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Effect of different source and rates of biochar application on the yield and yield components of mungbean on the acidic soil in western Ethiopia

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Abstract
Mungbean is one of the most important food legume crops in Ethiopia. The yield of mungbean was reduced due to nutrient depletion and soil acidity. With this in view, effect of different source and rates of biochar application on the yield, and yield component of mungbean were studied. The treatments consists three source of biochar (maize, sesame and soybean source) and five rates of biochar (control, 2, 4, 6, 8, and 10 t ha^{-1}) were laid out as a randomized complete block design in a factorial arrangement with three replications. The result showed that effects of biochar on the number of leaf per plant (17), number of branches(5), number of seed per plant (14.6), 1000 seed weight (168g) and grain yield (628.49 kg/ha) were significantly different at $P<0.05$. However days of flowering, days of maturity, plant height, pod length, number of pod per plant, biomass yield and Harvest index were statistically non-significant different at $P<0.05$. The results indicated that sesame sources at 10 t h^{-1} rates of biochar application gave the highest grain yield. In contrast, the lowest grain yield (513.4 kg ha^{-1}) was recorded from control treatment, although the interaction effects of different source and rates of biochar application were significant on munbean varieties. The future studies should articulate towards the studies involving more varieties, multi-location and additional different source and rates of biochar applications, under diverse management practices such as research and farmer's field's conditions.

Keywords: Biochar, local variety, acidic soil and grain yield

Introduction

Mungbean is one of the most important pulse crops for protein supplement in subtropical zones of the world. It is a short duration catch crop between two principal crops. Mungbean contains 51% carbohydrate, 24–26% protein, 4% mineral, and 3% vitamins (Afzal *et al* 2008) [2]. Besides providing protein in the diet, mungbean has the remarkable quality of helping the symbiotic root rhizobia to fix atmospheric nitrogen and enrich soil fertility (Anjum *et al* 2006) [9]. It is grown from the tropical and sub-tropical areas around the world (Khan *et al*., 2012) [24]. It is herbaceous, annual legume crop, fast growth under warm conditions, low water requirement (Ali *et al*., 2011) [7], and it provides protein in the diet, consumed as dry seeds, fresh green pods or leaves forage or green pods and seeds as vegetables due to its high nutritional contents (Tang *et al*., 2014) [37].

Mung bean is originated from Asia (India) center of origin and it has diversified to East, South, Southeast Asia (China) and some countries in Africa (Sehrawat *et al*., 2013) [32]. It is also a recent introduction in Ethiopian pulse production and grown in the north eastern part of Amhara region (North Shewa, Oromia region and Southern Wollo), SNNP (Gofa area) and pocket areas in Oromia region (Hararge and illubabor areas (ECX, 2014) [19].

In Ethiopia it is the 6th product Commodity Exchange trading next to Coffee, sesame, white pea beans, maize and wheat (ECX, 2014) [19]. According to Ethiopian pulse production report 2004 the average yield production of mungbean is limited to 600-800 kg ha^{-1} due to the soil degradation, low productivity of varieties, low soil moisture during the grain filling stage, fertility management, disease prevalence and soil acidity (Amanullah *et al*., 2015) [8] and lack of promotional activities suitable for different cropping systems and agro-ecologies (Urgessa, 2015; ATA, 2013) [39, 5]. The use of biochar for soil improvement for crop yields in agricultural fields is lately recognized (Srinivasarao *et al*, 2013) [34].

Biochar is a carbon (C) rich product produced from the organic (waste) material relatively at the same or different temperatures and burned with little oxygen (gasification process) and no exposure to oxygen (pyrolysis) (Lehmann and Joseph 2009) [25]. Biochar also increases nutrient availability pH, CEC, increases the crop yield, decreases risk of crop failure and cropping of high value crops, reduce the soil acidity by increasing the soil pH thus it is a sustainable technology to improve highly weathered or degraded soils with the intention to improve soil fertility (David *et al.* 2013) [17]. It can enhance plant growth by improving soil chemical characteristics, physical characteristics and biomass properties all contributing to an increased crop productivity (Yamato *et al.*, 2006) [40].

The production and productivity of Mungbean was far below world average, as the national average yield of the crop is less than 0.4 ton per hectare (CSA, 2015) [16] due to soil acidity and decline in soil fertility. Soil degradation was adversely affecting sustainable crop production in Ethiopia in general and in western parts of our country particular (Abdenna *et al.* 2007) [1]. The nutrient uptake was greatly improved with increasing biochar application in combination with other commercial fertilizer (Major *et al* 2010) [26]. Addition of biochar enhances the efficacy of N fertilizers and hence augmented the growth and yield (Arif *et al*. 2012) [10].

Biochar addition to mungbean crop made it capable to compensate for low N availability due to improved biological N2 fixation (Zwieten *et al*, 2010) [1]. Hence, no information is available on the yield potential of mungbean variety with different source and rates of biochar application on the yield and yield components of in acidic soil. The different source and rates of biochar is needed to investigate in order to utilize the potential yield of mungbean in the area. Therefore, the objective was to determine the effect of different source and rates of biochar application on the yield and yield components of mungbean in acidic soil of Guto Gida districts western Ethiopia.

Material and Methods

Description of the study site

The study was carried out at uke research and demonstration site of Wollega University, Guuto Gidda woreda, Eastern Wollega zone which is located in the Oromia Regional State. It is located at 375 km Western of Addis Ababa. The study area is located on $8^o11^{'}52$ and $10^0 94^{'}44$ North latitude and 36^0 97'51 and 37^o $11^{'}$ 52 East longitude, and the altitude of 1500-1700 masl.

Experimental design and treatment

The experimental materials used for the experiment were mungbean local varieties and the experiment was designed in factorial arrangement with randomized complete block design (RCBD) and three replications comprising three source of biochar (Control, maize stalk, sesame stalk and soybean residue) and five rate of biochar application (Control. 2, 4, 6, 8 and 10 t ha^{-1}). Hence, the total number of treatments combination used was fifteen (15) and one control.

Experimental procedure

Experimental materials (Maize stalk, sesame stalk and soybean residue) were collected from farmer's field during the off season (during the harvesting season/January/2018) and drying for the biochar production through gasification process. The 3 kg acidic soils were filled Plastic pots (polyethylene pots) with 30 cm diameter and 35 cm height with the total area of 0.105 $m^{2.}$ The mung bean (*Vigna radiata*) seed were planted after 3 month incubation period.

Data collection

Phenological parameters

- **Days to flowering:** Days to flowering was recorded through visually counting the number of days until 75 % of flower initiated from the date of sowing in each pot
- **Days to maturity:** Days to maturity was recorded by counting the number of days until the 95 % of pods become fully matured or turned brown or black in color from the date of sowing in each pot.

Growth parameters

- **Plant height (cm):** This was taken from plants grown in each pot. A carpenter's tapes were used for measuring the plant height from the ground level to the tip of the leaves at maturity period. The mean from the two plants was determined.
- **Number of leaves:** were recorded by counting of leaves on the two plants and the mean values were calculated for each pot.
- **Number of branches:** was recorded from two plants through visual observation.

Yield parameters

- **Number of pods per plant:** Number of pods per plant was recorded through counting two plants each pot and then averages were taken.
- **Number of seeds per pod:** Number of seeds per pod was calculated on randomly selected three pods for each plant and then average was worked out.
- **Biomass yield:** Data on biomass yield was recorded by harvesting plant in each pot and measured both the straw with their pods of a plant then converted into kg ha^{-1}.
- **1000 Grains weight:** The 1000 grain weights were taken randomly from the sample harvested and threshed and was weighed with the help of electronic balance.
- **Grain yield:** The harvested seed from each treatment after drying were threshed; the seeds were cleaned, weighed and then converted into kg ha^{-1}.
- **Harvest index:** were computed as the ratio of grain yield (GY) to the total above ground Dry-mass (DM) yield.

Data analysis

Data analysis was done using SAS version 9.0 and the analysis of variance (ANOVA) were performed to see the significance differences of the growth, yield and yield components of a Mungbean on acidic soil parameters and the mean comparison were done to analyze the physico-chemical properties of the acidic soil and mean separation of the growth, yield and yield components were done using least significant difference (LSD) of the treatment if the treatment were significantly different at ($P<0.05$).

Result and Discussion

Days of flowering and maturity

Analysis of variance on the Table 1 showed that the interaction effect of different source and rates of biochar application on the days of flowering and maturity were non significantly different ($P<0.05$). Nevertheless different rates of biochar application on the days of flowering and maturity were significant different ($P<0.05$). The results indicate that the late days of flowering (56 days) were recorded from 4 t ha^{-1} and 6 t ha^{-1} rates and the early flowering days (55days) were recorded from 10 t ha^{-1} rate of biochar application. The biochar treated soil shows late flowering than the untreated soil (54 days). This result is against to the work of Ahmed *et al* (2005) [6] biochar application can enhance days of flowering. However the different source of biochar application were non significant different (*P*<0.05).

Table 1: Effect of different biochar sources and rates of application on Mungbean grown on acidic soil during 2017/2018 season.

Biochar source	DF	DM
Control	54.0	97
Maize	55.6	96
Sesame	55.5	95
Soybean	55.3	95
LSD (5%)	Ns	Ns
Biochar rates (t ha^{-1})		
Control	54.00	97
2	55.66	96
4	55.88	96
6	55.88	96
8	55.44	95
10	54.66	94
LSD (5%)	1.73	1.74
CV (%)	3.23	1.882

DF: Days of flowering DM: Days of maturity Ns: Non significant different

The results explained on the above table 1 indicates that different rates of biochar application on days of maturity were significantly different (*P*<0.05). The delayed (late) maturity of mung bean (96 days) were recorded at 4 t ha^{-1} and 6 t ha^{-1} rates and early days of maturity (94 days) were recorded at 10 t ha^{-1} rates however the biochar application to the soil can increase the earliness of the mungbean crop regarding to the maturity especially as the biochar application rates increase. The maximum application of biochar application on the mungbean which causes increase the earliness of flowering and maturity of a crop due to increasing vegetative growth and ultimately earliness of the maturity. The results are supported by Minfal 2012 [27] studied the effects of different levels of biochar significantly affected days to maturity Likewise decreasing in biochar levels enhance maturity while increase in biochar levels resulted in delay maturity.

Number of leaves and fruit bearing branches per plant

Analysis of variance explained on Table 2 indicates, the interaction effect of different source and rates of biochar application were significantly (*P*<0.05) affects the number of leave and fruit bearing branches per plant. The maximum leave number per plant (17 leaves) and fruit bearing branches per plant (5 branches) were recorded from sesame at 10 t ha^{-1} and maize source of biochar applied at 10 t ha^{-1} rates respectively and minimum number of the leave per plant (12.6) and fruit bearing branches per plant (3.65) was recorded from the soybean source at 2 t ha^{-1} rates while the biochar treated soil showed more number of fruit bearing branches than the untreated soil. This result shows that biochar application rate increases the vegetative growth due to nutrient contents of biochar similarly Baha (2016) [12] reports biochar application can improve the morphological characteristics of wheat growth and yield by increase in the number of leaves and number of fruit bearing branches. The results corresponding to Carter *et al.* (2013) [14] who stated that biochar treated lettuce was increased the number of leaves and branches of lettuce plant in comparison to control treatments. The results were in line with Jama *et al.* (1997) [23] increased in number of branches per plant with increase of biochar application levels. The nutrient contents of biochar can increase number of branches per plant of mungbean in biochar amended plots could be attributed to release of nutrient timely and slowly throughout the growing season. These results are in line with the findings of Deotale *et al*. (2005) [18], who concluded that biochar as such and also in combination with mineral nitrogen were found useful in improving the branches plant of green gram.

Table 2: Interaction effect of different source and rates of biochar application on the Number of leaves and number of branches of mungbean

Treatments	Maize source		Sesame source		Soybean source	
	NL	NB	NL	NB	NL	NB
Control	12.30	3.55	12.30	3.55	12.30	3.55
2 t ha^{-1}	13.30	3.88	14.00	4.00	12.60	3.65
4 t ha^{-1}	13.60	3.77	14.00	4.00	16.30	4.88
6 t ha^{-1}	13.00	3.66	14.00	4.00	13.00	3.66
8 t ha^{-1}	14.0 0	4.00	13.80	4.00	14.10	3.66
10 t ha^{-1}	17.00	5.00	17.00	5.00	14.60	4.22
LSD (5%)	2.10	0.65				
CV (%)	8.39	9.23				

NL: number of leaves NB: number of branches, LSD: least significance difference, CV=coefficients of variance

Plant height of mungbean

Analysis of variance explained that interaction effect of source and rate of biochar application on plant height of mungbean were non-significantly different (*P*<0.05) nevertheless the different rates of biochar application indicated on the table 3 explained that the plant height of mungbean were significantly different (*P*<0.05). The maximum mungbean height (29.502 cm) were recorded at 10 t ha^{-1} biochar application rates while the minimum plant height (22.27cm) were recorded from 2 t ha^{-1} rates. The biochar treated soil can increase the plant height of a mungbean than the control (19.83 cm) due to the nutrient contents of biochar which increase the cell division and cell enlargement and ultimately increase the vegetative growth particularly height of the plants. This finding corresponding to Carter *et al.* (2013) [14] reports stated that the treatment containing biochar were to increase plant height of lettuce plant in comparison to control treatments.

Table 3: Effect of different source and rates of biochar application on the plant height of mungbean

Biochar source	Plant Height (cm)
Control	19.83
Maize	25.86
Sesame	26.86
Soybean	25.93
LSD (5%)	Ns
Biochar rates (t ha^{-1})	
Control	19.83
2 t ha^{-1}	22.27
4 t ha^{-1}	27.83
6 t ha^{-1}	23.11
8 t ha^{-1}	28.38
10 t ha^{-1}	29.5
LSD (5%)	3.56
CV (%)	14.59

Analysis of variance on table 4 explained the interaction effect of different source and rates of biochar application on pod length and number of pod per plant of the mungbean were non-significantly different ($P<0.05$). The longest pod lengths (6.87 cm) were recorded at soybean source but the number of pod per plant were non significant different likewise the longest pod lengths (7.40cm) and maximum numbers of pod per plant were recorded at 10 t ha^{-1} rates of biochar application whereas little number of pod per plants (6.33) and shortest pod length (5.86cm) were recorded at the 2 t ha^{-1} rate. The biochar treated soil can increase the pod length and number of pod per plant than the untreated soil (4.7 cm). The result explained that as the rates of biochar application rates increase the pod length and number of pod per plant becomes increasing linearly.

Pod length, number of pod per plant

Table 4: Effect of different source and rates of biochar application on the pod length, number of pod length and number of pod per plant.

Biochar source	PL(cm)	NPP
Control	4.7	4.6
Maize	6	8.06
Sesame	6.75	8.86
Soybean	6.87	8.06
LSD (5%)	0.48	Ns
Biochar rates (t ha^{-1})		
2 t ha^{-1}	5.86	6.33
4 t ha^{-1}	6.31	7.11
6 t ha^{-1}	6.49	7.88
8 t ha^{-1}	6.66	9
10 t ha^{-1}	7.40	11.33
LSD (5%)	0.62	1.26
CV (%)	9.84	15.77

Similarly Pietikainen *et al.* (2000) [29] and Lehmann *et al*., 2003 reports the rates of biochar application increase the plant responses, until it reaches the maximum, above which growth response was negative for beans with application of 30 to 93 t ha^{-1}. These findings were also confirmed with Ahmed *et al* (2005) [6] who explained biochar application on the acidic soil can increase the pods plant^{-1} and seed yield of the crop. According to Bishwoyog *et al* (2015) [13] report that different source of biochar application can increase number of seed per pod. The increase may be associated with increase in the number of seeds per plant, sustained nutrient supply, increased photosynthetic activity and good translocation efficiency (Tandaie, *et al.* 2009) [36]. Similar to the present study, high seed numbers per pod were reported for soybean sown in low pH soil that was amended with biochar (Agboola and Moses, 2015) [3].

Thousand (1000) grain weight, number of seed per pod

The analysis of variance showed table 5 explained that the interaction of the different source and rates of biochar application on thousand seed weight of mungbean plants were significant different ($P<0.05$). The maximum thousand seed weight (168.8 g) were recorded at the soybean source at 10 ton/ha rates and the minimum thousand seed weight (82.1 g) were recorded from sesame source of biochar applied at 2 ton/ha rates of biochar application. Biochar treated plot showed greater thousand seed weight than the control plot (69.996 g). This is due to soybean source of biochar at 10 ton/ha rates of biochar application containing maximum phosphorus and which response to seed formation and increasing the seed weight while the phosphorus elements were highly responsible to the seed formation than the other elements in seed production. This is agreed with the finding of Umar *et al.* (2012) [38] who reported that seed weight increase with increasing biochar level when biochar application rates increase assimilates and vegetative growth and ultimately maturity is exceeded and grain filling duration is extended and finally assimilates are toward reproductive units which make heavier, bigger and well-filled grains as compared to no biochar application.

Table 5: Effect of different source and rates of biochar application on the number of seed per pod and thousand seed weight of mungbean on the acidic soil.

Treatments	Number of seed per pod			Thousand seed weight		
	Maize Source	Sesame Source	Soybean Source	Maize Source	Sesame Source	Soybean Source
Control	8.00	8.00	8.00	69.80	69.80	69.80
2 t ha^{-1}	10.3	8.66	12.00	92.67	82.10	86.60
4 t ha^{-1}	6.33	12.00	10.30	95.61	117.70	107.40
6 t ha^{-1}	9.66	10.00	12.00	96.80	99.78	106.80
8 t ha^{-1}	11.30	11.00	12.60	104.40	102.10	155.00
10 t ha^{-1}	13.30	14.00	14.60	137.00	138.20	168.00
LSD (5%)	1.61	27.9				
CV (%)	8.48	14.86				

Biomass yield and harvest index

The biomass yield of mungbean was non significantly ($P<0.05$)

affected by application of integrated different source and rates of biochar application on the acidic soil (Table 6). Significantly higher dry biomass yield was obtained from higher rates of biochar applied as compared to control. The highest 2812.6 kg/ha biomass of mungbean were recorded at the 10 t ha^{-1} rates of biochar application and the minimum biomass yield (1376.8kg/ha) were recorded at 2 t ha^{-1}biochar application rates. While Maximum biomass yield (2065.1kg/ha) were recorded at the sesame source and the minimum biomass yield (1819 kg/ha) were recorded at soybean source of biochar application. Likewise Glaser *et al.* 2002 [21] reported that significantly increase in biomass yield occur with increase in biochar levels. Steiner *et, al* 2007 [35] explained that biochar application improve nitrogen availability in soil and increase the photosynthesis which increase and enhanced the fertilizers use efficiency and hence increased plant biomass is the ultimate effect of biochar.

Table 6 Effect of different source and rates of biochar application on the biomass yield and harvest index on the acidic soil.

Biochar source	BY(kgha^{-1})	HI (%)
Control	1175	0.43
Maize	2012	0.31
Sesame	2065	0.46
Soybean	1819	0.34
LSD (5%)	210	Ns
2 t ha^{-1}	1376	0.39
4 t ha^{-1}	1420.9	0.67
6 t ha^{-1}	1991.5	0.30
8 t ha^{-1}	2226.7	0.27
10 t ha^{-1}	2812.6	0.22
LSD (5%)	271	Ns
CV (%)	14.28	2.62

Grain yield

The analysis of variance explained that the interaction effect of different source and rates of biochar application on grain yield of mungbean were significantly different (P<0.05). The maximum grain yields (635.4 kg/ha) were recorded at the sesame source at the 10ton/ha while the minimum grain yield (521 kg/ha) were recorded at the sesame source at 2 ton/ha rates of biochar application. The biochar treated soil show greater grain yield than the untreated soil (513.4 kg/ha). The result shows the applications of different source of biochar with different rates increased the grain yield of the mungbean when the rate of biochar application becomes increase. Similarly Agegnehu *et al.* (2016) [4] reports crop yield increases higher when biochar was made from nutrient-rich material such as poultry litter. Similar results were reported by Miranda *et al.* (2017) [28] and Asai *et al.* (2009) [11] revealed that biochar improved pollen development and anther dehiscence while they also increased yield.

Table 7: Effect of Different source and rates of biochar application on the Grain yield (kg/ha) of mungbean on the acidic soil.

Treatments	Maize source	Sesame source	Soybean source
Control	513.40	513.40	513.40
2 t ha^{-1}	541.90	521.00	561.60
4 t ha^{-1}	572.90	577.00	591.50
6 t ha^{-1}	595.10	620.20	603.40
8 t ha^{-1}	584.80	626.70	605.90
10 t ha^{-1}	606.50	635.40	628.50
LSD (5%)	18.88		
CV (%)	2.48		

According to Chan *et al.* (2008) [15] report significant increases up to 96 % in radish yield was observed from application of biochar produced from poultry litter in a greenhouse experiment this suggested that the increased yield was largely due to the biochar's ability to increase nitrogen availability. Similarly to Rondon *et al.* (2007) [31] reported that the positive effects of biochar, including nitrogen fixation led to 30 to 40% increase in bean yield with biochar additions up to 50 g kg^{-1}. They also reported a progressive increase in beneficial effects of biochar over time like increased NPK availability in soil.

Harvest index

Interaction of different source and rates of biochar application on the harvest index were non-significant different (P<0.05). The decrease in harvest index at high biochar application rates could also suggest excessive increase in vegetative growth relative to increase in the rate of translocation of carbohydrates to the grain filling.

The maximum harvest index shows the biochar application can increase the yield of mung bean rather than the biomass of a crop (assimilates) and the smallest harvest index shows that the biochar application cannot convert the nutrient to the yield rather they convert to biomass yield. This is inconsistent with previous studies on rice (Ahmed *et al*., 2005) [6], wheat and barley (Shafi *et al*., 2011) [33].

Conclusion

This study indicates that different growth, yield and yield components of mungbean were increased due to application of biochar compared to the control. The increased growth and yield of the crop were due neutilization and nutritional contents of biochar to acidic soil and the ash content in biochar. Due to the application of biochar, number of leaf per plant, number of branches, number of seed per plant, 1000 seed weight and grain yield were significantly increased. All growth and yield parameters mungbean showed significantly increase the yield and yield components of mungbean in acidic soil. Of the three source of biochar, at sesame source at 10 $tha^{-1}$of biochar applications was maximum grain yield than the other source of biochar application than the soybean and maize source of biochar. Among the biochar from different feedstock, sesame source of biochar application were effective to increase agronomic performance of mungbean crop in acidic soil in western Ethiopia. Therefore, different source and rates of biochar application are very important nutrients in limiting the growth and development of mungbean crops which has direct effect on productivity of the crops. The future studies should articulate towards and studies' involving more varieties, multi-location, additional rates and different source biochar application under diverse management practices, which may facilitate improvement of biochar recommendations.

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