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Full Length Research

Effects of eucalyptus wood (*Eucalyptus globulus)* ash on biomass yield and nutritive value of elephant grass *(Pennisetum purpureum)* at Habru District, North Wollo Zone, Ethiopia

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ABSTRACT: The objective of this study was to determine the biomass yield and chemical composition of Elephant grass (*Pennisetum purpureum*) at two successive harvests using five levels of eucalyptus (*Eucalyptus globulus*) ash as a fertilizer. Thus, a 2 x 5 factorial experiment was used in a randomized complete block design (RCBD) with four replications. The factors considered were successive harvests (first harvest performed after 90 days of planting and second harvest after 70 days of first harvest), and five levels of eucalyptus ash (0.0, 0.5, 1.0, 1.5 and 2.0 kg/m^2). The highest plant height (2.5 ± 0.14 m) was recorded on plots to which a 2.0 kg/m^2 eucalyptus ash was applied. The highest mean value of tiller numbers per plant (41± 1.5), green biomass yield (GB) (5.8 ± 0.2 MT/ha) and CP contents (8.85 %) were significantly increased with an increase in the level of eucalyptus ash with increasing successive harvests. The highest mean dry matter yield (DMY) 6.2 ± 0.16 was attained at the first harvest which receives 2.0 kg/m^2 of eucalyptus ash. The highest mean value of ash (20.9 ± 8.4) was recorded at the two higher ash levels at the first harvest. However, the lowest mean value of NDF (53.3 ± 3.35) and ADF (40 ± 0) were recorded at the second harvest with the highest ash levels. All the fiber contents of the forage grass decreased with increase in successive harvests and amount of ash levels. It can be concluded that the second harvest and application of 2.0 kg/m^2 of eucalyptus ash improved yield and nutritive value of elephant grass.

Keywords: Elephant grass, eucalyptus, nutritive value, successive harvest, yield.

INTRODUCTION

Ethiopia is known as one of the largest livestock producer in Africa and in the world. This livestock sector has been contributing a considerable portion to the economy of the country, and still promising to rally round the economic development of the country. Despite this huge potential of livestock population and its diversity, the benefits obtained from this sector are low compared to other African countries and the world standard (Asfaw et al., 2011). According to Berhe (2010), the major gaps in the livestock sector are diseases, poor nutrition, unimproved genetic base, poor product handling and processing, socio-economic and market information and technology transfer. Among the major gaps, poor nutrition was the researcher's concern because of the major feed resources for livestock comes from natural pasture and crop residues. However, they are poor in quality and provide inadequate protein, energy, vitamins and minerals (Gemiyo et al., 2017). The other challenges that face the livestock producers in the Ethiopia were low adoption of improved forages and utilization system (Zekarias and Teshale, 2015).

The feed supply to animals can be improved by the cultivation of tropically adapted forage species, which give reasonable yield under drought and unstable climatic conditions. Elephant grass is an adaptable, vigorous, and highly productive and withstands considerable periods of drought which means, elephant grass has the potentioal of adaptability in different agro-ecology and is also highly productive as compared to other grass species. It rapidly recovers from stagnation of growth with the onset of rains after extended dry periods (Gemiyo et al., 2017). Elephant grass is palatable and could be fed fresh, as silage or directly grazed on the field (Kabirizi et al., 2015). Using the ash can prove to be a sustainable alternative supply of phosphors (P) to the agricultural systems (Cruz-Paredes et al., 2016). As it is versatile in nature, wood ash could be utilized along with liquid waste to boost its nutrient supply.

Planting of eucalyptus by poor households could contribute about 28% of the household’s income and more than 90% of wood source for household consumption (Mekonnen et al., 2007). Therefore, the aim of this study was to evaluate the effect of eucalyptus wood ash with different ratios and successive harvests on the nutritive value and yield performance of elephant grass.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Amhara regional state, North Wollo zone of Habru district. The study area is located in north eastern part of Ethiopia at 491 km far from Addis Ababa Ethiopia. The topography represents 40% plane, 30% mountain, 22% valley and 3% others. The mean annual temperature is 21.9°C and the means rainfall is 725 mm. The cultivating land of the study area covers 24,253 hectares. The economy of the district predominantly depending on crop production, followed by livestock production. The total livestock population in the study area is 257,904. Recently it has the total population of cattle 130,013, sheep 31,732, goat 72,751, equine 12,045, and camel 11,363. The main crops cultivated are sorghum, teff, wheat, maize, and fruits and vegetables (Gedefaw and Gebremariam, 2019).

Treatments and experimental design

An experimental site with a total area of 255 m^2 (15 m x 17 m) with a slope of 5 to 10% was used for the study. The site was plowed and thoroughly prepared before planting elephant grass (*Pennisetum purpureum*) cuttings. Then, the experimental site was divided into 4 blocks based on its gradient (slope) where each block had 5 plots with two successive harvests; thus, a total of 40 observations each with an area of 9 m^2 (3 m x 3 m) were prepared. There were 5 rows per plot and the distance between consecutive rows and plants within a row was 0.5 m (Kabirizi et al., 2015). The spaces between consecutive plots and blocks were 0.5 m and 1 m, respectively. The elephant grass cuttings were planted during the onset of the main rainy season. When the main rainy season terminated (end of September), supplemental furrow irrigation was used.

Two factors were used in the study: eucalyptus ash with five levels (0.0, 0.5, 1.0, 1.5 and 2.0 kg/m^2), and successive harvests (90 days after planting and 70 days after the first harvest). Therefore, the two-way factorial experiment (2 x 5) was arranged in a randomized complete block design (RCBD) where each of the 4 blocks accommodated the 10 treatment combinations, that is, 2 x 5 (Table 1).

Description of experimental materials

Eucalyptus (*Eucalyptus globulus*) was recommended by the Ethiopian Institute of Agricultural Research (EIAR) as it spread to the mild mid-latitude and the cool highlands of more than 2000 m.a.s.l. (Mesfin and Wubalem, 2014); ash used as fertilizer for elephant grass was collected from Woldia University Student Cafeteria. The fuel wood (*Eucalyptus globulus*) for the university in ordered to cook the food for the student is collected from the highland areas and it also designated as “nech baharzaf”.

The elephant grass (*Pennisetum purpureum*) used for planting was collected from the Mersa campus of Woldia University. Each cut of elephant grass having 3 nodes were planted at an angle of 30-45º where two of the nodes were covered under the soil and the third node was exposed to the surface (Kabirizi et al., 2015).

Soil analysis

Prior to laying out the experiment and planting the elephant grass, five composite soil samples were collected at 0 to 30 cm depth using auger to determine initial soil physiochemical characteristics. Each composite sample consisted of five samples taken along the diagonals and a transect line across the middle of the experimental area. Samples were air dried, ground, and passed through 2 and 0.5 mm sieves. The pH and soil organic carbon (SOC) were determined using the Walkley-Black method (Walkley and Black, 1934), and soil organic nitrogen (SON) was analyzed by the Kjeldahl method (Van Schouwenberg and Walinge, 1973) using the <0.5 mm fraction of soil at Sirinka Agricultural Research Center.

Experimental procedures

Before application, the ash was grounded and passed through a 2 mm sieve and thoroughly homogenized. It was

Table 1. Treatment combinations of the factors.

S/N	Treatment combinations	Factors	
		S = Successive harvest	A = Eucalyptus ash (kg/m^2)
1	S_1A_1	1	1
2	S_1A_2	1	2
3	S_1A_3	1	3
4	S_1A_4	1	4
5	S_1A_5	1	5
6	S_2A_1	2	1
7	S_2A_2	2	2
8	S_2A_3	2	3
9	S_2A_4	2	4
10	S_2A_5	2	5

S_1 = harvest at 90 days after planting; S_2 = harvest at 70 days after first harvest; A_1, A_2, A_3, A_4, and A_5 = eucalyptus wood ash at 0, 0.5, 1, 1.5, and 2 kg/m^2, respectively.

Table 2. Selected physiochemical properties of initial soil and chemical properties of eucalyptus ash.

Physiochemical properties	Values from initial soil sample	Values from eucalyptus ash
Electric conductivity (EC Ds/m)	0.03	0.3
pH	6.79	12.1
Organic C (%)	1.08	0.189
Available P (%)	0.613	0.431
TN (%)	0.378	0.252
Exchangeable Ca (mg/100g)	8.94	2.97
Exchangeable Mg (mg/100g)	11.2	3.54
Organic matter (%)	1.86	0.32

Where: TN –Total Nitrogen; mg – milligram.

analyzed for organic C, N, P, Ca and Mg and acid-neutralizing capacity (Table 2) following the procedures of Walkley-Black method (Walkley and Black, 1934) and ash organic nitrogen was analyzed by the modified Kjeldahl method in which the organic nitrogen was changed into ammonium by acid hydrolysis with H_2SO_4, together with reagents to raise the temperature and to hasten the rise of decomposition as catalysts. Seven days after planting the elephant grass, five rates of ash (0.0, 0.5, 1.0, 1.5 and 2.0 kg/m^2) were applied with reference to the recommendations made by Bonfim-Silva et al. (2015) for BRS Piatã grass in which ash of corn stubbles and eucalyptus wood was used as fertilizer. The five rates of ash were assigned randomly to each block using a random number table (Gomez and Gomez, 1984).

The elephant grass was harvested at two successive harvests to determine the biomass yield and quality parameters such that the first harvest was carried out at 90 days of planting (at an average height of 1 m) in which the grass was considered to have good nutritional value and biomass yield (Kabirizi et al., 2015). The second harvest was performed at 70 days after the first harvest.

The land was prepared by ploughing by ox and the available plant residues and weeds were removed. The experimental site was divided into 4 blocks against the slope where each block was divided into 5 plots. Thus, forty (2 x 5x 4) plots each with an area of 9 m^2 (3 m x 3 m) were prepared. The spaces between consecutive plots and blocks were 0.5 m and 1 m, respectively. There were 5 rows per plot and the distance between consecutive rows and plants within a row was 0.5 m (Kabirizi et al., 2015). Therefore, 30 cuttings of elephant grass were planted on each plot (6 cuttings per row).

Planting holes (pits) were dug out with an average depth of 30 cm. Ash was mixed with the top (up to 30 cm depth) soil in furrows and applied to the holes of the plots based on the required rate one day before planting. The weight of the different levels of ash was weighed by electronic sensitive balance identified as YP series precision balance (model YP 50001, the maximum and minimum balance were 5000 g and 1 g respectively and made in china) at Sirinka Agricultural Research Center (SARC). The elephant grass cuttings were planted during the onset of the main rainy season (July). Each cut of elephant grass having 3 nodes was planted at an angle of 30 to 45º where two of the nodes were covered under soil and the third node was exposed to the surface (Kabirizi et al., 2015). Weeding was carried out at two occasions: three weeks after planting and two weeks after the first harvest.

Agronomic data collection

Excluding the two outer most rows (to minimize border effect), the remaining three middle rows of each plot were used as sampling rows. The total dry matter yield was determined by taking fresh samples of 500 g of each plant parts (stem and leaf) which were taken from representative samples from harvestable middle rows. The samples were taken to Sirinka Agricultural Research Center (SARC) and Debre-Birhan Agricultural Research Center (DBARC) for drying using forced-air in a draft oven at a temperature of 65°C for 72 hours and for further analysis. Soil, eucalyptus ash and forage samples were ground and became ready for further analysis at SARC. Soil parameters (pH, SOC, and SON), and contents of eucalyptus ash (organic C, N, P, Ca, Mg, and acid neutralizing capacity) were analyzed at SARC; whereas, chemical analysis of the forage samples (DM, CP, ADF, NDF, ADL, and ash) was carried out at DBARC. The biomass yield, height, number of tillers, fresh weight and dry matter yield were measured at the two successive harvests.

Chemical analysis

The dry matter (DM), ash and nitrogen (N) contents were determined following the procedure of AOAC (1990). The nitrogen content was analyzed using Kjeldahl procedure where the CP was calculated as N x 6.25. The neutral detergent fiber (NDF), acid detergent lignin (ADL), and acid detergent fiber (ADF) were analyzed using the procedure of Van Soest and Robertson (1985). Organic matter was calculated as 100-ash.

Data analysis

The collected data were subjected to the analysis of variance (ANOVA) procedures of SAS computer package version 9.1 (SAS 2008). The least-squares means were generated using the LSMEANS option and were separated by the PDIFF option for treatments with significant effects at $\alpha = 0.05$ level of significance by employing Tukey's multiple comparison procedure. The results have been reported as LSMEANS with accompanying standard error (SE). The following statistical model has been employed in this study:

$$Y_{ijkl} = \mu + A_i + B_j + C_k + (AB)_{ij} + \varepsilon_{ijkl},$$

Where: Y_{ijkl} = the response variable, μ = overall mean, A_i = the i^{th} successive harvest effect, B_j = the j^{th} rate of ash effect, C_k = the k^{th} block effect, $(AB)_{ij}$ = the interaction between successive harvest and rate of ash, and ε_{ijkl} = the random error

RESULTS AND DISCUSSION

Morphological parameter of elephant grass

Plant height

The means value of plant heights of elephant grass (*Pennisetum purpureum*) are presented in Table 3. One of the main effects of eucalyptus (*Eucalyptus globulus*) ash rates is that it had a highly significant ($p<0.01$) effect on plant height, but the other main effect, successive harvest, and the interaction term have no significant ($p>0.05$) effect. The highest mean value was recorded on plots to which a 2.0 kg/m^2 eucalyptus ash was applied; whereas, the lowest mean plant height was obtained at the control group (plots to which ash was not applied). Generally, the increase in plant height was directly proportional to the rate of eucalyptus ash applied.

The significance level of 5% was noted for grass height among the different eucalyptus ash rates, adjusted to the LSD in the first and second harvests for comparison of means. During the first harvest, the 2.0 kg/m^2 rate induced the maximum height in the elephant grass, showing more than 95% increase compared with the treatment that was not fertilized with the eucalyptus ash. During the second harvest, the eucalyptus ash dose of 2.0 kg/m^2 induced the maximum plant height, producing a 47% increase compared with the treatment with no eucalyptus ash.

According to Risse (2010), due to its potential of liming effect, wood ash can increase plant height up to 45%. The liming potential of wood ash; improves plant growth by increasing the availability of nutrients such as phosphorus, calcium and magnesium to plants, and decreasing the availability of certain metals.

Wood ash as fertilizer supplied an appreciable amount of potassium to plants and the potassium enhances the activation of enzymes responsible for nitrogen assimilation, protein synthesis and synthesis of leaf starch (Meurer and Fernandes, 2006). This result might be due to the massive roots development and efficient nutrient uptake allowing the plant to continue increase in height. The result of the present study is in line with the findings of Bezerra et al. (2016), who reported that increased plant height and yield with increasing level of ash.

The rates that induced the maximum heights for each harvest were slowly increased at each stage of growth. Identical results were noted in a research in which the residual effect of the application of eucalyptus ash on the structural features of elephant grass was visible as stated

Table 3. Interaction effect of successive harvesting and eucalyptus ash on plant height and tiller number of Elephant grass grown.

Successive harvesting	Eucalyptus ash (kg/m2)	Plant height (m)	Tiller density (No/m^2)
	0	1.3^{d}	22^{d}
	0.5	1.9^{c}	26^{dc}
1st harvest (90 days after planting)	1	2.2^{bc}	28^{bc}
	1.5	2.4^{ab}	30^{ab}
	2	2.4^{ab}	32^{a}
	0	1.7^{d}	32^{d}
	0.5	1.8^{c}	34^{dc}
2nd harvest (70 days after 1st harvest)	1	2^{bc}	36^{bc}
	1.5	2.3^{ab}	41^{ab}
	2	2.5^{a}	41^{ab}
SE (±)		0.14	1.5
LSD (P <0.05)		0.19	3.13
CV (%)		14.2	9.6

^{a,b,c} Means in the same column followed by a common superscript letter at each successive harvest are not significantly different at 5% probability level; SE-Standard error; LSD- least significant difference; CV-Coefficient of variation.

earlier by Bonfim-Silva et al. (2015). Grass height, among others, is a significant feature that was evaluated to assess the productive potential of elephant grasses. Plant height is regarded as a structural characteristic, pertinent for adopting adequate management (Garay et al., 1997).

Wood ash has been frequently reported to be used as a fertilizer. Post burning, appreciable quantities of P, Ca, Mn and Mg (about 75%) have been confirmed in the residue (Ingerslev et al., 2011). The application of wood ash for the growth of tropical plants is advantageous as it minimizes the Al and Mn toxicity besides supplying the plants with nutrients (Nkana et al., 1998). The authors also emphasized that nutrient imbalance may occur in the soil so that appropriate correction is necessary by addition of nutrients, mainly those of N, P and K.

Number of tillers per plant

The main effects, successive harvests and level of eucalyptus ash had significant effect (p<0.01) on number of tillers per plant as presented at Table 3; however, the interaction of these terms has no significant (p>0.05) effect on number of tillers per plant. The highest mean tiller count per plant was observed at the second harvest that occurred 70 days after the first harvest. On the other hand, the highest tiller count per plant was recorded at 2.0 kg/m^2 ash level; while, the lowest tiller density was obtained at 0.0 kg/m^2 eucalyptus ash levels (Table 3). This indicated that the number of tillers per plant increased with an increase in repeated harvests as well as eucalyptus ash levels. The present result agrees with the result observed by others (Silsbury, 1966; Bonfim-Silva et al., 2015) who reported that increase in tiller number was due to longer days of maturity and the associated continuous increment in photosynthetic rate of the grass. Increased tiller numbers with increasing rate of ash indicate enhanced development of new shoots and the development of new tillers.

The present finding is also in line with the findings of Bonfim-Silva et al. (2011), who reported that application of optimal level of wood ash significantly affects the appearance of new tillers and increases the dynamics of tiller population of elephant grass. Moreover, the present result is also supported by the findings of Ajala et al. (2017), who reported that wood ash generates the activation of dormant buds and enhances the vegetation sward filling through the highest rate of tiller replacement which supports a higher proportion of very active healthier young tillers for each plant, which results in higher tiller density and consequently increases biomass production.

Dry matter content

Dry matter (DM %) content of elephant grass was significantly affected (p<0.01) by successive harvests and eucalyptus ash application; however, it was not influenced (p>0.05) by their interaction effect. The highest mean dry matter yield recorded was at the first harvest. Regarding the ash levels, there was significant variation among all levels of ash applied in their effect on DM content of elephant grass such that a significantly higher value of DM was obtained from samples produced with application of 2.0 kg/m^2 ash than at the rest ash levels, followed by the second lower level of ash (1.5 kg/m^2), and declined so on correspondingly (Table 4). This indicates that as frequency of harvesting increased, DM yield inversely decreased.

Table 4. Interaction effect of successive harvesting and eucalyptus ash on DM and green biomass yield of elephant grass.

Successive harvesting	Eucalyptus ash (kg/m2)	DM yield (%)	Green biomass yield (MT/ha)
1st harvest (90 days after planting)	0	3.5^{e}	2.8^{c}
	0.5	4.1^{d}	3.2^{bc}
	1	4.6^{c}	3.4^{b}
	1.5	5.5^{b}	3.9^{a}
	2	6.2^{a}	4.3^{a}
2nd harvest (70 days after 1st harvest)	0	2.6^{e}	3.8^{c}
	0.5	2.9^{d}	4.4^{bc}
	1	3.2^{c}	5^{b}
	1.5	3.5^{b}	5.8^{a}
	2	3.9^{a}	6.7^{a}
SE (±)		0.16	0.2
LSD (*P* <0.05)		0.32	0.25
CV (%)		7.8	8.97

[a,b,c] Means in the same column followed by a common superscript letter at each successive harvest are not significantly different at 5% probability level; SE-Standard error; LSD- least significant difference; CV-Coefficient of variation.

This was due to the reason behind that the removal of above ground growth will limit the capacity of the grass to photosynthesizes, leading to lacking of carbohydrate for root and rhizome development, as the grass will use up most of the carbohydrate produced (Turgeon, 2008; Fung et al., 2018).

However, DM yield was linear with the increasing of eucalyptus ash application. This is because the tendency of ash to stimulate N-mineralizing microbes when applied to the soil can increase N supply to plants, resulting in increase in DM yields (Augusto et al., 2008; Huotari et al., 2015).

On the other hand, increasing ash fertilizer rate leads to increasing dry matter accumulation by supplying a better level of P. According to Sárdi et al. (2012), the better levels of P supply had a beneficial influence on K uptake and K concentrations in plants. During the uptake of K^+, root may exchange another cation such as H^+ for K^+, or it may absorb an anion such as NO^{3-} or $H_2PO_4^-$ in order to maintain the electrical balance in cells.

The present result is supported by the findings of Bezerra et al. (2016), who reported that the highest wood ash application had significant effect on DM yield in the case of elephant grass when compared to the treatment without fertilization. This result also agrees with the result obtained by Santos (2012), who found overall mean forage dry matter yield increase with increasing level of ash application. The present result also agrees with the findings of Pavla et al. (2017) who reported that DM yield, nutrient content of the soil and nutrient uptake by the grass increased with application of wood ash in various forms to the soil.

Green biomass

Higher total green biomass yield ($p<0.01$) was observed on plots to which a 2.0 kg/m^2 eucalyptus ash was applied; whereas, the lowest mean green biomass yield was obtained at the control group. However, the interaction of the main effects has no significant ($p>0.05$) effect on green biomass yield of elephant grass (Table 4). The significantly ($p<0.01$) highest biomass yield of elephant grass recorded at the highest ash rate might be due to the fact that the application of increased levels of eucalyptus ash presumably increased the availability of soil P which might have enhanced the meristemtic growth and resulted in higher forage yield. Arshad et al. (2012) indicated that higher soil pH subsequently increased the solubility of P provided through wood ash, all of which consequently provoked an improved grass yield.

The present findings are in line with the results of Rodríguez et al. (2019), who stated that the mean green biomass yield has increased ($p<0.05$) when the level of ash application increased from the control to higher wood ash levels. The author also concluded that the improved grass yield was dose-dependent of wood ash and can be related to increased N, P, and K, as well as to increased soil pH. It is apparent that elephant grass green biomass production in the present experiment was the highest (6.7 ± 0.2 MT/ha) at the second successive harvests with the level of 2.0 kg/m^2 ash as compared to the control group (2.8 ± 0.2 MT/ha) and (3.8 ± 0.2 MT/ha) at the first and second successive harvests respectively.

The result indicated that the effect of wood ash application on green biomass yield of elephant grass at

Table 5. Mean (± SD) of Crude Protein (CP %) content of elephant grass at successive harvests and different levels of Eucalyptus ash application.

Eucalyptus ash (kg/m^2)	Successive Harvests		
	1st harvest (90 days after planting)	2nd harvest (70 days after 1st harvest)	Grand mean
0	7.8^b±0^1	8.3^b±0^1	8.07±0.73
0.5	7.07^e±0^1	7.57^e±0^1	7.3±0.73
1	7.82^a±0^1	8.85^a±4.2^1	8.3±0.73
1.5	7.1^c±4.2^1	8.4^c±0^1	7.75±0.73
2	6.47^d±2.1^1	8.57^d±0^1	7.5±0.73
Over all mean	7.26	8.34	

^{a,b,c} Means in the same column followed by a common superscript letter are not significantly different at 5% probability level; ^{1}Standard deviation.

different successive harvesting was statistically significant (p>0.05). These results are in agreements with the findings of Pavla et al. (2017), indicated that application of wood ash in different forms and with different amendments resulted in significantly (p>0.05) higher total biomass yield production compared to the control treatment.

Chemical composition

Crude protein content

The crude protein (CP) contents of elephant grass (*Pennisetum purpureum*) recorded in the current study are presented in Table 5. The analysis of variance showed that the main effects, successive harvests and eucalyptus (*Eucalyptus globulus*) ash application had a highly significant (p<0.01) effect on CP content. The highest mean value of CP was recorded at the second harvest that occurred 70 days after the first harvest on plots to which a 1.0 and 2.0 kg/m^2 eucalyptus ash were applied; whereas, the lowest mean CP content was obtained at the first harvest that occurred 90 days after planting on plots to which a 2.0 kg/m^2 eucalyptus ash was applied. The result indicates that as the level of eucalyptus ash application increases and as frequency of harvest increased; the CP content also increased. This might be due to the fact that continued ash application levels allowed continuous sprouting of the vegetation, which was a bit fresh even during harvest of forage biomass. The present result agrees with that of Bernes et al. (2008), Ansah et al. (2010) and Shedrack (2017), who noted that the CP content of grass showed a decreasing trend significantly with increase in harvesting days and increasing with the addition of wood ash. The higher CP content from pastures early harvested than late harvested herbage is expectable in that CP content of pastures generally declines with maturity.

The result obtained in this study is also in agreement with those reported by Ashagre, (2008) and Muhammad et al. (2010), who indicated the decline in CP content of the pasture along with decreasing of successive harvests. According to Turgeon (2008), reducing the frequency of successive harvesting leads the grass to accumulate more nutrients. This results the to dilution of the CP content by an increasing amount of structural carbohydrates at lower frequency of harvest.

Neutral detergent fiber

The main effect of successive harvests (p<0.01), eucalyptus ash (p<0.01) and their interaction (p<0.01) significantly affected the NDF content (Table 6). The highest mean record was at the control plot and at the first harvest, and the lowest mean value was recorded at the highest ash fertilizer rate (2.0 kg/m^2) and at the second harvest. In this study, NDF significantly increased (p<0.01) with the increased date of successive harvests of the grass at all levels of fertilizer rate. This study is in line with that of Turgeon (2008) and Fung et al. (2018), who reported that decreasing NDF content with increasing of successive harvests of forage grass.

Additionally, the present study found that the NDF value decreased as the ash fertilizer rate increased from the control to the highest ash rate (2.0 kg/m^2). This study is in line with that of Ashagrie (2008), Agbede and Adekiya (2012), and Bonfim-Silva et al. (2015), who reported that decreased NDF content with increasing of ash fertilizer rate.

Meissner et al. (1991) reported that the threshold level of NDF that affects dry matter intake of forage is ≤ 60% beyond which voluntary feed intake is decreased and rumination time increased. Likewise, Barton et al. (1976) reported that NDF of tropical grass values that affect dry matter intake is 66.2%. The NDF content of the grass in the present study in the control (no fertilizer) and treatment to which ash fertilizer was applied at the rate of 0.5 kg/m^2 were around the tropical grass average value that is known to affect voluntary feed intake, except at 1.0 and 2.0 kg/m^2

Table 6. Interaction effect of successive harvesting and eucalyptus ash on fiber contents of elephant grass.

Successive harvesting	Eucalyptus ash (kg/m2)	Fiber content of the feed		
		NDF (%)	ADF (%)	ADL (%)
1st harvest (90 days after planting)	0	64.4^{a}	48.7^{a}	11.3^{a}
	0.5	63.2^{b}	46.7^{b}	10^{b}
	1	61.1^{c}	46.7^{b}	9.5^{c}
	1.5	60^{d}	44.4^{c}	10^{b}
	2	60^{d}	44.4^{c}	9.5^{c}
2nd harvest (70 days after 1st harvest)	0	60^{a}	45.5^{a}	10^{a}
	0.5	60^{a}	44.5^{b}	11.3^{b}
	1	55.5^{b}	42.2^{c}	9.5^{c}
	1.5	60^{a}	44.4^{b}	8.6^{d}
	2	53.3^{c}	40^{d}	10^{a}
SE (±)		0.49	0.37	0.1
CV (%)		5.2	5.2	6.7

^{a,b,c} Means in the same column followed by a common superscript letter at each successive harvest are not significantly different at 5% probability level; SE-Standard error; CV-Coefficient of variation.

of ash amended, which is slightly below the tropical grass average value, indicating that high level of fertilizer is required to significantly reduce NDF in forage grass.

Acid detergent fiber

The main effect of successive harvests and eucalyptus ash fertilizer rates and their interaction varied significantly ($p<0.001$) among the treatments (Table 6). The highest mean recorded was at 90 days of harvesting and 0.0 and 0.5 kg/m^2 ash amended plots and the smallest was at 70 days of harvesting and 2.0 kg/m^2 ash fertilizer rates. The results obtained also showed a linear increase in ADF content with a corresponding increase in days of harvesting ($p<0.001$), but as level of ash increases, ADF content decreases.

The absence of significance under the effect of eucalyptus ash levels at the first harvest that occurred 90 days on plots to which a control and 0.5 kg/m^2 eucalyptus ash might be the results of superior effect of extended date of successive harvests over the effect of eucalyptus ash application in the rate of structural carbohydrate accumulation. This might be due to an increase in ADF concentration and an increase in cell wall lignification with prolonged date of successive harvests (Gebrehiwot et al., 1996).

The present study is in line with the findings of Lounglawan et al. (2014), Afriyie (2016) and Shedrack (2017), who stated that the ADF content of elephant grass was significantly influenced by wood ash application rates and increased wood ash levels significantly decreased ADF content both with in the same and different days of harvesting.

Acid detergent lignin

The ADL contents observed for main effect of successive harvests ($p<0.001$), ash application and the interaction term ($p<0.01$) have shown highly significant difference (Table 6). The highest mean value was recorded at the first harvest that occurred 90 days after planting at the control group (plots to which ash was not applied); whereas, the lowest mean ADL value was recorded at the second harvest that happened 70 days after the first harvest on plots to which a 1.5 kg/m^2 eucalyptus ash was applied. This is because the ash promotes the growth of new leaves and shoots resulting in low lignin. Lignification of the grasses appeared to occur almost constantly with increase in harvesting days.

This might be due to the fact as the harvesting date increases, there is a greater increment of plant structural tissue, which results in higher structural carbohydrates and lignin contents; which are highly resistant to chemical and enzymatic degradation and are not appreciably broken down in the rumen digestive tract (Ranjhan, 1993). The present result is in line with the findings of Abdi (2014), Bharat et al. (2015) and Afriyie (2016), who stated that lignin content increased as the number of days in successive harvests became longer but decreased as wood ash levels increased.

Total ash

Ash application rates has highly significant ($p<0.01$) effect, and similarly, successive harvests and the interaction term has significant ($p<0.01$) effect on total ash content of elephant grass (Table 7). The highest mean total ash

Table 7. Mean total ash (%) yield of elephant grass at successive harvests and different levels of eucalyptus ash application.

Eucalyptus ash (kg/m^2) (A)	Successive harvests (days) (B)	
	1st harvest (90 days after planting)	2nd harvest (70 days after 1st harvest)
0	$17.4^d \pm 0^3$	$8.7^d \pm 0$
0.5	$18.5^c \pm 8.4^3$	$18.7^b \pm 0$
1	$19.6^b \pm 0^3$	$20.7^a \pm 0$
1.5	$20.9^a \pm 8.4^3$	$20.7^a \pm 0$
2	$20.9^a \pm 8.4^3$	$17.4^c \pm 0$
Grand mean	18.3 ± 3.5^3	
CV (%)	19.1^1	
Significance of contrasts		
A	s^2	
B	s^2	
AxB	s^2	

[a,b,c] Means in the same column followed by a common superscript letter are not significantly different at 5% probability level; [1]Coefficient of variation;[2] Significant at 1% significance level; [3] Standard deviation. Contrast: A = Main effect of eucalyptus ash; B = Main effect of successive harvest; AB = Interaction between ash and harvests.

content was recorded at the first harvest that occurred 90 days after planting on plots to which a 1.5 and 2.0 kg/m^2 eucalyptus ash was applied; whereas, the lowest mean ash value was obtained at the control group (plots to which ash was not applied). The total ash content increased as days of successive harvests increased as well as level of eucalyptus ash increased. This might be due to decline in total ash content of forages which brings about earlier dilution and translocation of different minerals associated with vegetative portion of leaf at increased date of successive harvests (Maynard et al., 1981). In this study, eucalyptus' effect as at different successive harvests on total ash content was significant ($p<0.001$).

This result agrees with studies of Kanak et al. (2012), who reported increased trend of total ash content as the increasing date of successive harvests. The present result of total ash increases as level of wood ash fertilizer increases agrees with that reported by Lindvall et al. (2015) who noted increased total ash content as a result of an increase in the level of ash application. As a result, ash application sustains and replaces early dilution and translocation of ash nutrients to root of plants.

Conclusions

As the eucalyptus ash levels and days of successive harvests increased the morphological traits such as plant height, number of tillers per plant, DM yield, and green biomass of the elephant grass increased as well. The DM yield obtained between successive harvests and eucalyptus ash levels had a major difference. The data recorded from weighing of the forage samples for the different successive harvests indicated that highest mean DM yield of 6.2 and 5.5 ton ha^{-1} were attained at the first successive harvests on plots to which a 2.0 and 1.5 kg/m^2 eucalyptus ash were applied, respectively. Here, it can be conclude that:

1. Successive harvest results more plant population and consequently increased tiller number per plot and resulted higher biomass yield.
2. Increased eucalyptus ash level also increased number of leaves and promotes good plant growth, which leads to higher biomass production with improved forage quality (reduced fiber contents).
3. Cultivation of improved forage using eucalyptus ash as a fertilizer under optimum days of successive harvesting system increases average biomass yield and nutritive values of the grass.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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