	63.8a^{bc}
10tha $^{-1}$ CH	9978.6^{ab}	194.7^{bc}	71.3	61.7^{bc}
15tha $^{-1}$ CH	10298.2^{ab}	**207.22**^{a}	**72.8**	66.96^{ab}
20tha $^{-1}$ CH	9063.3^{c}	183.5^{c}	72.0	63.3^{bc}
5tha $^{-1}$ SF	9986.2^{ab}	191.9^{bc}	71.8	67.0^{ab}
10tha $^{-1}$ SF	9686.1^{bc}	190.35^{bc}	71.4	62.2^{bc}
15tha $^{-1}$ SF	**10844.8**^{a}	200.4^{ab}	72.1	**72.2**^{a}
20tha $^{-1}$ SF	10185.5^{ab}	200.4^{ab}	71.7	68.9^{ab}
CV	9.3	6.9	2.6	14
$LSD_{0.05}$	876.8	12.28	NS	8.73

Remark: * significant $p<0.05$, **significant $p<0.01$, ***significant $p<0.001$, ^{ns} not significant. Means with the same letter in column are not significantly different at 5% level for Least Significant Difference Test. CH - biochar from coffee husk, SF- biochar from sugar factory, FBM –fresh biomass, NLPH-no of leaf per hill, MC-moisture content, EOY-essential oil yield.

The combined analysis of variance over years indicated that, fresh biomass and number of leaf per hill was significantly different ($p<0.05$) among biochar rates (Table 4). The highest fresh biomass, number of leaf per hill and moisture content was obtained by the application of 15ton/hectare biochar rate from coffee husk followed by the application of 15ton/hectare biochar rate from sugar factory and the highest essential oil yield was obtained by the application of 15ton/hectare biochar rate from sugar factory followed by the application of 15 ton/hectare biochar rate from coffee husk. There was 20% and 13% increment in fresh biomass and number of leaf per hill of T4 respectively compared to the control.

The results corroborated the finding of (Malisa et al., 2011), for the impact of biochar application use on the yield of Kenaf (*Hibiscus cannabinus* L.) by applying biochar rate 10 tone ha^{-1} on soil of poor physico chemical properties of Malaysia and Crop yield improvements with biochar have been demonstrated repeatedly for acidic and highly weathered tropical field soils (Lehmann et al., 2003; Rondon et al., 2006), and there is new data on biochar use in temperate soils of higher fertility (Husk and Major, 2010). (Steiner et al., 2008) also believed that beneficial effects of applying biochar to soil improve with time.

Table 5
Effect of biochar application on yield and yield components of lemon grass at W/Genet combined by year.

Treatments	FBM kg ha^{-1}*	NLPH*	MC (%)	EOY kg ha^{-1}
0 (control)	6619.66^{c}	140.756^{b}	74.05	39.52
5tha $^{-1}$ CH	6959.6^{bc}	144.856^{b}	74.68	44.28
10tha $^{-1}$ CH	7611.3^{ab}	146.356^{b}	74.72	43.60
15tha $^{-1}$ CH	**7996.4^{a}**	**159.456^{a}**	**75.28**	46.75
20tha $^{-1}$ CH	7261.3^{abc}	140.344^{b}	74.95	45.83
5tha $^{-1}$ SF	7611.3^{ab}	144.856^{b}	74.79	46.72
10tha $^{-1}$ SF	7389.7^{abc}	141.256^{b}	74.75	42.97
15tha $^{-1}$ SF	7897.9^{a}	147.856^{b}	75.23	**49.70**
20tha $^{-1}$ SF	7398.2^{abc}	149.744^{ab}	75.01	46.13
CV (%)	18.18	11.80	2.22	20.82
$LSD_{0.05}$	887.31	11.36	NS	NS

Remark: * significant p<0.05, **significant p<0.01, ***significant p<0.001, ^{ns} not significant. Means with the same letter in column are not significantly different at 5% level for Least Significant Difference.

4. Conclusion and recommendation

Understanding the soil resource in an area and adoptions of management options was to improve the productivity of the soils is necessary for better use of resources. Application of easily available and an environment friendly compound like bio-char by integrating with nutrients may improve both the productivity of crops and soils and very high significance towards meeting our goal of increasing agricultural production and ensuring food security. Based on that, the effect of biochar rates on yield, yield components of Lemon grass and soil properties was investigated.

The results obtained in this study reveal that addition of biochar increased soil pH, EC, organic carbon, total nitrogen, available phosphorous, CEC and exchangeable cations of soils. The presence of plant nutrients and ash in the biochar, high surface area and porous nature of the biochar and the capacity of biochar to act as a medium for microorganisms are identified as the main reasons for the increase in soil properties. biochar applications also have an effects on yield and yield components of Lemmon grass and its effect increase through time. The best treatment recommended would be 15 tone ha^{-1} biochar from coffee husk and followed by 15 tone ha^{-1} biochar from biogas in order to achieve optimum production and biochar from coffee husk is better than biochar from biogas. Therefore, application of biochar is imperative in order to increase soil fertility, enhance nutrient uptake and ameliorate poor soils but it is important to integrate with inorganic nutrients. Moreover, further researches on biochar application frequency, biochar rate for different crops, biochar residual effect and other works will be required.

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