Effect of different levels of biochar and inorganic fertilizer application on the growth of two grass species (Chloris gayana and Panicum coloratum)

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ORIGINAL ARTICLE

Effect of different levels of biochar and inorganic fertilizer application on the growth of two grass species (*Chloris gayana* and *Panicum coloratum)*

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ABSTRACT

The study was carried out to evaluate the productivity of *Chloris gayana* and *Panicum coloratum* by application of different levels of coffee husk biochar and inorganic fertilizers (DAP and urea). The Experimental design was Randomized Complete Block Design (RCBD) with three replications. The treatments were T1=zero fertilizer application (control), T2= inorganic fertilizer using 100 kg DAP and 50 kg Urea, T3=5 t ha-1 biochar with 40 kg ha^{-1} inorganic fertilizer, T4=3 t ha^{-1}t biochar with 40 kg ha^{-1} inorganic fertilizer and T5=5 t ha^{-1} biochar with 100 kg ha^{-1} inorganic fertilizer for the two grass species. The result revealed that combined application of biochar and inorganic fertilizer significantly (<0.05) affected phonological variables, agronomical parameters, seed and biomass yields of *Chloris gayana* and *Panicum coloratum* measured at 4, 8 and 12 weeks after planting. Delayed days to 50% flowering (74 and 55 days) and 50% maturity (96 and 69 days) were obtained due to the application of 5 t ha-1 biochar with 100 kg ha^{-1}kg ha-1 inorganic fertilizer for *Chloris gayana* and *Panicum coloratum*, respectively. The highest plant height, leave length, number of tiller per plant and number of leaves per plant at all weeks were recorded for (T5) while the lowest was from T1 in both grass species. The study results indicated that the productivity of *Chloris gayana* and *Panicum coloratum* can be improved by the combined application of biochar and inorganic fertilizer. In future, application of biochar combined with inorganic fertilizer should be repeated at different seasons and agro ecology conditions.

Key words: *Biomass yield, fertilizer use, growth of grasses, harvesting dates*

INTRODUCTION

The forage productivity is low in quality and quantity due to decline of soil fertility, rainfall variability, pest pressure, poor agronomic practice and poor accessibility of quality seed. Productivity can mainly be improved through the use of improved forages, application of fertilizers and other good agronomic practices. Many improved grass species including Rhodes *(Chloris gayana)*, and Coloured Guinea *(Panicum coloratum)* have been identified for the various ecologies in Ethiopia (Yenesew et al, 2015; Armando et al., 2017).

Rhodes grass *(Chloris gayana)*, is one possible perennial improved grass which can be grown on farm and used by small-holder farmers. Rhodes grass grows better in areas where annual rainfall is above 600 mm and altitude ranges between 1400 m and 2400 m (Yenesew et al., 2015). Rhodes grass, have better productivity and nutritive value when compared with natural pasture and it is a perennial, high-yielder, fast growing, palatable and deep rooted grassland harvest two to three times in rain-fed conditions, frequency of harvesting will increase if the farmers were able to use irrigation (Yenesew et al., 2015). Coloured Guinea grass *(Panicum coloratum),* is another perennial grass adapted to a wide range of soil and climatic conditions with potential to be used as forage in tropical and semi-arid regions around the world (Armando et al., 2017). It grows during the warm season on moist or seasonally waterlogged heavy soils, grasslands, open woodland, gardens, river beds, canal banks or in depression (Ecocrop. 2010) and grows best during the warm season, with annual temperatures ranging from 18°C to 36°C, with an annual mean temperature around 22°C, and annual rainfall ranging from 400 to 2000 mm.

Fertilizers are normally used to increase forage yield and quality, but since plant tissue reflects the mineral constituents of the soil in which the plants are grown, quality is also greatly influenced (Miles and Manson, 2000). Inorganic fertilizer application is essential for plant growth and productivity of forage grass. However, the increase cost of inorganic fertilizer and application of recommended dose is difficult to be afforded by farmers. Hence, easily accessible and low cost organic source of plant nutrients for supplementing and enhancing chemical fertilizer should be substituted which can be affordable to the majority of the farming community. In this contexts, integrate nutrient management would be available strategy for effective use of inorganic fertilizer with addition of organic soil amendment. Biochar is a carbon-rich solid material which is produced during pyrolysis. Pyrolysis is a thermos chemical process where biomass is heated in the absence of oxygen (Yaman, 2004). Application of biochar to soil causes numerous soil changes, ranging from chemical, physical, and biological effects (Alemayehu et al., 2020). Biochar is recently well known organic components of an integrated nutrient supply system, which improve soil health, increase productivity and releases some amount of macro and micro nutrients (Xu et al., 2015). The ability of to retain nitrogen and prevent its leaching can increase nutrient use efficiency, there by maintains crop yield under small nitrogen application (Zhang, et al., 2015). However, the physical, chemical and nutritional properties and thus the quality of biochar depends on the chemical composition of the feedstock used, pyrolysis system and production conditions, including temperature and residence time (Lie et al.,2017). Soil study in Jimma area indicated that decline of total nitrogen which is below the critical level due to nitrogen leaching problems as the area received high rain fall and farmers have a limited cultural practice to integration chemical fertilizer with organic amendments for enhanced forage production around Jimma condition is lacking. So far biochar has been applied to amend soil for crop production and little information is available for its application mainly around the study area. Hence, the objective of this study was to evaluate productivity of *Chloris gayana and Panicum coloratum* by application of different level of biochar and inorganic fertilizer. Therefore, the hypothesis in the present study was application of different level of biochar and inorganic fertilizer would influence productivity of *Chloris gayana* and *Panicum coloratum* forage.

MATERIAL AND METHODS

Description of the study area

The experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM), research field (Eladale) in the year 2017/18., located at an elevation of 1710 m.a.s.l., a latitude of at 7^{o}33′N latitude and 36^{0}57′E longitude. The mean annual maximum and minimum temperature are 26.8 and 11.4^{o}C and the mean annual maximum and minimum relative humidity are 91.4 and 39.92% respectively. The mean annual rainfall of the study area is 1250 mm. The soil of the experimental site is well-drained clay to silt clay with pH of 5.5. The most common and dominating soil type is Nitosol (Bayu et al., 2015).

Biochar preparation

The coffee husk used as a feedstock, was purchased from nearby coffee processing enterprise. After separating impurities it was dried in the sun until about a moisture content of 15%, the coffee husk was, then, taken to the pyrolysing machine. Then, it was heated to a temperature of 400^{0}C for 20 minutes. After it was cooked, the bio-char was taken and spread out in the sun, evaporating the water the machine sprayed to keep the temperature at the adjusted magnitude (400^{0}C). Finally, the bio-char was collected and put ready till it was used.

Experimental design, treatments and layout

A Randomized Complete Block Design (RCBD) was employed with two grass species, three replications and five fertilizer levels. Total area of land with 25 m x 9 m was selected and cleared by removing all unwanted threshes, grasses and weeds before ploughed. Then, the selected land was ploughed twice to make fine field and followed by harrowing using hoe and rack manually to break down the clods. The experimental field was divided in to 3 blocks with 30 plots. Each plot size was 2 m x 1.6 m (3.2 m^2) and consisted of four rows with 20cm between plants (Yenesew et al., 2015) and 40cm between rows for perennial grass suggested by Tekleyohanes et al, (2004).The spacing between plots and blocks was 1 m and 1.5m, respectively (Akililu and Alemayehu. 2007).

The assigned plots were top- dressed using biochar at the rate of 5 t ha-1 for 15 days prior to transplanting. The application was done in the assigned plots by incorporating coffee husk biochar to the top 15 cm of the soil with the aid of a hoe. The rate of application was made following the recommendation suggested by Dennis and Kou (2013).

Table 1: Treatment layout for the two grass species and five fertilizer levels

Species	Treatments
Panicum coloratum	T1=zero fertilizer application (control)
	T2=Inorganic fertilizer (100 %) =(100 kg ha-1 DAP and 50 kg ha-1 urea)
	T3=Biochar alone (100%) =5 t ha-1
	T4 =Biochar at 60 % (3 t ha-1 and inorganic fertilizer at 40 % or 40 kg ha-1 DAP) and 40 kg ha-1 urea
	T5=Biochar 100 % (5 t ha-1) and inorganic fertilizer 100 % (100 kg ha-1) DAP and 50 kg ha-1 urea)
Chloris gayana	T1= zero fertilizer application (control)
	T2= Inorganic fertilizer (100 %) =100 kg ha^{-1}) DAP and 50 kg ha-1 urea)
	T3=Biochar (100%) =5 t ha-1
	T4 =60 % Biochar (3 t ha-1 and 40 % inorganic fertilizer (40 kg ha-1)
	T5=Biochar 100 %(5 t ha-1) and inorganic fertilizer 100 % (100 kg ha-1) DAP and 50 kg ha-1 urea)

The assigned plots were fertilized with Di-ammonium phosphate (DAP) at a rate of 100 kg ha-1 at time of planting following the procedure by Yenesew et al., 2015. Urea was applied at the rate of 50 kg ha^{-1} after establishment and at every cut. Then the upper soil layer was mixed using hand rakes (Zelalem et al, 2009) by calculating the level of biochar and inorganic fertilizer based on the area of the plots in relation with area of one hectare. *Chloris gayana* and *Panicum coloratum* seedlings were prepared in plant science lath-house and transplanted to the plots after 30 days. The treatment was fenced off using locally available wooden materials. The plots were watered regularly after planting using water cane. Weeds were controlled through a manual and slashing inters row spaces to reduce weed competition within the replications and pest inspection was carried out every day during the whole trial period.

Data Collection

Agronomic parameters

For agronomic parameters, five sample plants were selected randomly from each plot area, and tagged using string on the plant. Various phonological characteristics such as plant height, tiller numbers, leaf length and number of leaf per plants were recorded at 4, 8 and 12 weeks after transplanting. Plant height (cm) was determined using a steel ruler and measuring the vertical from the ground to the last leaf (flag leaf) of the main shoot. The leaf length (cm) was measured from the node to the last leaf. Number of leaves per plant was determined by counting the total number of leaf from the main five randomly selected plants in each plot. Number of tiller per plant was also determined by counting the number of visible tillers in each of the five randomly selected plants in the plot (Tarawal, 1995) and the average of five plants was taken for each plot.

Biomass yield

Biomass yield of forages per plot was evaluated under successive cuts at 50 % flowering based on continuous visual observation. Samples were collected from inner row of 0.8 m^2 area of each replication and harvested at stubble 5 cm height of cutting. The harvested green forage was weighed plot wise using a top loading field balance. The fresh sub sample was measured from the inner rows of each plot, weighed and chopped into small pieces using sickle (2.5 cm), labeled and kept in separate perforated bags. Three hundred gm ffresh weight of sub ssamples was taken from each plot and dried in an oven at 65 °C for 72 hours to constant weight. Dry weight of sub sample was reweighed to have an estimate of dry matter production.as per the formula suggested by Tarawal (1995).

Flowering and seed yields determination

`Flowering and seed production in the two grass species were assessed from the first week of the inflorescence appearance in each plot using continuous visual observation. Days to 50 % flowering for *Panicum coloratum* and *Chloris gayana* were determined by recording the number of days after transplanting when half of the plants (or tillers) were flowering. The 50% maturity of *Panicum coloratum* and *Chloris gayana* was determined by recording the number of days from transplanting to time when the plant seed get matured.

Ripen seeds of *Panicum coloratum* and *Chloris gayana*, along with the inflorescence is mowed at the right stage of seed development and sweating immediately after harvest and left under a shed to assist the final maturation. Thereafter, the seeds were gently trashed to separate the seed from the sheaves, cleaned and weighted using a sensitive balance to determine seed yield.

Data Analysis

The data was analyzed by using GLM (ANOVA) with SAS software (SAS, 2011 version 9.3). Significantly different means were separated and compared using Least Significant Difference (LSD) test at 5 % significance level.

RESULTS AND DISCUSSION

Phonological variables

The effect of Biochar and inorganic fertilizer significantly ($p<0.05$) influenced 50% flowering and 50% maturity of *Chloris gayana* and *Panicum coloratum.* Delayed 50 % flowering and 50% maturity at application of biochar and inorganic fertilizer and early flowering and maturity were shown in Table 2. *Chloris gayana* had longer days of 50 % flowering when compared to *panicum coloratum*. The difference was due to morphological and species difference. The delay in 50% flowering was achieved at 55 and 74 days after transplanting for *Panicum coloratum and Chloris gayana,* respectively. The shortest days of 50% flowering (Zhang et al, 2015 and Patil et al, 2016) was observed after transplanting for *Panicum coloratum and Chloris gayana,* respectively for control treatment.

The delay 50 % in flowering could be due to application of biochar with inorganic fertilizer promoting vegetative growth, as it retains and contains high amount of nutrients especially nitrogen for fast vegetative growth and longer photosynthetic apparatus by delayed flowering (Zheng et al., 2013). Burhan, and Hago (2000) also reported that the level of biochar and inorganic fertilizer application might be attributed to the characteristics of biochar to retain applied nutrient and higher amount of nitrogen and phosphate fertilizer which enhanced vegetative growth of the crop and prolonged days required to attain 50 % of flowering. Similarly, Zelalem (2009) reported that increasing nitrogen and phosphorus fertilization level significantly delayed day required for 50% flowering. *Chloris gayana* had longer days to 50 % maturity than Panicum coloratum. The high level of biochar and inorganic fertilizer application results in significantly delayed 50% maturity of *Panicum coloratum* and *Chloris gayana* by 61 and 92 days, respectively after transplanting. Delayed days to 50 % maturity results indicated that the days to physiological maturity were prolonged in response to the increased level of biochar and inorganic fertilizer. Clough et al (2010) and Getnet et al, (2003)] reported that biochar play great role to supply and adsorb the applied nitrogen and this nitrogen plays in promoting vegetative growth in the plants and the nitrogen take up by plant root from the soil was used for increased cell division and synthesis of carbohydrate, which results in plant prolonged days to 50 % maturity.. The early 50 % days of maturity was recorded from control treatments with 56 and 84 days after transplanting for *Panicum coloratum* and *Chloris gayana*, respectively, due to nutrient deficiency.

Agronomic parameters

Application of biochar and inorganic fertilizer at different level had significant ($P<0.05$) affected plant agronomic parameters (plant height, leaf length, number of tillers per plant, and number of leaves per plant) of *Chloris gayana* and *Panicum Coloratum* at 4, 8 and 12 weeks of measurement (Table 3). The overall mean plant height in cm (62.67, 107.11, and 159.25) for *Chloris gayana* and (55.67, 93.60, and 153.83) for *Panicum coloratum* was recorded at 4, 8 and 12 weeks of measurements, respectively. Denbela (2015) reported double of the current finding that the average height growth potential at 50% heading was 118 cm and 148 cm respectively for *Panicum Coloratum* and *Chlorisgayana*. This difference was due to application of biochar and inorganic fertilizer that incites the plant cell division and increased the plant height. The overall mean leave length in cm (54.19, 57.80, and 63.96) for *Chloris gayana* and (47.78, 50.17, and 55.35) for *Panicum coloratum* was recorded at 4, 8 and 12 weeks of measurements, respectively. *Chloris gayana* was the tallest in all weeks when compared to *panicum coloratum*. The tallest plant height leaf length and number of tillers per plant were recorded on application of biochar 5 t ha-1 with inorganic fertilizer 100 kg ha-1 (T5) at all weeks of measurements taken. For both grass species, plant height increased with advanced weeks of measurement as well as from T1 to T5 or with increasing level of biochar and inorganic fertilizer. The increase in plant vegetative growth as a result of application of inorganic fertilizer combined with biochar could be attributed to increase up take of the nutrient by the plant. This result is in line with Chan et al, (2007) who reported that combined use of biochar and inorganic fertilizer enhanced plant height. Significant increase in plant height and leaf length was observed due to the fact that biochar has high surface area which enables to adsorb applied nitrogen and used as source of nitrogen to promote the formation of chlorophyll which in turn resulted in higher photosynthetic, plant growth and resulted taller plant (Harper, 1994).

Table 2. Means and Standard error values for 50% flowering and 50 % maturity stage of *Chloris gayana* and *Panicum coloratum* at different level of biochar and inorganic fertilizer application.

Species	TRT	50% flowering(days)	50% maturity (days)
	T1	42 ± 0.33^{d}	56 ± 0.33^{d}
	T2	50 ± 0.33^{c}	64± 0.33^{c}
Panicum coloratum	T3	52 ± 0.33^{b}	66 ± 0.33^{b}
	T4	54 ± 0.58^{a}	68 ± 0.58^{b}
	T5	55 ± 0.58^{a}	69 ± 0.58^{a}
p-value		0<0.0001	0<0.0001
Chloris gayana	T1	64 ± 0.33^{c}	84 ± 0.33^{d}
	T2	69 ± 0.67^{b}	90 ± 0.67^{c}
	T3	70 ± 0.88^{b}	92 ± 0.33^{b}
	T4	73 ± 0.58^{a}	94 ± 0.58^{b}
	T5	73 ± 0.88^{a}	96 ± 0.58^{a}
p-value		0.0001	0.0001

Means in a columns, values followed by different letter significantly (p<0.05), TRT =treatment, T1=zero fertilizer, T2=inorganic fertilizer (100 kg ha-1 DAP and 50kg urea; T3=100% Biochar (5 t ha-1), T4=60 % Biochar (3 t ha-1) and 40% inorganic fertilizer DAP, T5= 5 t ha-1 Biochar and inorganic fertilizer (100 kg ha-1 DAP & 50 kg ha-1 Urea).

Similarly, Walter and Rao (2015) reported that increased plant height in response to combined application of biochar with fertilizer might be ascribed to enhance up take of nitrogen and phosphorus as nitrogen fertilizer stimulates vegetative growth and phosphate incites stem elongation in plants.

The number of tillers per plant determines the rate of biomass accumulation and the quality of forage (Skinner et al., 2007). Tillers contain leaves which are easily digestible and more preferred since they have less structural carbohydrates, especially the newly developed tillers with young leaves. Laidlaw et al,, (2005) reported that grass with higher number of tillers are more persistent and contribute more resources to the next generation of reproductive tillers and a close relationship between tiller numbers and leaf recruitment per tiller. *Chloris gayana* had more number of tillers than *Panicum coloratum* in all counting may be due to high vegetative growth in *Chloris gayana* than *Panicum coloratum*. This observation is in agreement with Koech (2014) who reported that differences in tiller numbers and heights could be attributed to the morphological differences which are associated with genetic differences among the grass species. Under the current study, the increase in tiller number per plant with advanced maturity stage and increased fertilizer application (from T1 to T5) is in agreement with other reports by Kizima et al., (2014) who reported that application of nitrogen fertilization significantly affects the appearance of new tillers and increases the dynamics of tiller population of *Cenchrus ciliaris*.

The overall mean leaves per plant were 6.13, 6.93 and 11.07 for *Chloris gayana* and 4.99, 5.69 and 6.47 for *Panicum coloratum* at 4, 8 and 12 weeks of measurement. Furthermore, combined application of inorganic fertilizer with biochar (T4 and T5) has improved number of leaves per plant as compared to sole application of both. This result is in agreement with Saarnio et al., (2012) who reported that biochar application integrated with fertilizer helps to increase in plant leaf number. Xu et al., (2015) also reported that there was a significant improvement of leaf photosynthesis and capacity on biochar amended soils, which they attributed to increased leaf number and soil available nitrogen. Koul (1997) reported that the level of fertilizer increased number of leaf per plant increased due to the ability of fertilizer that promoted leaf yield via cell division and elongation. Number of leaves per plant is an exhalant indicator of herbage yield and nutritional quality and higher the amount of leaves has the higher content of protein and digestible dry matter (Miller, 1994).

Seed and Biomass yields

The analysis of variance showed that the seed and biomass yields were significantly (P<0.05) affected by biochar and inorganic fertilizer application on *Chloris gayana* and *Panicum coloratum* (Figures 1, 2 and 3). Rhodes grass had comparatively delayed maturity of seed and gave higher seed yield when compared to *Panicum coloratum,* which could be due to difference in morphological characteristics of grass species.

Table 3. Least square mean and standard errors for Plant height, leave length, number of tiller and number of leaves per plant of *Chloris gayana* and *Panicum coloratum* at 4, 8 and 12 weeks of measurements

SPS	TRT	Plant Height(cm)			Leaf Length(cm)			Number of tiller per plant			Number of Leaf per plant		
		Week 4	Week8	Week12	Week 4	Week8	Week12	Week 4	Week8	Week12	Week 4	Week8	Week12
Panicum coloratum	T1	41.4 ± 1.4^{c}	70.1 ± 1.0^{c}	140.7 ± 5.1^{c}	42.7 ± 2.4^{c}	44.9 ± 2.9^{c}	48.7 ± 2.9^{c}	$12.0 \pm 0 .7^{c}$	14.1 ± 0.5^{c}	23.3 ± 1.2^{d}	3.1 ± 0.1^{d}	4.1 ± 0.3^{c}	4.8 ± 0.2^{d}
	T2	59.8 ± 3.3^{ab}	91.1 ± 2.1^{b}	152 ± 1.2^{bc}	48.6 ± 1.9^{ab}	49.3 ± 2.2^{b}	54.5 ± 0.5^{bc}	16.0 ± 1.0^{b}	20.3 ± 1.7^{b}	26.9 ± 0.5^{b}	5.5 ± 0.2^{b}	5.6 ± 0.2^{b}	5.8 ± 0.3^{c}
	T3	51.3 ± 2.4^{b}	91.7 ± 11.9^{b}	154.9 ± 4.1^{ab}	45.3 ± 1.1^{bc}	49.5 ± 2.3^{b}	55.7 ± 1.2^{ab}	13.1 ± 0.5^{b}	22.9 ± 2.7^{ab}	30.6 ± 1.1^{b}	4.6 ± 0.4^{c}	5.8 ± 0.2^{b}	6.9 ± 0.3^{b}
	T4	59.9 ± 3.9^{ab}	99.5 ± 2.8^{ab}	154.9 ± 2.7^{ab}	49.4 ± 1.3^{ab}	52.7 ± 1.2^{ab}	57.3 ± 0.4^{ab}	16.3 ± 0.9^{ab}	24.3 ± 2.1^{ab}	31.9 ± 1.9^{ab}	5.7 ± 0.2^{ab}	$6. 2\pm 0.1^{ab}$	7.0 ± 0.3^{ab}
	T5	62.9 ± 1.5^{a}	115.7 ± 5.2^{a}	161.6 ± 1.8^{a}	52.9 ± 0.5^{a}	57.1 ± 1.5^{a}	60.7 ± 1.8^{a}	17.9 ± 1.4^{a}	26.9 ± 0.6^{a}	34.7 ± 0.6^{a}	6.1 ± 0.2^{a}	6.8 ± 0.2^{a}	7.9 ± 0.3^{a}
	P.V	0.0034	0.0014	0.0011	0.0005	0.0005	0.0017	0.0014	0.0012	0.0001	0.0001	0.0003	0.0001
Chloris gayana	T1	44.3 ± 2.5^{d}	84 ± 2.4^{c}	143.3 ± 2.8^{d}	42.3 ± 2.3^{c}	46.5 ± 1.7^{c}	52.7 ± 1.2^{d}	16.8 ± 0.9^{c}	18.9 ± 1.2^{c}	$25.1 \pm 1 .1^{d}$	3.8 ± 0.4^{d}	5.2 ± 0.2^{d}	9.2 ± 0.2^{d}
	T2	66.1 ± 2.10^{b}	101.9 ± 4.5^{b}	156.8 ± 1.7^{bc}	56.9 ± 1.6^{ab}	58 ± 1.2^{b}	60.3 ± 2.9^{c}	26.1 ± 0.4^{ab}	28.3 ± 1.4^{b}	35.7 ± 0.9^{c}	6.6 ± 0.1^{b}	7.1 ± 0.24^{bc}	10.4 ± 0.4^{c}
	T3	57.9 ± 1.9^{c}	108.7 ± 5.9^{b}	159.7 ± 3.5^{bc}	53.7 ± 2.0^{ab}	60 ± 1.5^{ab}	66 ± 0.6^{bc}	23.5 ± 1.9^{b}	32.3 ± 3.2^{ab}	40.7 ± 1.2^{b}	5.8 ± 0.1^{c}	6.5 ± 0.1^{c}	11.7 ± 0.1^{b}
	T4	69.6 ± 3.1^{b}	115.6 ± 3.5^{ab}	165.5 ± 4.6^{ab}	57.3 ± 0.7^{ab}	60.2 ± 1.1^{ab}	68 ± 1.5^{ab}	26.9 ± 0.70^{b}	32.9 ± 2.1^{ab}	42 ± 1.7^{ab}	6.7 ± 0.3^{ab}	7.5 ± 0.3^{ab}	11.7 ± 0.1^{ab}
	T5	75.1 ± 2.9^{a}	125.3 ± 5.2^{a}	171 ± 2.7^{a}	60.7 ± 0.7^{a}	64.3 ± 1.2^{a}	$72.8 \pm 2 .5^{a}$	29.2 ± 0.8^{a}	36.45 ± 0.3^{a}	45.7 ± 0.3^{a}	7.6 ± 0.1^{a}	8.3 ± 0.2^{a}	$12.4 \pm 0.2a$
	P.V	0.0001	0.0033	0.0002	0.0004	0.0003	0.0010	0.0014	9.0012	0.0001	0.0001	0.0003	0.0001

Means With the same letter in the same column are not significantly different (a P<0.05). RTR=treatment, SPS=species, T1=zero fertilizer, T2=inorganic fertilizer (100 kg ha-1 DAP and 50kg UREA),T3=100 % Biochar(5t ha-1), T4=60% Biochar (3 t ha-1) and 40% (40 kg ha-1) inorganic fertilizer, T5= 5 t ha-1 Biochar and inorganic fertilizer (100 kg ha-1 DAP & 50 kg ha-1 Urea

High clean seed yields were obtained by harvesting Rhodes grass between one and four weeks after the first heads start shattering and maximum clean seed yield of *Panicum coloratum* was obtained by harvesting two weeks later (Karta, 2012).

Although the establishment and growth of Rhodes grass was slow compared to *Panicum coloratum* the reverse is true for increased seed production. The highest seed yield per hectare 526.58 and 391.50 kg ha/ha was obtained from (T5) followed by (T4) while the lowest seed yield (201.67 and 165.33 kg ha-1) in control treatments (T1) for *Chloris gayana* and *Panicum coloratum,* respectively. This result is in agreement with Getnet et al., (2003) who reported that seed yield among different nitrogen fertilization rates had a significant effect and the highest seed yield was obtained by applying high amount of nitrogen fertilizer.

The mean seed yield of *Chloris gayana* and *Panicum coloratum* were 404 kg ha-1 and 305 kg ha-1, respectively. This result is in line with Alemayehu (1994) who reported that 400 and 300kg ha-1 seed yield produced for *Chlorisgayana* and *Panicum coloratum,* respectively. Solomon, (2008) also reported that mean seed yield of *Chloris gayana* ranges 65-650kg ha-1 and *Panicum coloratum* ranges 45-400kg.The current result is higher than the result reported by Alemayehu, and Getnet (2012) 250kg ha-1 and 200kg ha-1 for *Chlorisgayana* and *Panicum coloratum,* respectively. This difference results could be due to the fact that biochar plays a great role to supply and adsorb the applied nitrogen and this nitrogen plays in promoting vegetative that increased the tillers number for produced more seed.

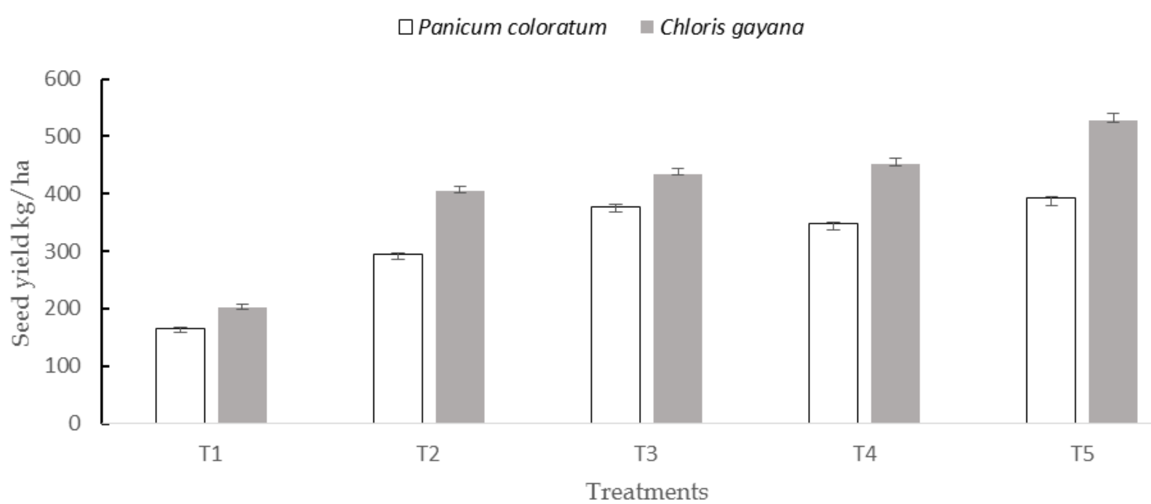

Figure 1. Seed yield of *Panicum coloratum* and *Chloris gayana* at different level of biochar and inorganic fertilizer application (T1=zero fertilizer, T2=inorganic fertilizer (100 kg ha-1 DAP and 50 kg UREA), T3=100% Biochar(5 t ha-1), T4=60 % Biochar (3 t ha-1) and 40% (40 kg ha-1) inorganic fertilizer, T5= 5 t ha-1 Biochar and inorganic fertilizer (100 kg ha-1 DAP & 50 kg ha-1 Urea).

Fresh biomass and dry matter yield of *Chloris gayana* and *Panicum coloratum* ($P<0.05$) was affected by application of biochar and fertilizer as well as at 8, 16 and 24 weeks of cutting after transplanting (Table 4). Denbela, (2015) reported that *Chloris gayana* produced more fresh biomass and dry matter yield than *Panicum coloratum* due to its ability to maintain higher vegetative productivity which, in turn, can account for a large portion of the higher dry matter yields than *Panicum coloratum*. Imaz et al., (2013) reported that the preferential biomass allocation of *Chloris gayana* towards roots during its recovery allowed re-establishing a shoot biomass more appropriate for facilitating water and nutrient supply under well drained soil than *Panicum coloratum*.

Table 4. Least square means and standard errors for Dry matter Yield (DMY) and Fresh Biomass yield of *Chloris gayana and Panicum Coloratum* in different Level of Biochar and fertilizer application

		1st cut (8 week)		2nd cut (16 week)		3rd cut (24 week)	
SPS	**Treatments**	**DMY**	**FBY**	**DMY**	**FBY**	**DMY**	**FBY**
Panicum coloratum	T1	4.84 ± 0.65c	23.83 ± 1.10c	6.58 ± 0.39c	27.50 ± 3.15c	8.75 ± 0.33c	29.88 ± 0.73c
	T2	7.07 ± 0.35ab	39.21 ± 0.79b	9.32 ± 0.72b	35.63 ± 2.95b	11.63 ± 1.470.b	38.67 ± 5.28bc
	T3	6.21 ± 0.41bc	33.33 ± 2.53bc	10.25 ± 0.13ab	41.88 ± 0.96ab	13.04 ± 1.340 ab	44.04 ± 3.37ab
	T4	7.59 ± 0.65ab	40.83 ± 2.92ab	11.27 ± 0.79ab	43.67 ± 3.68ab	13.80 ± 0.92 ab	47.2 ± 3.34ab
	T5	8.56 ± 0.43a	45.38 ± 2.51a	12.29 ± 1.09a	47.21 ± 3.63a	15.42 ± 0.57a	49.71 ± 1.06a
	Mean	6.85	37.25	9.94	38.48	12.53	41.90
	P	0.0010	0.0063	0.0027	0.0023	0.0011	0.0156
Chloris gayana	T1	5.96 ± 0.95c	41.88 ± 3.90c	12.35 ± 0.35c	45.83 ± 2.08c	15.11 ± 1.46c	46.25 ± 5.050.c
	T2	9.87 ± 0.45ab	58.54 ± 2.35ab	15.15 ± 0.62ab	57.08 ± 2.73b	17.67 ± 2.09bc	57.29 ± 6.22b
	T3	11.74 ± 0.18bc	51.42 ± 2.33bc	16.02 ± 0.64ab	62.5 0± 2.50ab	19.20 ± 1.42ab	64.54 ± 4.11ab
	T4	13.83 ± 0.45ab	58.75 ± 2.2ab	16.72 ± 0.91ab	65.21 ± 4.02ab	20.64 ± 0.85ab	65.38 ± 2.69ab
	T5	14.97 ± 0.95a	63.75 ± 3.31a	17.86 ± 1.02a	68.33 ± 3.00a	22.**20** ± 0.51a	69.09 ± 2.22a
	Mean	12.82	54.87	15.62	59.79	18.96	59.91
	P	0.0005	0.0071	0.0138	0.0083	0.0023	0.0015

Means with the same letter in the same column are not significantly different (a =0.05). T1= zero fertilizer, T2=inorganic fertilizer (100 kg ha-1 DAP and 50 kg UREA), T3=100% Biochar(5 t ha-1), T4=60 % Biochar(3 t ha-1) and 40% inorganic fertilizer (40 kg/h), T5= 5 t ha-1 Biochar and inorganic fertilizer (100 kg ha-1 DAP & 50 kg ha-1 Urea)

The highest fresh and DM biomass yield was obtained from (T5) and followed by (T4) for both *Chloris gayana* and *Panicum coloratum at* 8, 16 and 24 weeks of cutting, respectively shown in Table 4. The lowest biomass yield was recorded in control treatment for *Chloris gayana* and *Panicum coloratum at* all cuttings stage. This result is in line with earlier reports who reported that the highest above ground biomass was in the treatment with fertilizer addition and highest level of biochar application as compared to the non-fertilized and non-biochar amended soil (Saarnio et al. , 2013 and Patil et al, 2016). They indicated that fresh and dry biomass yield increased with increasing fertilizer levels due to nitrogen and other macro elements which played an important role in plant growth and physiological processes and enhance vegetative growth, consequently increase plant weight by producing more dry matter.

The overall mean fresh biomass yield (t ha-1) was 54.87, 59.79 and 59.91 for *Chloris gayana* and 37.25, 38.48 and 41.90 for *Panicum coloratum* at 1st, 2nd and 3rd cutting stage respectively. The result is in line with Tewdros and Messert. (2013) who reported that the fresh biomass yield of *Chloris gayana* ranged from 31.9-98.0 t ha-1 at the Southern Ethiopia. However, the current study was higher than the result reported by various researchers,(Murphy, 2010 and Denbela, 2015) who reported that the average fresh biomass yield for *Chloris gayana* were 49.8 t ha-1 and 40.8 t ha-1 for C*hloris gayana and Panicum coloratum* respectively. Burhan, and Hago (200) stated that nitrogen plays an important role in plant growth and physiological processes, as it enters all enzymes composition and enhances vegetative growth and yield.

This result indicated that combined application of biochar with fertilizer and cutting frequency increased dry matter yield (DMY). Dutta et al., (2003) noted that the use of organic together with chemical fertilizers, compared to the addition of organic fertilizers alone, had a higher biomass yield and hence soil health for biomass yield production. The DM yield increased with increasing age of re-growth and with increasing levels of N fertilizer (Adugna et al, 2006). Keftassa, (1990) found that the DM yield of Rhodes grass increased steadily up to 72–83 days of re-growth. Fathi, (2007) also reported that, nitrogen increases the photosynthetic capacity of growing plants, which enhances growth to produce adequate Dry matter yield.

CONCLUSION

The current study was conducted to evaluate the effect of biochar and in organic fertilizer on 50% flowering, 50% maturity, agronomic parameters (Plant height, leave length, number of tiller per plant and number of leaves per plant), biomass yield (fresh and dry matter yield) and seed yield of *Chloris gayana* and *Panicum coloratum*. Biochar in combined with inorganic fertilizer improved the agronomic parameters, seed yield and biomass yield of both grasses. Combined application of biochar at 5 t ha-1 with inorganic fertilizer 100kg ha-1 (T5) followed by application at 3 t ha-1 biochar and 40kg inorganic fertilizer (T4) has resulted in better agronomic parameters (plant height, leave length, number of tiller per plant and number of leaves per plant), phonological variables (50% flowering and 50%maturty), biomass yield and seed yield when compared to other treatments. Generally, the DM yield also increased with increasing age of re-growth and with increasing levels of N fertilizer. Therefore, biochar can be used as an alternative and/or in combination with inorganic fertilizers to improve productivity of grasses.

REFERENCES

Adugna, T, Alamayehu, K and Tesfamariam, W. 2006. The effect of nitrogen fertilization and cutting age on dry matter yield and protein content of Rhodes grass at Awassa, southern Ethiopia. *Tropical science*, *46*(2), pp.87-91.

Akililu, M and Alemayehu, M. 2007. Measurements in pasture and forage cropping systems. *Technical manual 18. Ethiopian Agricultural Research Institute*.

Alemayehu M. 1994. Fourth Livestock Development Project Report. Addis Ababa. Ethiopia.

Alemayehu, M and Getnet. A. 2012. The evaluation of forage seed production in Ethiopia. *Forage seed research and development in Ethiopia. Ethiopia institute of agricultural research, Addis Ababa, Ethiopia* :15-32.

Alemayehu. G, Diriba M, Fassil A, Solomon K, and Mariangela H. 2020. Biochar and Other Organic Amendments Improve the Physicochemical Properties of Soil in Highly Degraded Habita. *EJERS*, 5 (3):331-338

Armando, LV, Tomás, MA, Garibaldi, AF and Carrere, AD. 2017. Effect of pollination mode on progeny of *Panicum coloratum* var. makarikariense: Implications for conservation and breeding. *Tropical Grasslands-Forrajes Tropic ales*, *5*(3):117-128.

Bayu, D. Gezahagn, B. and Solomon, T. 2015. Characterization of biochar at different Temperatures and its Effect on Acidic Nitosol of Jimma, South, Ethiopia. *International Journal of Soil Science* 10(2): 63-73.

Burhan, H and Hago. TE. 2000. Principles of Crop Production. University of Khartoum Printing Press, Sudan (Arabic addition).

Chan, KY, Van Zwieten, I, Meszaros, A, Dowie and Joseph. 2007. Agronomic value of green west biochar as a soil amendment. *Aust. J. Soil Res,* 45 : 629-634.

Clough, TJ and Condron, LM. 2010. Biochar and the nitrogen cycle: introduction. *Journal of environmental quality*, *39* (4):1218-1223.

Denbela, H. 2015. Adaptation and evaluation of *Cenchrus ciliaris, Chloris gayana* and *Panicum coloratum* grass species on station of Jinka Agricultural Research Center, Jinka, Ethiopia. *Inter J Agri Biosci,* 4(6) :236-239.

Dennis, J and Kou, K. 2013. Evaluating the agronomic benefits of biochar amended soils in an organic system: results from a field study at the UBC Farm, Vancouver.

Dutta, S, Pal, R, Chakraborty, A and Chakrabarti, K. 2003. Influence of integrated plant nutrient supply system on soil quality restoration in a red and laterite soil: Einfluss integrierter pflanzennährst off versorgung auf die wiederherstellun der bodenqualität von rotem und laterit boden. *Archives of Agronomy and Soil Science*, *49*(6): 631-637.

Ecocrop. 2010. Ecocrop data base. FAO. Rome, Italy.

Getnet, A, Fekede, F and Abreham, G. 2003. Effect of manure and nitrogen fertilization on establishment, herbage yield and seed productivity of perennial grasses. Proceedings of the 10th annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, August 22-24, 2002.

Harper, JE. 1994. Nitrogen metabolism. In: Peterson, GA (ed)''Physiology and determination of Crop yield", ASA, SSSA, Madison, WI,pp. 285-302.

Imaz, JA, Giménez, DO, Grimoldi, AA and Striker, GG. 2013. The effects of submergence on anatomical, morphological and biomass allocation responses of tropical grasses *Chloris gayana* and *Panicum coloratum* at seedling stage. *Crop and Pasture Science*, *63*(12):1145-1155.

Jorge, MAB., van de Wou w, M. Hanson, J and Mohammed, J. 2008. Characterization of a collection of buffalo grass (*Cenchrusciliaris*). Tropical Grasslands, 42, pp.27-39.

Karta, K. 2012. Achievements and Directions of Forage Seed Research and Production in the Highlands of Arsi. *Forage Seed Research and Development in Ethiopia*, p.111.

Keftassa, D. 1990. Effect of developmental stage at harvest, N application and moisture
availability.

Kizima, JB, Mtengeti, EJ and Nchimbi, MS. 2014. Seed yield and vegetation characteristics of *Cenchrus ciliaris* as influenced by fertilizer levels, row spacing, and cutting height and season. *Livestock Research for Rural Development* Volume 26, Article#148.

Koech, OK. 2014. Comparative Evaluation of Six Indigenous Rangeland Grasses for Pasture Production Under Varying Soil Moisture Contents in Tana River County, Southeastern Kenya (Doctoral dissertation, University of Nairobi).

Koul, BG. 1997. Effect of Sowing Methods, Nitrogen Level and Seed Rates on Yield and

Quality of Fodder Maize (*Zea mays* L.). M.Sc Thesis. Faculty of Agriculture, University of Khartoum, Sudan.

Laidlaw, DH, Kirby, RM, Jackson, CD, Davidson, JS, Miller, TS, Da Silva, M, Warren, WH and Tarr, MJ. 2005. Comparing 2D vector field visualization methods: A user study. *IEEE Transactions on Visualization and Computer Graphics*, *11*(1):.59-70.

Li-li. H.E. Zhe-ke Z, Hui-minY, 2017. Effects on soil quality of biochar and straw amendment in conjunction with chemical fertilizers. J. itegrated agri. 16(2): 704-712

Miller, D.1994. *Forage crops*, McGraw-Hill.

Miles N & Manson AD 2000. Nutrition of planted pastures. In: Tainton NM (ed). Pasture management in South Africa University of Natal Press, Pietennaritzburg.

Murphy, S. 2010. Tropical perennial grasses – root depths, growth and water use efficiency. NSW Industry and Investment, Prime facts N° 1027.

Patil, VC, Al-Gaadi, KA, Madugundu, R, Tola, E, Marey, S, Mulla, D and Upadhyaya, S. 2016. Response of Rhodes grass to variable rate application of irrigation water and fertilizer nitrogen. *Pakistan Journal of Agricultural Sciences*, *53*(3).

Saarnio, S, Heimonen, K and Kettunen, R. 2013. Biochar addition indirectly affects N_2O

emissions via soil moisture and plant N uptake. *Soil Biology and Biochemistry*, *58*:99-106.

SAS, 2011. The Statistical Analysis System. Version 19, SAS Institute Inc., Cary

Skinner, RH, Moore, K J, and Barnes, RF. 2007. Growth and development of forage plants. *Forages, the Science of Grassland Agriculture*, *2*:.53-66.

Solomon, M. 2008. Forage development for sheep and goats. *In:* AlemuYami and R.C.

Merkel (Eds.). Sheep and goat production hand book for Ethiopia, Branna printing enterprise, Addis Ababa. Pp. 160-211.

Suárez-Abelenda, M, Kaal, J & McBeath, AV. 2017. Translating analytical pyrolysis finger-prints to Thermal Stability Indices (TSI) to improve biochar characterization by pyrolysis-GC-MS. *Biomass Bioenergy*. 98: 306–320.

Tarawal, SA. 1995. Methods for the evaluation of forage legumes, grasses and fodder trees for use as livestock feed (Vol. 1).ILRI (aka ILCA and ILRAD).

Tekleyohanes, B, Teshome, A, Bekele, M, Dawit, A, Solomon, B and Dagnachew W. 2004.Effect of season of grass establishment, Harvest time, seed rate and row spacing on seed yield and quality of perennial grass species page 368-372. *Proceedings of the 12th Annual conference of the Ethiopian Society of Animal Production (ESAP),* August 12-14, Addis Ababa, Ethiopia.

Tewodros M and Meseret M. 2013 Production Constraints, Farmers Preferences and Participatory on Farm Evaluation of Improved Forage Technologies in Selected Districts of Southern Ethiopia, *Greener Journal of Agricultural Sciences* 3 (9): 628-635.

Walter, R and Rao, BR. 2015. Biochar's influence sweet-potato yield and nutrient uptake in tropical Papua New Guinea. *Journal of Plant Nutrition and Soil Science*, *178*(3):393-400.

Xu, G, Li, Y, Sun, J, Shao, H and Wie, L. 2015. Recent advance in biochar application in agricultural soil, benefits and environmental implication. *CLEAN-soil, Air, water,* 40(10):1093-1098.

Yaman, S. 2004. Pyrolysis of biomass to produce fuels and chemical feedstocks. *Energy conversion and management*, *45*(5):651-671.

Yenesew, A, Tafere, M, Dagnew, S, Tolla, M and Gebre-Selassie, Y. 2015. Best fit practice manual for Rhodes grass (*Chloris gayana*) production. BDUCASCAPE.

Zelalem, A, Tekalign, T and Nigussie, D. 2009. Response of Solanum tuberosum L. to different rates of nitrogen and phosphorus fertilization on vertisols at Debre Berhan, in the central highlands of Ethiopia. *African Journal of Plant Science*, *3*(2): 016-024.

Zhang, X, Davidson, EA, Mauzer all, DL, Searching, TD, Dumas, P and Shen, Y. 2015. Managing nitrogen for sustainable development. *Nature*, *528*(7580), p.51.

Zheng, R, Chen, Z, Cai, C, Wang, X, Huang, Y, Xiao, B and Sun, G. 2013. Effect of biochar's from rice husk, bran, and straw on heavy metal uptake by pot-grown wheat seedling in a historically contaminated soil. *Bio Resources*, *8*(4):5965-59.

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