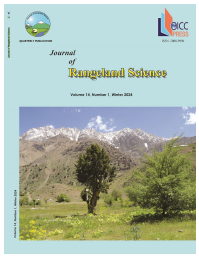

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Effects of Sudan Grass Cultivars and Cutting Frequency on Forage Yield and Quality Traits at the Central Gondar Zone, Ethiopia

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Abstract:

Understanding the relationship between biomass production and forage quality will help to use the selected cultivar and to optimize the cutting interval between harvests in forages to get the required biomass with the desired quality. Among potential forage grasses that required this knowledge, there were Sudan grass cultivars. The aim of the present work was to investigate the forage yield and quality traits of five Sudan grass cultivars with three harvest days intervals at G/Zuria and W/Dembia districts in 2019 and 2020. Five Sudan grass cultivars (DRLME, Mezrut, Wichello, Michello and Aden) and three harvest schedules (40, 50 and 60 days interval) were combined and used for the study. A factorial experiment was laid down in a completely Randomized Block Design (RCBD) with four replications. To assess their potential plant height (cm), number of tillers per plant, forage fresh yield, Dry Matter (DM) yield, Leaf to Stem Ratio (LSR), Crude Protein (CP) yield and quality traits including total ash, Crude Protein (CP), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) were recorded. Data were analyzed of variance, and when the difference was significant, the treatment means were compared using the LSD test at 5 %. The result revealed that there were significant differences between cultivars for all the traits except LRS, NDF, ADF and ADL ($P < 0.05$). The Drlme and Aden cultivars with average values of 82.44 and 80.03 cm respectively had higher plant height than the other ($P < 0.05$). For tiller number, Wichello and Mezrut with values of 17.08 and 15.47, respectively had higher density. The higher annual fresh biomass yield with average values of 28.65 and 26.77 $t\,ha^{-1}$ were obtained in Mezrut and Drlme, respectively. Drlme and Michello with values of 6.61 and 6.95 $t\,ha^{-1}$ produced maximum annual forage DM yield. For CP% and CP yield, the Cultivars Mezrut, Michello and Wichello were found efficient in total CP yield. There were significant differences between harvest days interval for all the traits except tiller number ($P < 0.05$). The higher values of plant height, forage fresh and dry yield and CP yield were observed in 60 days cutting interval. It was concluded that Mezrut, Wichello and Michello at 60 days interval cutting had higher CP yields and were recommended for further Sudan grass production.

Keywords: Cultivar; Cutting interval; Dry matter yield; Forage quality; Sudan grass

1. Introduction

Ethiopia has the largest cattle population in Africa with an estimated population of 42.92 million sheep, 52.46 million goats and 70.29 million heads of cattle (Central Statistical Agency, 2021). The livestock sector is a significant contributor to Ethiopia's economy at the national and household level. Livestock contributes to the livelihoods of approximately 70 % of Ethiopians and contributed up to 40 % of agricultural Gross Domestic Product (GDP), nearly 20 % of total GDP, and 20 % of national foreign exchange (Manage-

ment Entity, 2021). In addition to direct income benefits, livestock provides indirect benefits such as fuel and fertilizer from animal manure and draught power for crop production. Despite the large livestock population in Ethiopia Central Statistical Agency (2020), its contribution to the national economy is below potential, owing to range of factors including unavailability of sufficient and quality animal feed, poor genetic potential of animals for productive traits, poor health care and poor management practices (Management Entity, 2021). Of these factors, feed shortage both in terms of quantity and quality is a very crucial constraint for livestock production in the country and in the study area in general (Alemu et al., 2021). In a country like Ethiopia where subsistence farming is prevalent and landholding is small, livestock is an important segment of farming systems. However, due to increasing population and change in land use, livestock is facing severe competition for resources, especially land.

Because of the sever feed shortage problem in the area, farmers are efficient in utilizing crop residue to feed their livestock and are completely dependent on the crop residue for the long dry season which is poor in protein and vitamin content and digestibility. To combat the existing nutritional constraints for livestock production, using of productive and highly nutritious introduced forage plants is recommended (Management Entity, 2021). However, there are very few options to use such forages in Sorghum growing mid altitude areas. Despite the fact that farmers in the study area are trying to grow Sorghum by increasing its seed rate not only to produce grain but equally to get Sorghum Stover for their animals. However, the amount of Sorghum Stover obtained is much less, low palatable and digestible and its nutritional quality is very low which is much less than 4 % CP (Lima et al., 2017). To meet the demand for livestock feed, it needs to search adaptive and productive forages with better nutritional quality for the area. Among the recommended feed shortage mitigation strategies in the area, there is the utilization of the new Sudan grass cultivars.

Sudan grass is native to Sudan. Sudan grass as a forage crop has many reliable characters that include high yielding potential, drought and heat tolerance, very good water use efficiency, high response to N fertilization, less susceptible to disease, and most importantly, the crop's ability to provide 4-6 cuts per growing season. The green foliage of Sudan grass is succulent, very palatable, and nutritious feed for dairy cattle. It represents an ideal bulky feed crop due to its dense vegetative growth and high DM yield. It can be harvested as pasture, green chop, hay, or silage. Sudan grass yields have ranged from 7 to 12 t ha^{-1} DM yield (Kaplan et al., 2019). It can be ready for harvest as early as 45 days after planting. Trials at numerous places have demonstrated that the crude protein content of S. turcomanica was ranged from 8.33 (seed maturity) to 25.66 % (vegetative growth) and decreased with the progress of growth stages (Ahmadi et al., 2013). In this context, improving the growth, forage yield, and quality of Sudan grass requires the adoption of suitable agronomic practices among which use of high yielding cultivars and proper cutting time are important (Ibrahim et al., 2016). Selection of high yielding Sudan grass cultivars can therefore guarantee higher fodder with high nutritional quality (Turanira et al., 2015; Mansour et al., 2019).

Furthermore, besides to use high yield cultivars, proper harvest management such as cutting frequency between harvests is essential to profitable Sudan grass production, particularly in the manipulation of forage yield and quality. Field observations and research findings have established that earlier cutting of sorghum plants would provide higher quality while late cutting could produce higher forage yield. Moreover, most farmers usually decide to harvest their forage crops more or less dependent on market demand without consideration to proper cutting time that can produce the highest forage attributes (Turanira et al., 2015; Aslan et al., 2021). Thus, choosing the best cutting date should be managed, particularly so that Sudan grass is a multi-cut crop. The present investigation was therefore carried out to determine the effect of cultivar and different cutting treatments on forage yield and nutritional quality of Sudan grass.

2. Materials and methods

2.1 Description of the study areas

The study was conducted in 2019 and 2020 under rain fed condition in two districts; Gondar Zuria and West Dembia from Central Gondar zone, Ethiopia. The study location; Gondar Zuria ranged at latitude of 12°25′14.9″ N and longitude 037°36′18.5″ E at an elevation of 2104 m.a.sl and West Dembia 12°17′42.8″ N latitude and 37°13′25.39″ E, at an altitude of 1856.4 m.a.sl. Based on 10-year (2008-2017) meteorological data, the area has an annual temperature with a range of 15.6 – 29.5 and 16.7 – 30.5 °C and average rainfall varies from 641 – 1678 and from 918 – 2104 mm for Gondar Zuria and West Dembia districts, respectively, in bimodal type with the erratic rainfall distribution. The soil texture of the study area is sandy loam, good in water-holding capacity and fertility.

2.2 Research method

Five improved Sudan grass cultivars (Drlme, Mezrut, Wichello, Michello and Aden) were used for the experiment. Three cutting intervals (40, 50 and 60 days) were applied to the five cultivars, making the total number of treatments fifteen. The experimental plot was laid down in randomized complete block design with four replications in factorial arrangement. The experimental sites were harrowed to crash clods and leveled out to maintain a well prepared seed bed according to the land preparation requirement of the Sudan grass (Khelil et al., 2005). Net plot size was 2.5 × 3.0 m with spacing of 30 cm between rows and 10 cm between plants. Spacing between for both plots and replications was 1 m. Sudan grass was sown at a seed rate of 7 kg ha^{-1}. For the best establishment and growth, Nitrogen fertilizer at the rate of 46 kg ha^{-1} was applied half at planting and half at vegetative plant growth. Sowing was done by drilling along the row and tinning was done after the establishment considering 10 cm plant spacing. Weeds were effectively controlled by hand throughout the growing season. The cutting was done following its cutting interval for each treatment. A sickle was used for clipping the

Table 1. Mean of annual forage yield and total CP production of Sudan grass cultivars tested in 2019 and 2020 at G/Zuria and W/Dembia districts

Cultivars	Plant height (cm)	Tillers no. per plant	Annual fresh yield ($t\,ha^{-1}$)	Annual DM yield ($t\,ha^{-1}$)	Leaf to stem ratio	Annual CP yield ($t\,ha^{-1}$)
DRLME	83.44^{a}	9.73^{c}	26.77^{ab}	6.61^{a}	8.98^{b}	0.62^{b}
Mezrut	62.08^{c}	17.08^{a}	28.65^{a}	5.59^{c}	15.29^{a}	0.66^{a}
Wichello	72.40^{b}	15.47^{a}	21.27^{d}	6.47^{ab}	11.05^{ab}	0.76^{a}
Michello	73.82^{b}	13.48^{b}	23.71^{cd}	6.95^{a}	11.50^{ab}	0.68^{a}
Aden	80.03^{a}	6.53^{d}	25.35^{bc}	5.78^{bc}	14.41^{a}	0.61^{b}
Mean	74.35	12.46	25.15	6.28	12.25	0.67
CV (%)	12.12	20.64	21.03	20.31	10.21	16.87
LSD (0.05)	4.86	1.66	2.85	0.69	ns	0.01

a,b,c,d = means within column having different superscript letters are significantly different at ($P < 0.05$); ns = non-significant at ($P > 0.05$); CP = crude protein; CV = coefficient of variation; LSD = least significant difference.

plants 4 – 7 cm above the soil surface to give chance for faster recovery following cutting. At each cut, 500 g forage samples were taken, chopped to facilitate drying and dried in air draft oven at 65 °C for 72 h to determine dry matter content for DM yield estimation.

2.3 Data collection and processing

After planting, the overall performance of cultivars was evaluated using visual estimation and proceeded measurements of plant height at forage harvest, number of tillers per plant, forage fresh yield, forage DM yield and leaf to stem ratio. Plant height was measured by averaging the natural standing height of ten plants per plot in X fashion from the entire eight rows. The main tiller number was an average of primary tillers from ten plants per plot. Sudan grass forage harvested for herbage and DM yield were following each cutting interval. In each cutting, interval sampling was done from the middle eight rows excluding the guard rows. Immediately after forage sampling, the fresh samples were weighed using salter balance having a sensitivity of 0.1 kg for biomass yield estimation. A minimum of 500 g individual samples of Sudan grass forage was taken for DM% analysis, which was oven dried at 65 °C for 72 h until constant weight was obtained. For leaf to stem ratio determination, when any plot was harvested, five plants were taken at random, dried in a paper bag and the leaves were carefully stripped from the stems. The ratio was obtained by dividing the leaf weight to stem weight.

2.4 Forage quality analysis

Chemical analyses of forage samples were carried out by taking representative samples from different harvests of respective fields. Forage samples taken from each cutting were thoroughly mixed and sub-sampled for each cultivar. The composite feed sub-samples were dried in forced air draft oven at 65 °C for 72 h for partial dry matter determination. Dried samples of feeds were milled using a laboratory mill to pass through a 1 mm screen. Milled samples of feeds were taken to Debere Birhan Agricultural Research Centre and stored at room temperature pending chemical analysis, total ash and Nitrogen (N) was measured using (AOAC, 2000). Crude protein was determined by $N \times 6.25$. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed according to the procedures of Van Soest et al. (1991).

2.5 Data analysis

The data collected were subjected to analysis of variance (ANOVA) using SAS 9.1 software (SAS, 2003). When the difference was significant, LSD (least significant difference) test at the 5 % probability level was used.

3. Results

All of the obtained results represent the mean values acquired during a 2-year research period. From the statistical analysis result, there was significant ($P < 0.05$) differences between Sudan grass cultivars (Drlme, Mezrut, Wichello, Michello and Aden) for plant height, tillers number, forage, fresh and dry yield, total ash, CP content and CP yield (Table 1). There was a significant ($P < 0.05$) difference between cutting frequency (40, 50 and 60 days) for plant height, forage fresh and DM yield, leaf to stem ratio, CP yield, ash content, CP%, NDF%, ADF% and ADL% content (Tables 2 and 4). There were no significant effects of cultivars by cutting frequency interaction for all the traits, indicating the responses of cultivar similar to cutting interval.

3.1 Forage yield and agronomic traits

The plant height was significantly affected by both cultivars and cutting interval (Tables 1 and 2). Cultivar Drlme and Aden had higher plant heights (80.03 to 83.44 cm) during the two growing seasons. While the lowest values of plant height (62.08 to 73.82 cm) were recorded by Mezrut, Wichello and Michello during the two seasons combined (2019 and 2020) (Table 1). There were significant differ-

Table 2. Mean annual forage yield and total CP production of Sudan grass cultivars tested at different cuttings in 2019 and 2020 at G/Zuria and W/Dembia districts

Cutting interval	Plant Height (cm)	Tillers per plant	Annual fresh yield ($t\,ha^{-1}$)	Annual DM yield ($t\,ha^{-1}$)	Leaf to stem ratio	Annual CP yield ($t\,ha^{-1}$)
40 days	61.64^{c}	12.02	22.94^{b}	5.04^{c}	14.41^{a}	0.58^{c}
50 days	77.71^{b}	12.19	24.78^{b}	6.31^{b}	13.22^{a}	0.67^{b}
60 days	83.72^{a}	13.16	27.73^{a}	7.49^{a}	9.11^{b}	0.73^{a}
Mean	74.35	12.46	25.15	6.28	12.25	0.67
CV (%)	12.12	20.64	21.03	20.31	10.21	14.05
LSD (0.05)	3.76	ns	2.20	0.53	4.26	0.12

a,b,c = means within column having different superscript letters are significantly different at ($P < 0.05$); ns = non-significant at ($P > 0.05$); CV = coefficient of variation; CP = crude protein; LSD = least significant difference.

ences among cutting interval for plant height. The higher and lower plant heights with average values of 83.72 and 61.64 cm were obtained in 60 and 40 days cutting interval, respectively (Table 2).

There were significant differences between cultivars for tiller number ($P < 0.05$) (Table 1). The higher values of (15.47 and 17.08 tillers) were recorded by cultivar Wichello and Mezrut, respectively whereas the lowest value was (6.53) registered by cultivar Aden. Cutting interval had no significant ($P > 0.05$) effect on the tiller number during 2019 and 2020 growing seasons (Table 2).

Results of combined analysis over two years showed a significant difference among the cultivars for green fodder yield ($P < 0.05$) (Table 1). Mezrut ranked top for annual fresh yield (28.65 $t\,ha^{-1}$) closely followed by Drlme (26.77 $t\,ha^{-1}$). On the other hand, relatively the lowest green fodder yield (21.27 $t\,ha^{-1}$) was obtained from cultivar Wichello. For DM yield, a significant difference was detected ($P < 0.05$) among the cultivars. The cultivar Drlme and Michello with average values of 6.61 to 6.95 $t\,ha^{-1}$ produced higher annual DM yields, respectively, followed by Wichello (6.47 $t\,ha^{-1}$) (Table 1).

Cutting interval had significant effects on both fresh and DM yield during 2019 and 2020 growing seasons ($P < 0.05$) (Table 2). For annual fresh yield, the higher and lower values of 27.73 and 22.94 $t\,ha^{-1}$ and for annual DM yields, higher and lower values of 7.49 and 5.04 $t\,ha^{-1}$ were obtained in 60 and 40 days cutting interval, respectively (Table 2).

There were no significant ($P > 0.05$) differences among Sudan grass cultivars in leaf to stem ratio (LSR) (Table 1). However, the cultivar Mezrut and Aden with average values of 15.29 and 14.41 produced higher LSR, respectively. There were significant differences among cutting interval for LSR (Table 2). In the 40 days cutting interval, the relatively highest 14.41 LSR was obtained in comparison to 60 days cutting interval (9.11) (Table 2).

For total CP yield, there was a significant ($P < 0.05$) difference between Sudan grass cultivars (Table 1). Among the tested cultivars, Mezrut, Wichello and Michello with average values of 0.66, 0.076 and 0.68 $t\,ha^{-1}$ recorded higher total CP production than the rest of cultivars respectively (Table 1).

There were significant differences among cutting interval for CP yield (Table 2). The higher and lower values of 073 and 058 $t\,ha^{-1}$ were obtained in 60 days and 40 cutting interval, respectively (Table 2).

3.2 Forage quality

The mean response for nutritive values to Sudan grass cultivars is shown in Table 3. There were significant differences between Sudan grass cultivars for total ash, CP content, neutral detergent fiber (NDF) and acid detergent fiber (ADF) ($P < 0.05$). There was no significant ($P > 0.05$) difference detected among the cultivars in acid detergent lignin (ADL). For total ash, Mezrut had higher (13.37 %) in comparison with other cultivars. On the other hand, the higher CP% with average values of 11.86 and 11.75 % were recorded in Mezrut and Wichello, respectively so that they were significantly higher than those for Drlme (9.41 %) (Table 3). Among the tested cultivars, Mezrut recorded significantly ($P < 0.05$) higher NDF and ADF contents with the values 65.12 and 55.51 %, respectively While cultivar Aden produced relatively lower NDF and ADF contents (51.93 and 43.97 %, respectively) than other cultivars (Table 3).

From all Sudan grass cultivars, the early harvesting stage (40 days) resulted in higher ash content (13.66 %) followed by intermediate (50 days) harvesting stage recording an intermediate ash content (12.29 %) and later (60 days) harvesting stage recording the lowest ash content (11.01 %), respectively (Table 4). Sudan grass cultivars harvested at 40 days interval showed significantly ($P < 0.05$) higher CP% (11.52 %) while the lowest (9.75 %) was at 40 days cutting interval (Table 4). However, the intermediate CP% (10.68 %) was recorded from Sudan grass cultivars harvested at 50 days interval. Therefore, the result indicated that the CP% significantly reduced with increase in the harvesting age. On the other hand, Sudan grass cultivars produced a higher NDF% (67.23 %) at 60 days harvest interval. The overall mean of NDF% was 60.59. The current result indicated that the content of NDF increased as the grass matured. Similarly, the results obtained also showed a

Table 3. Means of quality traits of Sudan grass cultivars tested in 2019 and 2020 at G/Zuria and W/Dembia districts

Cultivars	Ash	CP	NDF	ADF	ADL
Drlme	10.54^{c}	9.41^{b}	61.37^{b}	49.25^{b}	7.13
Mezrut	13.37^{a}	11.86^{a}	65.12^{a}	51.93^{a}	7.39
Wichello	12.85^{b}	11.75^{ab}	58.12^{bc}	46.58^{bc}	6.46
Michello	11.85^{bc}	9.80^{ab}	62.88^{b}	50.77^{b}	7.53
Aden	10.02^{c}	10.58^{ab}	55.51^{c}	43.97^{c}	6.37
Mean	12.32	10.68	60.59	48.49	6.98
CV (%)	19.21	13.63	11.68	14.46	21.48
LSD (0.05)	2.29	1.13	7.61	6.96	ns

a,b,c = means within column having different superscript letters are significantly different at ($P < 0.05$); ns = non-significant at ($P > 0.05$); ADF = acid detergent fiber; ADL = acid detergent lignin; CP = crude protein; CV = coefficient of variation; LSD = least significant difference; NDF = neutral detergent fiber.

linear increase in the ADF and ADL contents with a corresponding increase in days of harvesting (Table 4).

4. Discussion

The observed variation in plant height might be attributed to genetic factor of the cultivars. Khelil et al. (2005) also reported similar results for the same cultivars. The Highest plant height at higher cutting interval (every 60 days) can be attributed mainly to sub-optimal solar radiation and thermal conditions required to plant growth. An increase in plant height with delayed harvesting has also been reported by Turanira et al. (2015) confirming our results. In conformity with this result, Kaplan et al. (2019) reported that plant height increased as the harvesting time extended, but the quality is reduced. This result also confirmed the report of El Naim et al. (2012) as the cutting interval extended plant height increases. This result might be due to increase in use of resources, especially moisture and solar radiation with extended cut, which generally enhances the growth of plants.

The variability in tiller number among cultivars could be related to genetic of cultivars and that caused the difference in suitability of the environment for the specific cultivar. This has been confirmed by the report of Naeem et al. (2018) who observed great tiller number among Sudan grass cultivars that ranged from 9.12 to 14.67.

The observed fresh forage yield difference between cultivars could be attributed to the genetic potential of different cultivars grown in the same condition. Much higher fresh fodder yield from this study with a value of (180.10 t ha^{-1}) was reported by Aslan et al. (2021) at steppe dry land zone of the Kabardino-Balkarian Republic from Sorghum-Sudangrass Navigator Sabantuy hybrid for sum of two cuts. Variations in the yields could be attributed to differences in the level of soil fertility, climatic zones, seasons, agronomic practices adopted and differences in cultivars used in different study areas. Likewise, also, the report of Sarfraz et al. (2012) discovered that the green forage yield variability among the cultivar is due to varietal or biological potential of Sudan grass cultivars. It is apparent that Sudan grass green fodder production in the present experiment was the highest (21.27 t ha^{-1}) at the extended cutting interval (60 days) as compared to the shortest cutting intervals (Table 2). The results are in agreement with the findings of Turanira et al. (2015) who indicated yield mostly increases as the harvesting time was extended by a serious quality reduction.

The variations in DM yield might be due to the differences in yield related components like plant height and number of tillers per plant and also differences in fresh yield. These results are in line with those of Turanira et al. (2015) who reported the DM yield of Sudan grass from 6.02 to 7.21 t ha^{-1} when different cultivars were cultivated and tested at different cuttings under semi-arid environments of the Makueni County in Kenya. Generally, cutting intervals had a significant effect on the DM yield of Sudan grass. This was due to the fact that as the plant advances in growth its fresh yield and other yield related component (plant height) will increase, which ultimately has a positive effect on total biomass production. The current study result is in agreement with the reports of Sarfraz et al. (2012) who discovered a better DM yield as the plant growth advances. In line with the current result, Turanira et al. (2015) also reported that forage DM yield mostly increases as the harvesting time was extended but quality reduced.

The variations in leaf to stem ratio at different cutting intervals could be due to the fact that as the plant advances in growth, leaf shattering become prominent and the plant becomes steamy which ultimately decreases in its leaf to stem ratio. These results coincide with the results of Turanira et al. (2015) who noted significant LSR variation among cutting treatments related to the plant growth for the sorghum Sudan grass hybrids.

The highest total CP production attained was due to higher biomass production achieved and the higher the CP% recorded by the cultivars since total CP production is a function of total biomass produced and CP%. In accordance with the current findings, Shafiq Zahid et al. (2002) also confirmed a significant total CP production among the sorghum

Table 4. Means of quality traits of Sudan grass cultivars at different cuttings in 2019 and 2020 at G/Zuria and W/Dembia districts

Cutting interval	Ash	CP	NDF	ADF	ADL
40 days	13.66^{a}	11.52^{a}	53.61^{b}	47.29^{b}	6.27^{b}
50 days	12.29^{ab}	10.68^{b}	60.93^{ab}	46.36^{b}	7.18^{a}
60 days	11.01^{b}	9.75^{c}	67.23^{a}	51.98^{a}	7.42^{a}
Mean	12.33	10.65	60.59	48.54	6.95
CV (%)	8.09	10.92	14.29	15.03	11.92
LSD (0.05)	1.94	1.63	10.21	3.92	0.98

a,b,c = means within column having different superscript letters are significantly different at ($P < 0.05$); ns = non-significant at ($P > 0.05$); CV = coefficient of variation; LSD = least significant difference; ADF = acid detergent fiber; ADL = acid detergent lignin; CP = crude protein; CV = coefficient of variation; LSD = least significant difference; NDF = neutral detergent fiber.

Sudan grass hybrids that ranges from 0.66 to 0.81 t ha^{-1}. On the other hand, the observed highest CP production at 50 days cutting interval could be due to the significant amount of DM yield at advanced plant growth.

The better ash production might be due to much higher cell wall content accumulated with cultivar Mezrut. In conformity with the current result, Shafiq Zahid et al. (2002) also reported that ash content of Sorghum Sudan grass hybrids may reach at 15.87 %. The better CP content in Mezrut, Wichello, Michello and Aden indicated that these cultivars are more efficient in nutrient uptake and this may be due to better root penetration into the soil than other cultivars. This result was similar to that observed by Shafiq Zahid et al. (2002) a 10.89 % CP for Sorghum Sudan grass hybrids.

The variations in NDF content in different Sudan grass cultivars might be due to differences in their LSR. For all Sudan grass cultivars, NDF contents were below 72 %, which indicates that they had no negative effect on feed intake when the forage was harvested at 40, 50 and 60 days interval. These features make these cultivars excellent alternatives for animals, with the purpose of providing quality feed in the dry season. The result of NDF found in the current result is in conformity with Naeem et al. (2018), who reported mean NDF content of (62.18 %) for Sudan grass germplasm collections. Unlikely to this study result, Lima et al. (2017) studied the chemical composition of nutritional characteristics of Sorghum hybrids hay (*Sorghum sudanense* vs. *Sorghum bicolor*) and achieved NDF content above 65 %. Variations could be due to differences in cultivars used, plant maturity at harvest, the type and amount of fertilizer used, agro ecology and nutrient content of the soil in different areas.

The observed higher ADF% in cultivar Mezrut may be correlated with the observed difference in LSR in different species. In this context, the digestibility of feeds 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., 2005). Ibrahim et al. (2016) also reported that forage with ADF content around 40 % or more shows low intake and digestibility.

Ash content finding in this study indicated that the decrease in ash content with a long harvesting interval is probably a normal phenomenon of maturity of grass forages (Awoke et al., 2020). It might have been caused partly by the dilution effect of higher yields in the presence of a constant amount of available minerals in the soil. Linn and Martin (1999) reported that most forage has an ash content ranging from 3 % to 12 %, but the current result has a greater value than this range. This difference could come from the variation of cultivars used and cutting interval, higher biomass yield, better chemical composition, environmental conditions, and different management practices as well as their interaction effects in natural pasture.

Crude protein (CP) content was higher in the early stage compared with the intermediate and late stage. Decreasing CP contents of grasses with increasing plant harvesting might be due to reduced leaf-to-stem ratio. The decline in CP content with advancing stage of maturity is also due to accretion of higher proportion of NDF corresponding to plant growth. This could be attributed mainly to dilution of the CP contents of the forage crops by the rapid accumulation of cell wall carbohydrates at the later stages of growth (Van Soest, 1994). Crude protein is one of the major criteria for determining the nutritional quality of a feed; as the level of CP increases, the DM intake by livestock and rumen microbial growth would also increase (Chanthakhoun et al., 2012). Crude protein content of all the plant materials analyzed met the minimum requirements for ruminants (> 7 %), i.e., 6.9 % for maintenance, 10.0 % for beef production, and 11.9 % for milk production (Ibrahim et al., 2016). All the studied grass species had a CP content which almost fulfilled the minimum requirement.

The increasing trend of NDF concentration by increasing in harvesting age agrees with the findings of Wubetie et al. (2019) in Brachiaria grass cultivars and Atis et al. (2012) in forage sorghum cultivars, in which NDF concentration increased from 70.8 at 90 days to 74.7 at 120 days of harvesting. This might be due to more seeds being produced at the time of plant maturity; there is a translocation of protein

from the leaf and stem to seeds, and therefore, high fiber remains on the plant. The reason might be due to environmental factors of temperature and water stress affecting the cell content and leading to accumulation of less carbohydrate. These current results also indicated that the NDF content increased with an increase in the days of harvesting from 40 to 60 days. This might be due to an increase in fiber content accompanied with the decrease in CP content associated with an increase in the proportion of lignified structural tissue at the later stage of growth.

The observed linear increase in the ADF and ADL content with a corresponding increase in days of harvesting might be due to the fact that as the plant matures, the cellulose, hemicelluloses, lignin, and silica which are found in the insoluble portion of the forage increase. Therefore, an increase in the ADF and ADL content with the increase in harvesting days of grass was in line with the results of Atis et al. (2012) who reported that forage sorghum cultivars harvested at 90 days interval had a higher ADF (50.68) and ADL (7.22) content. On the other hand, contrary to our result, the study in Uzun et al. (2009) demonstrated that some Sorghum X Sudan grass hybrids (*Sorghum bicolour* (L.) *Moench* X *Sorghum sudanenese* Stapf.) had a relatively lower ADF (42.52) and ADL (5.01) content. This difference might come from planting systems, environment, altitude, soil type, soil fertility, and harvesting age in the area where the current experiment was conducted.

5. Conclusion

From this study result, it can be concluded that better biomass yield was harvested from Drlme, Wichello and Michello Sudan grass cultivars. Maximum CP content was obtained from Mezrut with no difference with cultivar Wichello, Michello and Aden. However, cultivar Mezrut, Wichello and Michello were more efficient in CP producing per hectare. Though, cultivar Drlme produced a significant biomass yield, due to its lower CP%, it produced lower total CP. On the other hand, even though cultivar Aden produced higher CP%, it provides very low biomass yield, which resulted in lower CP production per hectare. Regarding harvesting intervals, biomass yield and related components were increased with delaying the harvest without compromising the quality. Among the cutting treatments, 60 days interval cutting was better in CP production per hectare. Therefore, maximizing the CP production per hectare as the ultimate objective of growing forages, in getting a higher forage yield of quality, the use of Sudan grass cultivar Mezrut, Wichello and Michello should be considered and also, 60 days interval should be used as an appropriate harvest time for the selected cultivars. To exploit its potential under a range of livestock production performances, further research should be done and these Sudan grass species with the selected harvest time should be widely demonstrated in the study area and other similar sorghum growing areas.

Ethical approval:
This manuscript does not report on or involve the use of any animal or human data or tissue. So the ethical approval does not applicable.

Authors Contributions:
All authors contributed equally to performing experiments, analyzing data, and writing the paper.

Availability of data and materials:
The data that support the findings of this study are available from the corresponding author upon reasonable request.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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