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ORIGINAL ARTICLE

Effect of nps fertilizer and harvesting stage on biomass yield and quality parameters of bracharia grass under supplementary irrigation in Southern Ethiopia

D. Mijena[1*], B. Mekete[2], A. Getiso[1]

[1]*Ethiopian Institute of Agricultural Research, Wondogenet Agricultural Research Center, P.O. Box 198, Shashemene, Ethiopia*

[2]*Department of Animal Science, School of Agriculture, Ambo University, P.O. Box 19 Ambo, Ethiopia*

**Corresponding author E-mail: hiliif@yahoo.com, jibatdm@gmail.com*

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This experiment aimed to evaluate the effect of NPS fertilizer and harvesting stage on biomass yield and quality parameters of Bracharia grass under supplementary irrigation. The study was conducted at Wondogenet Agricultural Research Center in a factorial arrangement of randomized complete block design with three replications using two factors (five NPS fertilizer levels:0, 50, 100, 150, and 200 Kg/ha and four harvesting stages: 45, 60, 75, and 90 days). Data were collected on biomass yield and quality parameters at each harvesting stage, weighed (for yield estimation), dried, and then ground subsamples taken for analysis of crude protein, ash, dry matter (DM), fiber contents, and *in vitro* dry matter digestibility (IVDMD) using a calibrated NIRS (Foss 5000 apparatus and Win ISI II software). The collected data were subjected to a general linear model for a statistical analysis system (SAS). The result indicated that DMY, CPY, DDMY, and ME yields were increased with increasing NPS fertilizer and extended harvesting stages. Crude protein concentration, IVDMD, and IVOMD were increased with increasing NPS fertilizer but decreased with the delayed harvesting stage. The neutral detergent fiber was also increased with the extended harvesting stage but decreased as NPS fertilizer increased. Based on DMY, CPY, and economic feasibility, a combination of 150 Kg/ha NPS fertilizer at 90 days stage could be recommended for the study area and similar agroecology. But, further study is needed on harvesting frequency to confirm the current finding.

Keywords: Bracharia grass, Biomass yield, Harvesting stage, NPS fertilizer.

Introduction

Livestock production is one of the most important activities in Ethiopia, and natural pastures are the main feed source for Ethiopian livestock. This results in lower production and productivity of livestock than that in intensive or semi-intensive systems, where animals are restricted and are fed with improved forages and concentrates. In Ethiopia, livestock production today almost exclusively requires improved forages like Bracharia grass.

Bracharia grass is a source of feed for most ruminants and is found to be one of the most preferred types of grass favored by livestock, and is the most important tropical forage crop. It is widely used in cut-and-carry feeding systems and is of growing importance in other agricultural systems. It is a high-quality forage that provides additional feed choices to forage growers and assists to link the livestock feed supply gaps, particularly at the time of dry seasons, and generates income for livestock farmers. Bracharia grass possesses many desirable characteristics, including high yield per unit area, tolerance to intermittent drought, and high water use efficiency, making it a forage of choice. It can withstand repeated cutting and will regenerate, producing palatable leafy shoots. In addition, Bracharia grass protects soil from erosion and sustains its productivity (Mundia, 2021).

Most of the species and varieties of Bracharia grass that have been developed are resistant to Napier grass stunt and smut disease affecting Napier grass varieties in Eastern Africa (Ghimire et al. 2015; Maass et al. 2015). It is well adapted to drought, diseases, and low-fertility soils, withstands heavy grazing, and sequesters carbon through its large roots system with enhanced nitrogen use efficiency and minimized greenhouse gas emissions (Arango et al. 2014; Moreta et al. 2014). Brachiaria plays important role in soil erosion control and ecological restoration. Moreover, grass has a high dry matter yield potential (Rodrigues et al. 2014).

Feed availability and quality are the two major factors limiting livestock production and productivity in Ethiopia, especially during the dry season (Shapiro et al., 2015) and for the sustainable solution to periodic shortages in feed availability and nutritive value, cultivating improved forage varieties with better management practices and supplementation of irrigation during the dry season is highly required. When livestock is fed with high-quality improved forage crops grown with the help of irrigation, they significantly increase milk yield and meat, benefiting the nutritional health of their keepers and consumers (Adie and Blummel, 2019). Management of forage crops through optimum fertilizer levels and appropriate harvesting stages will give improved productivity and reasonably good quality. This study assessed the effect of NPS fertilizer and harvesting stage on the productivity and nutritional quality of Bracharia grass using supplementary irrigation.

Materials and Methods

Description of the study area

The experiment was conducted in August 2020 to June 2021 at Wondogenet Agricultural Research Centre, 263 km southeastern of Addis Ababa, and 13km from the nearest town Shashemene (Belay, 2016). It is located within the geographic coordinates of 7°06′N to 7°11′N latitude, and 38°05′E to 38°07′ E longitude (Fig. 1) (Betru, 2006). The climate of the area is characterized by two rainy seasons, a long rainy season from June to September and a short rainy season from March to May. The total annual rainfall range is between 800 mm to 1780 mm (Belay, 2016). On the other hand, the average annual temperature varies between 11°C and 26°C. In most parts of Wondogenet area, the Midland (sub-tropical) agro-climatic type prevails. The research was conducted on sandy clay loam soil type with pH 8.84 (1:2.5 soil water suspension) and 0.18 of total nitrogen (Yirgu et al., 2017).

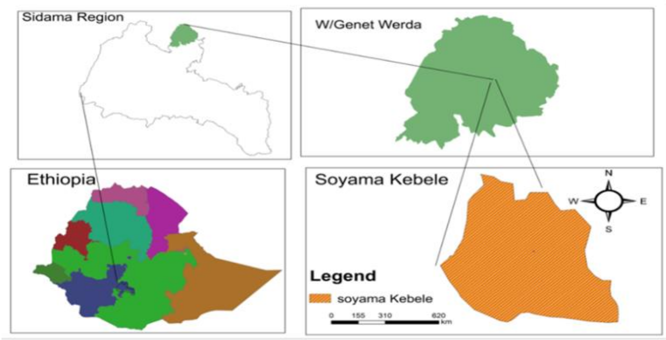

Fig. 1. Map of the study area.

Establishment of the experiment

The experiment was a 5 × 4 factorial in a Randomized Complete Block Design (RCBD) with three replications. High-yielding Bracharia grass (Bracharia Mulato II) root stalk was planted on well-prepared soil under rainfed conditions. The treatments were five NPS fertilizer applications (0, 50, 100, 150, and 200 Kg/ha) and four harvesting stages (45, 60, 75, and 90 days after total clearing). The plot size was 3 m × 2.1 m with 1.5 and 1 m between replications and plots and 30 and 60 cm between plants and rows, respectively. Di-ammonium phosphate fertilizer (DAP) was applied during planting at 100 Kg/ha for establishment as recommended. NPS fertilizer was applied according to the treatment setup after total clearing was done at sixteen weeks of planting. Other agronomic practices were carried out uniformly according to the need of the crop. At the second harvest, 50 Kg/ha Urea was applied equally to all plots as a top dressing.

Measurements

Harvesting was done two times at the first and the second harvest after total clearing. For the determination of biomass yield, each plot at the fixed harvesting stage was harvested in a randomly laid quadrant of 1m by 1m area from the entire rows leaving out border rows. The weight of the total fresh biomass yield was recorded from each plot in the field and a 500g sub-sample was taken from each plot to the laboratory to determine the total dry matter yield (DMY).

Crude protein yield (CPY) is the amount of crude protein harvested, expressed in terms of t/ha, estimated by multiplying the estimated DMY with the crude protein content of the herbage.

CPY=[DMY (t/ha) × CP (%)]/100

Digestible dry matter yield (DDMY) was calculated by multiplying DMY (t/ha) by IVDMD (%). There are several techniques for determining the digestibility of forage crops. In all the techniques, be it *invitro* or *invivo*, the final estimation of digestibility is based on the following formula.

DDMY**=**Total DMY × IVDMD%

DMY, CPY, and digestible DMY presented in this paper were the mean of the two harvests.

To determine the chemical constituents of the sample, samples collected from the first and the second harvesting cycle were bulked and ground to pass through the lmm sieve. Near-Infrared Reflectance Spectroscopy (NIRS) was used to analyze the samples. The NIRS instrument used was a FOSS Forage Analyzer 5000 with the software package Win ISI II. The samples were analyzed on a percentage DM basis for ash, crude protein concentration, neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), IVDMD, and *invitro*-organic matter digestibility using a calibrated NIRS (Foss 5000 apparatus and Win ISI II software). The metabolizable energy (ME) content was estimated from IVDMD as suggested by AOAC (1980) using the following equation.

ME (MJ/kgDM)=0.17 IVDMD%-2

Feasibility cost analysis

Feasibility cost benefit is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. Information on all charges of production including fertilizer purchase and labor expenses was collected. The price of fresh Bracharia grass was esteemed by farmers on a field with a fixed plot area and after price estimation, the forage in the fixed area was harvested, weighed, and dried to convert to DM basis in kilogram per hectare. Benefits (income from selling the grass) are also calculated on a hectare basis in birr based on the estimated local price. DMY obtained as the combined mean of the two harvests was used to calculate gross income from the grass. The total cost, gross income, net benefit, and benefit-cost ratio of all treatments were calculated as follows:

- Total cost=Total variable cost+Total fixed cost.
- Total variable cost=Fertilizer cost.
- Total fixed cost=Cost expended from planting to the end of the experiment.
- **Gross income (GI)**: Income from the sale of the grass. Considering the local market sale prices of Bracharia grass (1kg=4.25 birrs) on a dry matter basis.
- **Net Benefit (NB)**: was calculated as the amount of money left when the total costs (TC) for each treatment were deducted from the gross income (GI).
- Benefit-cost ratio=Gross income/Total cost.

Statistical data analysis

All collected data were statistically analyzed using the procedure outlined for a factorial experiment in a randomized complete block design using the General Linear Model (GLM) procedure of the SAS statistical computer package version 9.4. Data on yield and quality parameters were subjected to analysis of variance (ANOVA). LSD test at 5% significance was used for the comparison of means. The statistical model for the data analysis was:

$Yijk=\mu+Fi+Hj+(FH)ij+\beta k+eijk$

- Where, Yijk=the response variable (forage yield and chemical composition value),

- μ=grand mean,
- Fi=the factor effect of fertilizers (i=0, 50, 100, 150, and 200 NPS Kg/ha),
- Hj=the factor effect of harvesting stage (j=45,60,75, and 90 days),
- (FH)ij=the ijth interaction effect (Fertilizers x harvesting stage) on the response variables
- βk=the block effect (k=1, 2, 3), and eijk=the random error

Results and Discussion

Effect of NPS fertilizer, harvesting stage, and their interaction on biomass yield of Bracharia grass

The effect of NPS fertilizer, harvesting stage, and their interaction on biomass yield of Bracharia grass under supplementary irrigation was indicated in Table 1. The biomass yield of the grass was influenced by the main effect of NPS fertilizer, the harvesting stage, and their interaction.

Dry matter yield (DMY)

Except for 45 days harvesting stage, NPS fertilizer, harvesting stage, and its interaction had a significant (P<0.01) effect on the DMY of Bracharia grass. DMY of Bracharia grass was significantly increased in response to increasing NPS fertilizer and delayed harvesting stage. The highest DMY was recorded from 150 and 200 Kg/ha NPS fertilizer application combined with 90 days of harvesting stage while the least was from 50 and 0 Kg/ha NPS fertilizer at 45 days and 45-and 60-days harvesting stage, respectively.

The significant increase in DMY with the increase of NPS fertilizer could be attributed due to the availability of macronutrients and some secondary nutrients formulated with the blended fertilizer, which could increase the vegetative growth and consequently the biomass of yield. This occurred because, an increased concentration of fertilizer can increase the nitrogen uptake and this increase has a positive effect on chlorophyll concentration, photosynthetic rate, leaf expansion, the total number of leaves, and DM accumulation (Najm et al., 2010). Similarly, the application of phosphorus fertilizer also gradually increased plant height, stem diameter, number of leaves per plant, leaf area per plant, and fodder yield (Mahmood et al., 2003). The report of Tessema et al. (2010b) also reveals that the DMY of the grass component increased as the level of nitrogen fertilizer increased.

The higher DMY at later stages of harvesting was to be expected as plants were a physiological trigger, which leads to the increased production of tillers and more leaves per plant. All these characteristics would contribute to increased photosynthetic activity and hence higher DM production. The yield increase might be due to the extra tillers advanced, which resulted from an increase in leaf development, leaf elongation, and stem expansion (Nguku et al., 2016; Asmare et al., 2017). The outcome of the current investigation was supportive of the finding of Hare et al., (2013); Ondiko et al., (2016) report, the highest DMY was observed at the last harvesting stage on wild Bracharia grasses in different countries. Similarly, Tessema et al. (2010a); Feyissa et al. (2014); Asmare et al. (2017) report highest DMY was produced from cultivated grasses and natural pastures as harvesting stages were delayed. The mean (8.22 t/ha) DMY obtained from this study was comparable with the finding of Adnew et al. (2019) and Tadesse et al. (2021) were 10.38 and 9.18 t/ha from Bracharia grass in Ethiopia. Similarly, Mutimura and Everson (2012) also reported 8.30 t/ha in Rwanda which was also comparable with the current finding. But, the current value was lower than the finding of Yiberkew et al. (2020) was 14.59 t/ha DMY for Bracharia grass in Ethiopia.

Crude protein yield (CPY)

NPS fertilizer, harvesting stage, and their interaction had a highly significant (P<0.01) effect on the CPY of Bracharia grass. The result of this study showed that CPY increased with increasing fertilizer levels and extended harvesting stages. The highest CPY was recorded from 150 and 200 Kg/ha NPS fertilizer harvested at 90 days after total clearing while the smallest was from the control group at the 45 and 60 days harvesting stages.

The reason CPY increased as NPS fertilizer increased might be that plants take up the bulk of nitrogen early in the growth stage, which results in high CP content; this, in turn, increased CPY of grass as an application of NPS fertilizer rates increased. As the amount of available nitrogen in the soil decreases, the plants' rate of uptake cannot keep pace with their rate of growth. This results in the dilution of available protein over a greater amount of DMY, resulting in decreased protein content; this, in turn, decreased the CPY of grass as application rates of NPS fertilizer decrease. On the other hand, CPY increased as harvesting age was delayed, the reason may be due to as plants matured, the dry matter content of grass was higher, resulting in an increased DMY; this, in turn, increased CPY of grass at late days of harvesting due to the CPY is mathematically derived from the DMY.

The present study indicated that the CPY was lowest at early harvesting days due to lower DM concentration and higher water content in the plant tissues resulting in lower DMY, which contributed to the lower CPY. In line with the current finding Bayble et al. (2007) and Kefyalew et al. (2020) also reported an increasing trend in CPY with extended days of harvesting in the case of Napier and Desho grass, respectively. The CPY mean (0.82) obtained in this study was lower than the finding of Adnew et al. (2019) and Yiberkew et al. (2020) was 1.32 t/ha and 1.18 t/ha for Bracharia grass in Ethiopia. The variation in the findings could be due to environmental conditions such as soil, temperature, moisture, management systems, type of fertilizer application, and management systems.

Digestible dry matter yield (DDMY)

The result of this study indicated that all NPS fertilizers had a significant ($P<0.001$) effect at each harvesting stage on the DDMY of Bracharia grass. Regarding the harvesting stage, each harvesting stage had a significant ($P<0.05$) effect at all NPS fertilizer levels on the DDMY of the grass. The current analysis shows that the highest DDMY was recorded from 150 and 200 Kg/ha NPS fertilizer at 90 days of the harvesting stage while the lowest was from 50 Kg/ha at 45 days of the harvesting stage and the control group at 45-and 60-days harvest after total clearing.

The reason for the increment of DDMY with increasing fertilizer and harvesting time may be due to increased DMY (hence DDMY is derived from the DMY) with a level of fertilizer and harvesting time and also nitrogen fertilizer increases leafiness and digestibility of plants. On the other hand, an increasing trend in DDMY as the age of plants advanced might be due to the function of DMY and DM concentration in the plant tissue and also a decline in leaf to stem ratio. The current result that DDMY increased as the application of NPS fertilizer increased is in line with Waramit (2010) who reported increased DDMY of grasses with increased nitrogen fertilization during the early vegetative stages.

Table 1. Interaction effect of NPS fertilizer and harvesting stage on biomass yield of Bracharia grass.

Parameters	NPS (Kg/ha)	Factors: Harvesting stage (d)				Mean	SE	SL
		45	60	75	90			
	0	3.40^{j}	4.47^{ij}	6.41f	9.30^{d}	5.90	0.34	***
	50	4.20^{ij}	5.90^{fgh}	8.07^{e}	9.66^{cd}	6.96	0.45	***
	100	4.80^{i}	6.13^{fg}	9.37^{cd}	13.18^{b}	8.37	0.38	***
DMY	150	4.97^{hi}	6.43^{f}	10.20^{cd}	17.19^{a}	9.70	0.04	***
	200	5.12^{ghi}	7.65^{e}	10.41^{c}	17.49^{a}	10.17	0.23	***
	Overall mean	8.22						
	CV (%)	8.08						
	SL	***						
	0	0.35^{i}	0.41^{hi}	0.52^{gh}	0.74^{e}	0.50	0.04	***
	50	0.49^{gh}	0.54^{g}	0.74^{e}	0.87^{d}	0.66	0.05	**
	100	0.60^{fg}	0.59^{fg}	0.89^{d}	2.51^{b}	0.83	0.04	***
CPY	150	0.68^{ef}	0.68^{ef}	1.06^{c}	1.67^{a}	1.02	0.07	***
	200	0.71^{ef}	0.80^{de}	1.09^{c}	1.73^{a}	1.08	0.04	***

	Overall mean	0.82						
	CV (%)	9.53						
	SL	***						
	0	2.14^{l}	2.80^{kl}	3.94^{gh}	5.67^{de}	3.64	0.21	***
	50	2.67^{kl}	3.69^{ghij}	4.99^{ef}	5.92^{cd}	4.32	0.28	***
	100	3.05^{jk}	3.86^{ghi}	5.83^{cd}	8.17^{b}	5.23	0.27	***
DDMY	150	3.19^{ijk}	4.07^{g}	6.37^{cd}	10.40^{a}	6.01	0.35	***
	200	3.30^{hujk}	4.87^{f}	6.52^{c}	10.93^{a}	6.41	0.15	***
	Overall mean	5.12						
	CV (%)	8.43						
	SL	***						

ns=non-significant, *=P<0.05, **=P<0.01, ***=P<0.001, d=day, SL=Significance level, SE=Standard error CV=Coefficient of variance, DMY=Dry matter yield, CPY=Crude protein yield, DDMY=Digestible dry matter yield. Means followed by the same letters within a column and rows are not significantly different (p>0.05).

Effect of NPS fertilizer, harvesting stage, and their interaction on quality parameters of Bracharia grass

The effect of NPS fertilizer, harvesting stage, and their interaction on quality parameters of Bracharia grass under supplementary irrigation was indicated in Table 2 and 3. Except for crude protein concentration and neutral detergent fiber (Table 3), there was no interaction effect of NPS fertilizer and harvesting stage on the majority quality parameters of the grass (Table 2).

Dry matter content (DM)

DM content of Bracharia grass was significantly (P<0.001) affected by the harvesting stage but doesn't by the NPS fertilizer (P>0.05). DM content was increased with the increasing of the harvesting stage. The highest (P<0.001) DM content was obtained from the harvesting stage of 90 days while the lowest was from the 45-and 60-day harvesting stages.

Increasing DM content with delayed harvesting time might be because of decreased moisture content in leaves as the plants aged and became lignified. The current result agrees with the finding of Tessema et al. (2010a) who reported that the DM content of grass increased with an increase in the growth and development of plants. Waramit et al. (2011) also reported that the DM content of tropical grass including blue panic grass increased linearly with an advance in the age of the forage. This is characterized by an increase in structural components (cell walls) and a decline in the ratio of leaves to stems. The mean (92.86%) DM content was comparable with the earlier finding of Yiberkew et al. (2020) was 90.20% for Bracharia grass in Ethiopia.

Ash content

The harvesting stage had a significant (P<0.001) effect on the ash content; however, NPS fertilizer doesn't significantly (P>0.05) influence it. The ash content of the grass harvested at 45 days harvesting stage was significantly (P<0.001) higher than the other harvesting stage while the lowest was from the 75-and 90-day of harvesting stages.

The decline of ash content with delayed harvesting time might be because of decreased moisture content in leaves as the plants aged and became lignified and dilution and translocation of different minerals associated with the vegetative portion of a leaf at the late stage of maturity. This result agrees with the result of Tessema et al. (2010a) who reported decreased total ash content as the age of grasses advanced in maturity, presumably because the greater proportion of grass stems at late season contains less silica, a major component of ash, than do leaves. The mean (9.39) ash content was lower than the finding of Adnew et al. (2019); Yiberkew et al. (2020) 12.89% and 14.26% for Bracharia grass in Northwestern and lowlands of Northwest Ethiopia, respectively.

Acid detergent fiber (ADF)

ADF was significantly (P<0.001) affected by the harvesting stage. The ADF increased with the extended harvesting stage with the lowest ADF content from the harvesting stage at 45 days after total clearing. The increment of ADF content as age increases might be associated with the development of the structural component/cell wall constituents of the grass as age increases. This might be because as plants become matured there is a greater development of structural carbohydrates. The mean value (31.77%) of ADF obtained was within the favorable range of 33.3% to 59.40% which is considered medium-quality roughages (Nsahlai et al., 1996). The value obtained in this study was lower than the finding of Adnew et al. (2019) was 38.31% ADF content for Bracharia grass in Northwestern Ethiopia. The digestibility of the feed is related to the fiber because the indigestible portion has a proportion of ADF, and the higher the value of ADF the lower the feed digestibility (Costa et al., 2012). Nussio et al. (1998) reported that forage with ADF content of around 40%, or more, shows low intake and digestibility. According to the suggestion of this author, the Bracharia grass studied in this experiment had moderate digestibility.

Acid detergent lignin (ADL)

ADL was significantly (P<0.001) affected by the harvesting stage. The ADL increased with the extended harvesting stage with the lowest content from the harvesting stage at 45 days after total clearing. The increase of ADL content as age increased was probably because of an increase in cell wall concentration with maturity. This could be because as the plants grow longer, there is a greater need for structural support by an increased proportion of stem that has higher structural carbohydrates (cellulose and hemicelluloses) and lignin and the upper leaves produced by older plants appear to be more lignified than earlier produced leaves (Whiteman, 1980). Forages with higher ADL content had low overall digestibility of the feed by limiting nutrient availability (Van Soest, 1994). Hence, Van Soest (1982) reported a lignin content value above 6% to affect the digestibility of forage negatively. Thus, the overall mean (3.72%) obtained in this study was within the favorable range. The mean value (3.72%) of ADL content was lower than the finding of Adnew et al. (2019) was 10.44% ADL content for Bracharia grass in Northwestern Ethiopia. But, there was a comparable result (4.11%) reported by Yiberkew et al. (2020) for Bracharia grass in the lowlands of Northwest Ethiopia.

Invitro dry matter digestibility (IVDMD)

Application of NPS fertilizer beyond 100 Kg/ha doesn't show a significant difference in IVDMD while the lowest was from the application of 50 Kg/ha NPS fertilizer and control one. Regarding the harvesting stage, plants harvested at 45 days gave higher IVDMD while the lowest value was from the 75-and 90-day harvesting stages.

IVDMD increased as NPS fertilizer increased but decreased with the extension of the harvesting stage. The reason for the high content of IVDMD in the NPS fertilizer-treated group could be that fertilizer might have added the soil nitrogen which stimulated new growth of tillers, shoots, and leaves and accelerates the rate of stem development that contributed to increment in CP content of plants which leads to higher and low in the cell wall and lignin contents. On the other hand, the decline of IVDMD concentration with the extended harvesting stage also might be due to the loss of leaves part of the plants and the accumulation of more structural materials on the stems which were assumed to be the causes for poor digestibility of plants. In other words, as the plant matures, the stem comprises an increasing proportion of the whole plant than the leaf in the later days of harvesting (Van Soest, 1982).

The result of this study agreed with the findings of Sileshi et al. (1995); Zewdu and Baars (2003); Abate, (2008), and Tessema et al. (2010b) who reported that depressed IVDMD of the grass species harvested at relatively advanced stages of maturity. This might be due to the presence of certain substances notably lignin, which might have been deposited in the cell wall with increasing maturity (Van Soest, 1982). The current mean (62.70%) of IVDMD was higher than the earlier finding of the Faji et al. (2021) report which was (56.98%) for different perennial forage grass species at the central highland of Ethiopia. Generally, Owen and Jayasuriya (1989) reported that the critical threshold level of IVDMD for feeds to be 50% to be considered as having acceptable digestibility. Mugerwa et al. (1973) reported that IVDMD values greater than 65% indicate good feeding value and values below this threshold level result in reduced intake due to lowered digestibility. Thus, the mean IVDMD values observed in this study were comparable with this threshold level which may be considered as this grass had acceptable digestibility.

Invitro organic matter digestibility (IVOMD)

NPS fertilizer and harvesting stage had a significant (P<0.001) effect on the IVOMD of Bracharia grass. IVOMD increased as NPS fertilizer increased and reduced as the harvesting stage was extended. The highest (P<0.001) IVOMD was obtained from 200 Kg/ha NPS fertilizer application while the least was from the control group. Regarding harvesting time, the least (P<0.001) IVOMD was obtained at 90 days age of harvesting.

The reason for increasing IVOMD with increasing fertilizer and decreasing with extended harvesting time might be due to IVOMD as the function of IVDMD and also a decline in LSR. IVOMD is influenced by the availability of the degradable materials of the feed nutrients and there was a scarcity of information on the IVOMD of Bracharia grass in different parts of Ethiopia.

Metabolizable energy (ME) yield

ME yield of Bracharia grass was significantly (P<0.001) influenced by NPS fertilizer and harvesting stage. ME yield of the grass was increased with the increase of NPS fertilizer and decreased with the extended harvesting stage. The ME yield content of plants that received 150 and 200 Kg/ha NPS fertilizer was significantly (P<0.001) higher than the plants that received 0 and 50 Kg/ha NPS fertilizer, respectively. Regarding the harvesting stage, the highest ME yield was recorded from 45-and 60-days of the harvesting stage while the lowest was from 75-and 90-days of the harvesting stage.

Metabolizable energy yield increased as NPS fertilizer increased from nil to the highest (200 Kg/ha) and this might be due to the amounts of energy obtained from herbage depending largely on the degree of lignification of the tissue so an application of inorganic fertilizer rates increases leaf to stem ratio and leaf portions so this attributed to declining in the lignification of the forage thereby; ME yield of the forage increased due to decreased lignin. A decreasing trend in ME yield with advancing stages of plant maturity in the current study is consistent with the report of Sileshi et al. (1995); Zewdu et al. (2002). The mean value (8.64 MJ/KgDM) of ME was above ME of 7 MJ/kg DM might be better to supply energy to ruminant livestock (Datt et al., 2008).

Crude protein (CP) concentration

The interaction of NPS fertilizer and the harvesting stage had a significant (P<0.001) effect on the CP content of Bracharia grass. The result of this study revealed that CP increased with the increase of NPS fertilizer but decreased as the harvesting stage extended. Plants receiving 150 and 200 Kg/ha NPS fertilizer at 45 days harvesting stage gave higher (P<0.001) CP content.

The result of the highest CP content in the NPS fertilizer treatment could be because fertilizer might have added soil nitrogen which was important for the growth of plant leaves that contributed to increment in the CP of plants. Concurrent with the result of this study Adewumi (2013) reported that the increment in CP content with the increment of fertilizer could have been due to an increase in the level of inorganic fertilizer applied. The reason for the declination of CP content as harvesting age advanced may be because the CP content of plants generally declines with advanced maturity. As the plant becomes mature, there could be a progressive increase in the cell wall contents of the grasses and legumes. As the age increases, the grass becomes lignified causing a decline in CP content. Another reason for the decline of CP concentration with the advancement of the harvesting stage also might be due to the loss of leaves part of the plants and the accumulation of more structural materials on the stems which were assumed to be the causes for lower CP concentration.

The current finding of declining CP concentration with delayed harvesting time was in line with the finding of Wassie et al. (2018) report, the highest CP concentration was obtained at the earliest stage of harvesting, and with values declining as harvesting was delayed in different Bracharia ecotypes in Ethiopia. Limenih (2016) also reported CP content of Desho grass (Pennisetum pedicellatum) was significantly decreased as the harvesting date increased from 90-150 days in Ethiopia.

The mean value (10.24%) of CP content is in line with the earlier finding of Yiberkew et al. (2020) which was 11.70% for Bracharia grass in Ethiopia. Likewise, Nguku et al. (2016) reported a comparable result that was 7-10% CP content in the semi-arid region of eastern Kenya, and Ondiko et al. (2016) report lower CP content in the coastal lowlands of Kenya was 5.3-7.7% for Bracharia hybrid Mulato II grass. However, the value obtained in the current finding was lower than the result of Adnew et al. (2019) report that was 8.57-14.93% CP content for Brachiaria grass in Northwestern Ethiopia and Kifuko-Koech et al. (2016) report that was 12.9-16.2% CP content concentrations of Bracharia hybrid cultivar Mulato II grass at western Kenya. The variation might be due to the soil structure, management practices, and weather conditions which are major factors that influence the nutritional quality of grasses. Machogu (2013) reported that forages with a CP content range of 9-12% are highly palatable and according to the finding of this author, the current finding of 10.24% CP content of Bracharia grass is in the highly palatable range.

Neutral detergent fiber (NDF) content

The NDF content of Bracharia grass was significantly (P<0.001) influenced by the interaction of NPS fertilizer and the harvesting stage. NDF content was decreased with increasing NPS fertilizer while increased with an extended harvesting stage. The application of 200 Kg/ha NPS fertilizer at the 45-and 60-day harvesting stage and 150 Kg/ha NPS at 45 days of harvesting after total clearing had the lowest (P<0.001) NDF content than the other studied NPS fertilizer level and harvesting stage.

The NDF decreased as NPS fertilizer increased, but increased as the harvesting stage extend. This might be because chemical fertilizer improves plant growth and raise new leaves and shoots, which minimizes the NDF content of the grass. On the other hand, the increment of NDF content as age increases might be due to an increase in fiber content and lignified structural tissue at the later stage of growth. The NDF content of plants is reported to result in decreased voluntary feed intake, feed conversion efficiency, and longer rumination time dry matter intake will decrease (Schreuder et al., 2012).

The result of this finding was consistent with the previous result of Hare et al. (2013); Nsinamwa et al. (2005) reported that increasing cutting interval significantly reduced CP concentrations and increased ADF and NDF concentrations in stems and leaves, and the fiber contents in forage increases with increase in plant age and the higher the fiber fractions, the lower the digestibility. The mean value (64.66%) of NDF content was comparable with the finding of Adnew et al. (2019); Yiberkew, et al. (2020) was 61.98% and 61.70% for Bracharia grass in Northwestern and lowlands of Northwest Ethiopia, respectively. In this study, forage materials from all treatments had>60% NDF which may account for the low intake and digestibility.

Table 2. Effect of NPS fertilizer and harvesting stage on quality parameters of Bracharia grass.

	Parameters						
Factors	**DM (%)**	**Ash (%)**	**ADF (%)**	**ADL (%)**	**IVDMD (%)**	**IVOMD (%)**	**ME (MJ/kgDM**
				NPS (Kg/ha)			
0	92.82	9.06	31.91	3.75	62.04^{c}	53.17^{c}	8.49^{d}
50	92.84	9.25	31.76	3.73	62.39^{bc}	54.10^{b}	8.56^{cd}
100	92.87	9.42	31.74	3.72	62.76^{abc}	54.31^{b}	8.65^{bc}
150	92.88	9.59	31.72	3.71	63.01^{ab}	54.44^{b}	8.74^{ab}
200	92.89	9.64	31.70	3.70	63.34^{a}	55.28^{a}	8.78^{a}
SE	0.03	0.23	0.45	0.08	0.26	0.28	0.05
SL	ns	ns	ns	ns	**	***	***
				Harvesting stage (d)			
45	92.78^{c}	10.54^{a}	30.06^{c}	3.35^{b}	63.82^{a}	54.97^{a}	8798^{a}
60	92.79^{c}	9.33^{b}	31.53^{b}	3.78^{a}	63.03^{b}	54.72^{a}	8.70^{a}
75	92.89^{b}	9.01^{c}	32.63^{a}	3.87^{a}	62.16^{c}	54.48^{a}	8.55^{b}
90	92.98^{a}	8.68^{d}	32.84^{a}	3.88^{a}	61.81^{c}	52.87^{b}	8.53^{b}
SE	0.23	0.09	0.26	0.04	0.15	0.22	0.04
SL	***	***	***	***	****	***	***
Interaction (NPS*Hs)	ns	ns	ns	ns	ns	ns	ns
Mean	92.86	9.39	31.77	3.72	62.70	54.26	8.64
SE	0.03	0.08	0.30	0.04	0.12	0.13	0.03

ns=non-significant, **=P<0.01, ***=P<0.001, d=day, Hs=Harvesting stage, SL=Significance level, SE=Standard error, DM=Dry matter, ADF=Acid detergent fibre, ADL=Acid detergent lignin, IVDMD=*Invitro* dry matter digestibility, IVOMD=*Invitro* organic matter digestibility, ME=Metabolizable energy yield. Means followed by the same letters within a column and rows are not significantly different (p>0.05).

Table 3. Interaction effect of NPS fertilizer and harvesting stage on CP and NDF of Bracharia grass.

Parameters			**Factors**					
	NPS (Kg/ha)		**Harvesting stage (d)**			**Mean**	**SE**	**SL**
		45	**60**	**75**	**90**			
	0	11.10^{cd}	8.36^{h}	8.07^{h}	8.02^{h}	8.89	0.27	***
	50	11.65^{c}	9.12^{g}	9.10^{g}	9.03^{g}	9.73	0.08	***
	100	12.56^{b}	9.55^{fg}	9.52^{fg}	9.51^{fg}	10.29	0.16	***
	150	13.80^{a}	10.49^{e}	10.43^{e}	9.69^{f}	11.11	0.22	***
CP (%)	200	13.86^{a}	10.55^{de}	10.48^{e}	9.87^{f}	11.19	0.18	***
	Overall mean	10.24						
	CV (%)	3.28						
	SL	***						
	0	65.33^{a}	65.51^{a}	65.64^{a}	65.76^{a}	65.56	0.79	ns
	50	63.43^{b}	65.27^{a}	65.48^{a}	65.70^{a}	64.97	0.41	*
	100	62.91^{b}	65.26^{a}	65.34^{a}	65.66^{a}	64.79	0.14	***
NDF (%)	150	62.51^{bc}	65.04^{a}	65.28^{a}	65.42^{a}	64.56	0.66	*
	200	61.25^{c}	61.97^{bc}	65.22^{a}	65.24^{a}	63.42	0.46	***
	Overall mean	64.66						
	CV (%)	1.37						
	SL	***						

ns=non-significant, *=P<0.05, ***=P<0.001, d=day, SL=Significance level, SE=Standard error CV=Coefficient of variance, CP=Crude protein, NDF=Neutral detergent fibre. Means followed by the same letters within a column and rows are not significantly different (p>0.05).

Correlation among biomass yield and quality parameters of bracharia grass

The relationship between biomass yield and quality parameters of Bracharia grass is presented in Table 4. The current result revealed both positive and negative relationships.

Table 4. Correlation among biomass yield and quality parameters of Bracharia grass.

Parameters	**DMY (t/ha)**	**CPY (t/ha)**	**DDMY (t/ha)**	**CP (%)**	**IVDMD (%)**	**IVOMD (%)**	**ME (MJ/kgDM)**	**DM (%)**	**Ash (%)**	**NDF (%)**	**ADF (%)**	**ADL (%)**
DMY(t/ha)	1	.962**	.998**	-.295*	-.407**	-.319*	-.258*	.646**	-.536**	.344**	.516**	.450**
CPY(t/ha)		1	.967**	-.031	-.188	-.138	-.054	.599**	-.320*	.161	.378**	.282*
DDMY(t/ha)			1	-.278*	-.383**	-.297*	-.241	.640**	-.524**	.329*	.503**	.441**
CP (%)				1	.817**	.614**	.752**	-.241	.879**	-.715**	-.586**	-.695**
IVDMD (%)					1	.721**	.733**	-.400**	.838**	-.697**	-.683**	-.662**
IVOMD (%)						1	.660**	-.363**	.605**	-.605**	-.427**	-.351**
ME(MJ/kgDM)							1	-.272*	.681**	-.626**	-.500**	-.450**
DM (%)								1	-.430**	.293*	.483**	.421**
Ash (%)									1	-.736**	-.688**	-.725**
NDF (%)										1	.523**	.509**
ADF (%)											1	.664**
ADL (%)												1

** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level, DMY=Dry matter yield, CPY=Crude protein yield, DDMY=Digestible dry matter yield, CP=Crude protein, IVDMD=*Invitro* dry matter digestibility, IVOMD=*Invitro*-organic matter digestibility, ME=Metabolizable energy yield, DM=Dry matter, NDF=Neutral detergent fiber, ADF=Acid detergent fiber.

The positive relationship of DMY with CPY (r=0.962), DDMY (r=0.998), DM content (r=0.646), NDF (r=0.344), and ADF (r=0.516) might be because DMY and DM content of the plant increased as the harvesting stage extended and DDMY and CPY increased as they are the product of DMY. NDF and ADF also increased with the increasing harvesting stage. On the contrary, the negative correlation of DMY content with ash (r=-0.536), IVDMD (r=-0.407), CP content (r=-0.295), IVOMD (r=-0.319), and ME (r=-0.258) might be due to decrease in quality parameters like CP, ash, IVDMD, IVOMD, ME, and LSR as harvesting stage increased while DMY increased.

The positive correlation between CPY and DDMY (r=0.967) might be since both CPY and DDMY were the function of DMY. The positive relation of CPY with DM content (r=0.599) also DM content increases DMY increase and with that CPY and DDMY increase. The direct positive correlation between CP content with IVDMD (r=0.817), IVOMD (r=0.614), ME (r=0.752), and ash content (r=0.79) might be due to high crude protein concentration was obtained at the early harvesting stage with the application of highest fertilizer level. Similarly, IVDMD, IVOMD, ME and ash content, and crude protein content are related to the quality and digestibility of feed parameters.

Partial budget analysis

Partial budget analysis indicated that the application of 150 Kg/ha NPS fertilizer combined with 90-days of harvesting stage gave the highest 2.40 and 48, 244.80-birr benefit-cost ratio and net benefit, respectively (Table 5).

Table 5. Partial budget analysis of Bracharia grass as affected by NPS fertilizer and harvesting stage.

Treatment	GI	TVC	TFC	TC	NB	BCR
1	16218.00	0.00	15873.02	15873.02	344.98	1.02
2	21930.00	893.39	15873.02	16766.41	5163.59	1.31
3	25385.25	1786.78	15873.02	17659.80	7725.45	1.44
4	25997.25	2680.17	15873.02	18553.19	7444.06	1.40
5	26328.75	3573.56	15873.02	19446.58	6882.17	1.35
6	24123.00	0.00	21428.57	21428.57	2694.43	1.13
7	27489.00	893.39	21428.57	22321.96	5167.04	1.23
8	29172.00	1786.78	21428.57	23215.35	5956.65	1.26
9	30714.75	2680.17	21428.57	24108.74	6606.01	1.27
10	36771.00	3573.56	21428.57	25002.13	11768.87	1.47
11	32703.75	0.00	25396.83	25396.83	7306.92	1.29
12	41603.25	893.39	25396.83	26290.22	15313.03	1.58
13	49393.50	1786.78	25396.83	27183.61	22209.89	1.82
14	51153.00	2680.17	25396.83	28077.00	23076.00	1.82
15	52440.75	3573.56	25396.83	28970.39	23470.36	1.81
16	41871.00	0.00	31746.03	31746.03	10124.97	1.32
17	43095.00	893.39	31746.03	32639.42	10455.58	1.32
18	56227.50	1786.78	31746.03	33532.81	22694.69	1.68
19	82671.00	2680.17	31746.03	34426.20	48244.80	2.40
20	82964.25	3573.56	31746.03	35319.59	47644.66	2.35

GI=Gross income, TVC=Total variable cost, TFC=total fixed cost, TC=Total cost. NB=Net benefit, BCR=Benefit cost ratio

Conclusion and Recommendations

From the finding of this experiment, Bracharia grass responded differently to NPS fertilizer and harvesting stage, the main effect of NPS fertilizer, harvesting stage, and their interaction significantly influenced forage yield and chemical composition of Bracharia grass.

- DMY, CPY, and DDMY of the grass increased with increasing NPS fertilizer and extended harvesting stage.
- CP concentration, IVDMD percentage, IVOMD content, ME yield, and LSR were increased with increasing NPS fertilizer but decreased with the extended harvesting stage.
- NDF content decreased with increasing NPS fertilizer levels but increased with the delayed harvesting stage.
- DM content, ADF, and ADL were increasing with the increased harvesting stage while ash content decreased with the extended harvesting stage.

In this regard, the application of 150 Kg/ha NPS fertilizer combined with 90 days of harvesting stage was found to be the most appropriate level for better Bracharia grass production in the study area and similar agroecology. At this level, it produces statistically similar TDMY and TCPY with the application of 200 Kg/ha NPS fertilizer at 90 days of harvest but higher than the rest treatment groups. In addition, it was also found to be economically feasible as it provides higher NB and BCR compared to the other fertilizer level and harvesting stages. So, based on the information generated on DMY, CPY, and economic feasibility, the following recommendations are forwarded.

- Livestock keepers and forage producers are advised to apply 150 Kg/ha NPS fertilizer and harvest at 90 days of harvest to get a better yield and to be profitable from the cultivation of Bracharia grass.
- Further research is needed on harvesting frequency with different organic and inorganic fertilizers in different agroecological zones under rainfed and irrigation conditions.
- Further investigation is also needed in different locations across years and using animal performance trials to confirm the present finding.

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