ZANCO Journal of Pure and Applied Sciences
The official scientific journal of Salahaddin University-Erbil
https://zancojournals.su.edu.krd/index.php/JPAS

ISSN (print):2218-0230, **ISSN (online):** 2412-3986, **DOI:** **http://dx.doi.org/10.21271/zjpas**

RESEARCH PAPER

The Effect of Different Nitrogen Concentration and Cutting Frequency on Some Quality Characters of Two Sorghum (*Sorghum bicolor* L. Moench) Varieties

[1]Tara Abubakr Mohammed, [1]Namam Bahram Ismael

[1]Department of Field Crops, College of Agricultural Engineering Sciences, Salahaddin University-Erbil, Kurdistan Region, Iraq

A B S T R A C T:

This investigation was carried out at two locations the first location was college of Agricultural Engineering Sciences / Salahaddin University at Grdarasha research and the second location was Kurshaxlu station during summer season 2021 to assess the effect of three levels of nitrogen (0,50 and 100) kg ha^{-1} and two different cutting frequency (once and twice), applied on two sorghum varieties; (Money Maker and Jowari) to investigate some quality characters (crude ***protein %,*** crude fiber %, ***ether extraction*** %, ash % and total carbohydrates %). Jowari variety had highest protein % than money maker, (13.211 and 13.095) (%) and at nitrogen 100 kg ha^{-1}. The results showed that the fiber content were decreased and carbohydrates increased in Jowari variety with the nitrogen concentration 50 kg ha^{-1}. Cutting twice recorded lower fiber content and higher carbohydrates percentage than cutting once. More studies might conduct to determine the effect of nitrogen applications on growth and quality of sorghum by using different rates.

KEY WORDS: Sorghum; Nitrogen; Forage; Different cutting period; Quality.
DOI: http://dx.doi.org/10.21271/ZJPAS.34.5.8
ZJPAS (2022) , 34(5);92-102 .

1.INTRODUCTION :

Sorghum (*Sorghum bicolor* L. Moench) is an important short-day summer annual grass that ranks fifth in the world's cereal crops (Ghani *et al.*, 2015). Sorghum is a drought-resistant fodder crop in the Poaceae family (Karthika and Kalpana 2017).The center of origin was domesticated and diversified in Africa before moving to other parts of the world, Ethiopia and Indian (Doggett, 1988). There are five main races of cultivated sorghum (bicolor, guinea, caudatum, durra and kafir) (Barnaud *et al*., 2009). Sorghum enzymes allowed for categorization into three enzymatic groups. The first includes race guinea is widely grown in West Africa the second Southeast Africa of all five races and third race durra and race caudatum central Africa. All cultivated sorghums could be descended from a primitive domesticated bicolor-like race (Dewet *et al*., 2011).

FAO (2008) showed that sorghum has spread throughout the world with the five countries with the highest production being the United States, Nigeria, Ethiopia, Mexico, and India. In 2007, for example, over 40 million hectar of land were dedicated to sorghum production globally with 60 percent of that land dedicated to sorghum production.

Mahfouz *et al*.(2015) illustrated that in terms of importance and production, sorghum is the fifth most important cereal crop in the world, after wheat, maize, rice, and barley. Sorghum is becoming an increasingly important forage crop in many arid and semi-arid regions of the world because of its advantages over other forage crops

* **Corresponding Author:**
Tara Abubakr Mohammed
E-mail: tara.muhammad@su.edu.krd
Article History:
Received: 03/04/2022
Accepted: 29/05/2022
Published: 20/10 /2022

(Zerbini and Thomas 2003).Sorghum is famous for its high stress resistance and adaptability, and one of its main characteristics is salt tolerance. Increasing sorghum production on saline-alkaline land is one of the best options for making the most of this marginal soil. Domestic and overseas studies on plant tolerance to soil salinity and alkalinity in sorghum have led to many achievements (Huang, 2018).

Sorghum is widely cultivated in arid, semiarid, tropical, subtropical, and temperate climates. It is a significant source of food and feed (Huang, 2018). Excellent opportunity to provide fodder to the bovine population for better nutrition (Singh and Sumeriya 2012). Taking this into consideration, multi cut genotypes were developed to ensure a continuous supply of green fodder for a longer period of time. Sorghum green fodder contains 12(%) protein, 70(%) carbohydrates and remaining part consists of minerals, and crude fats palatable to animals (Malik *et al*., 2007).

These multi cut varieties have high nutritive value than single cut under same set of management (Malik *et al*., 1992). It grows quickly, is palatable, and nutritious, so it's used as silage and hay as well as fresh fodder (Rana *et al*., 2012).

Many factors influenced sorghum fodder quality including fertilization, irrigation, genotype, plant density, and harvesting time. Increased nitrogen fertilization improved nitrogen uptake significantly, resulting in increased photosynthetic activity and protein synthesis (Oberoi *et al*., 2020). Nitrogen application has a direct impact on forage quality (Kaur *et al*., 2016).

Neylon and Kung (2003) reported that the increase in protein content with increasing the nitrogen level could be due to nitrogen application enhancing amino acid formation and thus increasing protein content. Nitrogen application reduces the fiber, lignin, and neutral detergent fiber content of forage, improving succulence and palatability (Yang *et al*., 2020). Increased nitrogen levels reduced crude fiber content, resulting in a crude fiber range of 32.76 – 30.72 percent (Almodares *et al*., 2009).

Mohammed *et al*. (2014) showed that that higher nitrogen levels enhanced the concentration of ether extractable fat. Ayub *et al*. (2002) who found that the effect of nitrogen application on ash percent contents shows a significant effect on sorghum forage nitrogen application at the rate of 100 kg N ha^{-1} has the highest ash percent contents followed by nitrogen application at the rate of 50 kg N ha^{-1} ash percent contents.

Kumar et *al*.(2015) describe that if the proper amount of fertilizers are not applied, the crop quality of sorghum fodder suffer greatly.

Although sorghum is considered as a dual purpose (grain and forage), it is not considered important crop in Iraq until now depended on old varieties. This crop is not well-known in Kurdistan, and little information and published research on it can be found. In terms of varieties or agronomic practices such as planting date, cutting frequency, row spacing, and nutritive value.

The objective of this study was to investigate the effect of different rates of nitrogen fertilizer and cutting frequency on some green forage quality of *Sorghum bicolor* L. varieties.

2. MATERIALS AND METHODS

2.1 Materials

Two varieties of sorghum (*Sorghum bicolor* L. Moench) as the plant material were used.

(Money Maker and Jowari) three levels of nitrogen were used as N1 with no nitrogen as a Control, N2 with 50 kg ha^{-1} and N3 with 100 kg ha^{-1} nitrogen. In regards to application of Phosphorus and potassium, Mono Potassium Phosphate MKP fertilizer with the rate of (0, 52, and 34) respectively was used as basal application in 160 gm/ 20 liters for each replication and 1.5 liter for each plot which equivalent to 20kg ha^{-1}.

2.2. Experimental Design

The experiments were carried out during summer season 2021, at two locations the first location was College of Agricultural Engineering Sciences / Salahaddin University at Grdarasha research station located at (Latitude 36˚06′44″.8 N Longitude 44˚ 00′44.4″ E) and evaluation of 420 MASL. The second location was Kurshaxlu station which located at (Latitude 35˚ 55′33.6″ N Longitude 43˚ 54′42.6″ E) and evaluation of 415 MASL.

Randomized Completely Block Design (RCBD) with three replicates were used, implemented in three nitrogen fertilizer rate of (0, 50 and 100 kg ha^{-1}) were distributed, while the two cutting frequency (cutting once and cutting twice), there are 40 cm between rows, each plot consists of 4 rows , 30 cm between plants, each plot contains 28 plants. Drip irrigation system were designed for both locations and were irrigated twice a week for 30 minutes.

2.3. Studied characters:-

All data recorded for ten plants from two middle rows of each plot.

2.3.1. Forage quality parameters for different cutting periods:

For quality characteristics samples were used from leaves and stem when it was oven dried for 2 days at 70℃, were determined for all samples after drying and grinding the samples were ground to small portions then mixed together to be used in chemical analysis.

2.3.1. 1. ***Protein percentage (%):***

The nitrogen % was determined using micro Kjeldal apparatus according to (A.O.A.C, 1980). Protein (%) was estimated according to the following equation:

Protein (%) = Nitrogen (%) × 6.25

2.3.1. 2. Fiber percentage (%):

Two gram of sample (fat free) was dissolved in 200 ml of 1.25(%) H_2SO_4 and placed in 500 ml capacity beaker. The mixture was boiled for 30 minutes with continuous stirring; also the level of water was supplemented, contents were filtered and washed 2-3 times with hot water (150 ml) until acid free. The residue was transferred to a 200 ml, again boiling such as first time alkali NaOH 1.25 (%) places in 1000 ml capacity beaker were add also for 30 minutes and, contents washed until alkali free. The residue was carefully transferred to a tarred crucible and dried in an oven at 100°C for 3- 4 hours, the later was placed in a muffle furnace at 550°C for 4 hours until a grey ash was obtained, then cooled in desiccators and weighed. The difference in weights represented a crude fiber a calculated by using the following formula:-

Crude fiber (%) = 100* A-B / C

Where: A = weight of crucible with dry residue (g)
B = weight of crucible with ash (g)
C = weight of sample (g)
(A.O.A.C, 1990).

2.3.1.3. Ether extraction (%): Fat was extracted by using Soxhlet apparatuses. According to (A.O.A.C, 1980)

Fat (%) = weight of fat / weight of sample ×100

2.3.1.4. Ash percentage (%):

A. two gram of samples (stems and leaves) of were placed into crucible, ignited, cooled in desiccators and weighed at room temperature.
B. Then the sample was moved to muffle furnace at 605°C but gradually from 100°C, incinerated until light grey ash was obtained. The sample was put in desiccators and weighed at room temperature (Zou *et al.,* 2007).

Ash (%) = weight of ash/ weight of sample × 100

2.3.1.5. Total carbohydrates percentage (%).

After the determination of the ash, fiber, protein and ether extracts percentage the total carbohydrates percentage was found according to A.O.A.C. (1975) by using the following equation:

Total carbohydrates (%) =100-(ash (%) + fiber (%) + protein (%) + ether extracts (%).

2.4. Statistical analysis:

Data of quality characters were analyzed according to technique of analysis of variance (ANOVA) with MINITAB 19 statistical package (Minitab, 2014) using a General Linear Model (GLM). All data were tested for normality using the Ryan-Joiner similar to Shapiro–Wilk test (a = 0.05). Tukey’s test with a significance level of 0.05 was applied to test for significance between the all factor means and their interactions.

3. RESULTS

3.1 Effect of nitrogen, cutting frequency and varieties on quality characteristic

Table 1 and 2 displays the main comparison of quality characteristic (Protein (%), Ether extracts (%), Fiber (%), ash (%) and Carbohydrate (%), at both locations. The results indicated that all the mentioned quality parameters were significantly influenced by different nitrogen concentration, cutting frequency and varieties separately. As well as, there was significant differences between the interactions of factors such as nitrogen, cutting frequency and varieties for all quality parameters at both locations. This was because nitrogen may enhance quality of sorghum.

3.2 Effects of nitrogen, cutting frequency and varieties on Crude Protein percentage (%)

Nitrogen, cutting frequency and varieties alone were significantly difference as showed in Table1 and 2. The results of Figure 1 showed the interaction of VNC on crude Protein (%) at both locations. Grdarasha location indicated that, nitrogen and interaction treatments were significantly affected the crude protein **(%)** Interaction treatments V1N2C1 recorded highest crude protein (%) (14.35), and the lowest value was obtained in V2N1C1 (11.20) crude protein (%).This means that application of nitrogen with 50kg h^{-1} once cutting for V1 were better as compared to control nitrogen. On the other hand, the results of kurshaxlu field showed that V1N1C1 recorded highest crude protein (%) (14.70) and the lowest value was obtained in V1N2C2 (11.20) crude protein (%) The value between both locations for crude protein percentage (%) showed the kurshaxlu location gave highest value than grdarasha location.

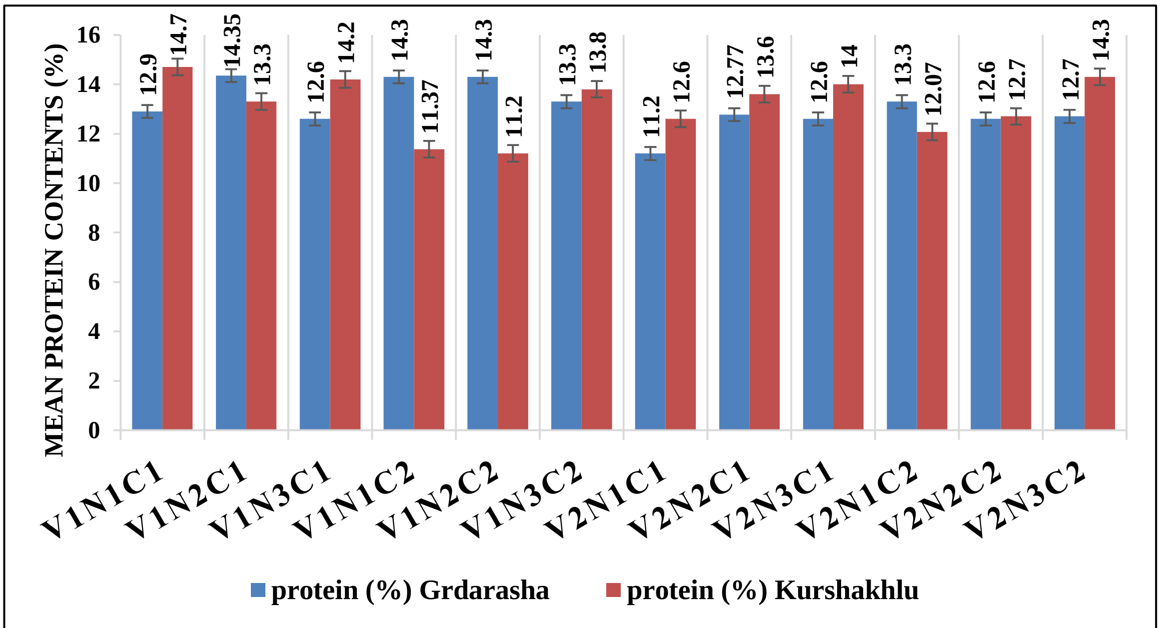

Figure 1. Effects of nitrogen, cutting frequency and varieties on protein (%) at Grdarasha and Kushaxlu locations.

3.3 Effects of nitrogen, cutting frequency and varieties on fiber percentage (%)

Figure 2. Represented that results of interaction treatments were significantly affected the fiber **(%).** Grdarasha location indicated that, interaction treatments V2 N3 C2 recorded lowest value fiber **(%)** **(**19.28) while V2 N1 C2 recorded highest value fiber **(%)** (26.52 **).** This means that nitrogen 100 kg ha^{-1} with twice cutting for V2 was better as compared to nitrogen control. On the other hand, the results of kurshaxlu field interaction treatments showed that V1N1C1 recorded lowest fiber (%) (20.52) and the highest value was obtained in V1 N3 C1 (26.83) fiber (%). Tables 1 and 2 showed that, at locations nitrogen, cutting frequency and varieties alone were significantly difference affected fiber content (%). The value between both locations for fiber percentage (%) showed the kurshaxlu location gave highest value than grdarasha location.

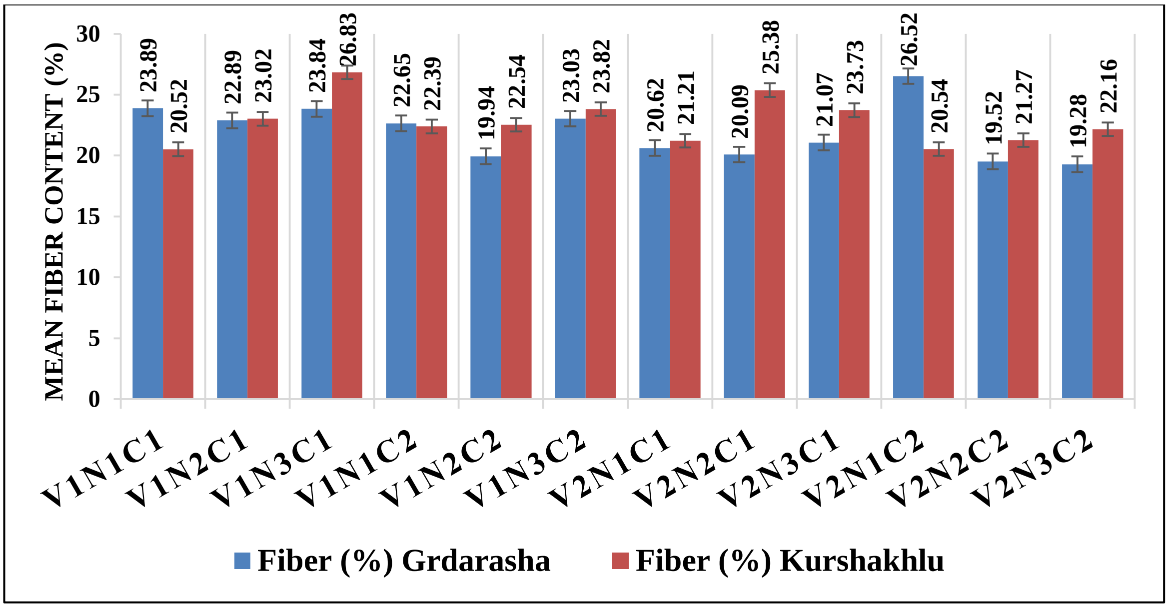

Figure 2.Effects of nitrogen, cutting frequency and varieties on Fiber (%) at Grdarasha and Kushaxlu locations.

3.4 Effects of nitrogen, cutting frequency and varieties on Fat percentage (%)

Table1 demonstrated that nitrogen, cutting frequency and varieties alone was significantly affected the fat percentage **(%)** in Grdarasha location. The results of Figure 3 illustrated that this quality parameter was also changed dramatically by interaction treatments VNC. The lowest value was recorded by (1.29) fat (%) in, V2 N3 C2 treatment, while V1 N2 C1 was recorded highest (2.24) fat (%). This means that application of nitrogen with 50kg ha^{-1} once cutting for V1 were better as compared to control nitrogen. In kurshaxlu location that nitrogen, cutting frequency and varieties alone was again significantly affected fat (%) as showed Table 2. There more, nitrogen, cutting frequency and varieties their interaction were significance. Interaction treatments V2 N2 C1 recorded highest fat (%) (2.18) while lowest value was recorded V2 N1 C2 fat (%) (1.23).The value between both locations for fat percentage (%) showed the grdarasha location gave highest value than kurshaxlu location.

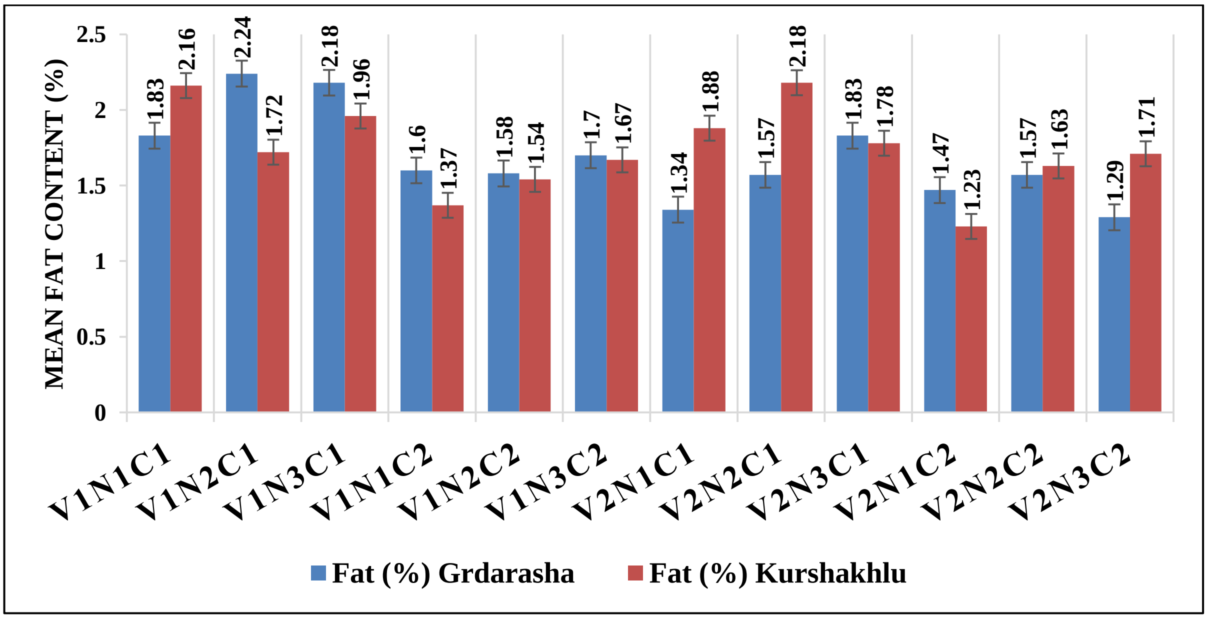

Figure 3. Effects of nitrogen, cutting frequency and varieties on Fat (%) at Grdarasha and Kushaxlu locations.

3.5 Effect of nitrogen, cutting frequency and varieties on Ash percentage (%)

Table 1 and 2 demonstrate that the results of location, nitrogen, cutting frequency and varieties alone were significantly affected the ash **(%).** The results of Figure 4 showed that interaction of VNC treatments significantly difference. Grdarasha location indicated that, interaction treatmentsV1 N2 C2 recorded lowest value ash **(%)** (10.87) while V1N1C1 recorded highest value ash **(%)** **(**12.61)**.** This means that nitrogen 50kg ha^{-1} with twice cutting for V1 was better as compared to nitrogen control. On the other hand, the results of kurshaxlu field showed that V1 N3 C2 recorded lowest ash (%) (10.48) and the highest value was obtained in V1 N2 C1 (12.55) ash (%). The value between both locations for ash percentage (%) showed the kurshaxlu location gave highest value than grdarasha location.

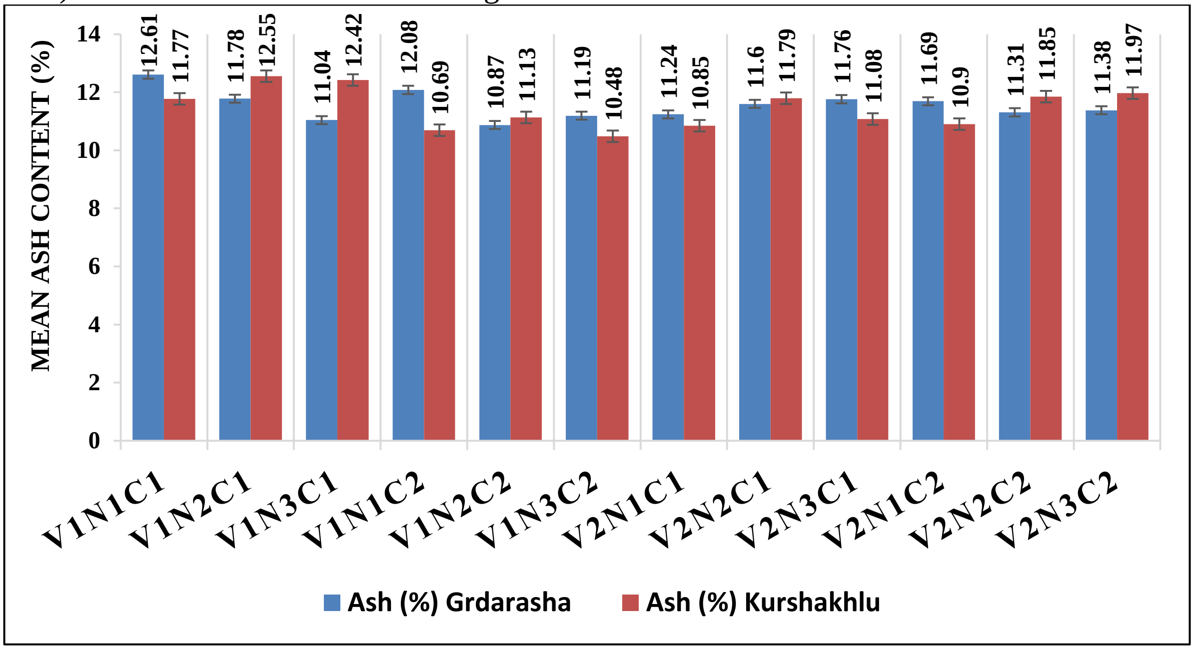

Figure 4. Effects of nitrogen, cutting frequency and varieties on Ash (%) at Grdarasha and Kushaxlu locations.

3.6 Effects of nitrogen, cutting frequency and varieties on Carbohydrate percentage (%)

The results of Grdarasha location as showed in Table1 indicated that, nitrogen, cutting frequency and varieties alone were significantly affected carbohydrate **(%)**. Figure 5 reported that there were significantly differences between the interaction VNC. At Grdarasha location interaction treatments V2 N1 C1 recorded height (55.60) carbohydrate (%), and V2N1C2 recorded lowest (47.02) carbohydrate (%). This means that nitrogen control with once cutting for V2 were better as compared to twice cutting. On the other hand, the results of kurshaxlu field showed that interaction treatments V2 N1 C2 recorded height (55.26) carbohydrate (%) V1 N3C1 recorded lowest (44.59) carbohydrate (%). Table2 showed that kurshaxlu field, nitrogen, cutting frequency and varieties alone were significantly affected carbohydrate **(%).** The value between both locations for carbohydrate percentage (%) showed the grdarasha location gave highest value than kurshaxlu location.

Table 1. The analysis of variance (ANOVA) for the influence of different factors **(**nitrogen, cutting frequency and varieties**)** and their interactions on the quality traits at Grdarasha fields

Source of variation S.O.V	Degree of freedom d.f	protein (%)	Ether extracts (%)	Fiber (%)	Ash (%)	Carbohydrate (%)
Replication	2	3.000	3.000	3.000	3.000	48.000
Varieties	1	10.824*	1.060*	20.884*	0.087*	84.364*
Nitrogen	2	1.698*	0.137*	23.864*	1.167*	22.493*
Cutting frequency	1	4.161*	0.792*	0.532*	0.570*	0.112*
Varieties*Nitrogen	2	1.491*	0.003*	9.522*	1.453*	1.519*
Varieties*Cutting frequency	1	0.0001*	0.230*	18.232*	0.286*	27.825*
Nitrogen *Cutting frequency	2	2.771*	0.161*	15.058*	0.277*	39.072*
Varieties*Nitrogen *Cutting frequency	2	0.324*	0.098*	12.485*	0.466*	24.154*
Error	22	0.000	0.000	0.000	0.000	0.000
Total	35					

*Significant at 0.05 probability levels

Table 2. The analysis of variance (ANOVA) for the influence of different factors (nitrogen, cutting frequency and varieties) and their interactions on the quality traits at kurshaxlu fields.

Source of variation S.O.V	Degree of freedom d.f	protein (%)	Ether extracts (%)	Fiber (%)	Ash (%)	Carbohydrate (%)
Replication	2	3.000	3.000	3.000	3.000	48.000
Varieties	1	0.122*	0.000*	5.832*	0.090*	5.617*
Nitrogen	2	7.645*	0.052*	27.110*	1.822*	72.907*
Cutting frequency	1	12.110*	1.600*	15.880*	2.958*	109.203*
Varieties*Nitrogen	2	1.922*	0.186*	6.530*	0.153*	14.059*
Varieties*Cutting frequency	1	5.522*	0.000*	5.593*	7.398*	7.290*
Nitrogen *Cutting frequency	2	2.910*	0.225*	8.366*	0.025*	4.314*
Varieties*Nitrogen *Cutting frequency	2	0.902*	0.076*	5.341*	0.604*	7.987*
Error	22	0.000	0.000	0.000	0.000	0.000
Total	35					

*Significant at 0.05 probability levels
N=Nitrogen, V=Variety, C=Cutting

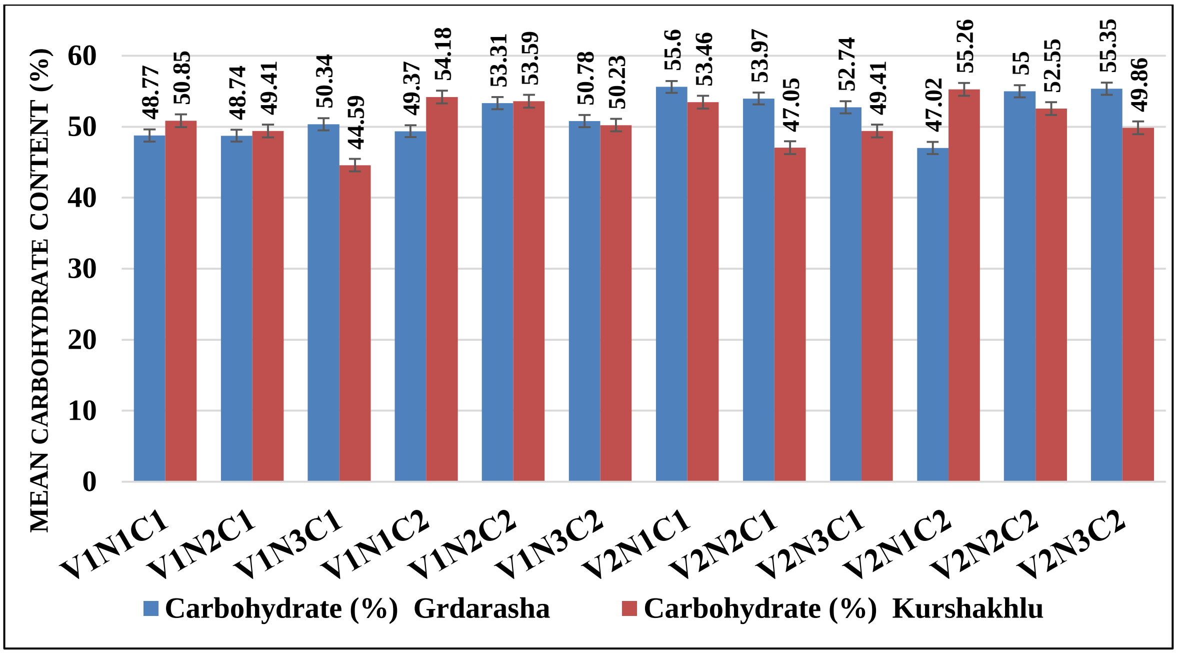

Figure 5. Effects of nitrogen, cutting frequency and varieties on Carbohydrate (%) at Grdarasha and Kushaxlu locations.

4. DISCUSSION

The results in this study were similar with Afzal *et al*. (2012) who reported that one of the most important factors impacting the nutritional value of fodder crops is protein content. The highest crude protein concentration was found in (100 kg N ha^{-1}).While the lowest crude protein concentration was found in (0 kg N ha^{-1}). Significant differences for crude protein contents among the sorghum cultivar reported by Neylon *et al*. (2002), Reddy *et al*. (2005) who reported that nitrogen significantly improved the crude protein content (%) The increase in protein content with increasing the nitrogen level could be due to nitrogen application enhancing amino acid formation and thus increasing protein content. Similar results were also reported by Almodares *et al*. (2009), Mahmud *et al*. (2003) and Duraisami *et al*. (2002). These findings are consistent with those of who discovered significant differences in crude protein contents among sorghum cultivars and nitrogen significantly improved crude protein content percent. Protein content differences among sorghum genotypes were also suggested by (Zulfiqure and Asim 2002; Carmi *et al*., 2005; Miron *et al*., 2006 and Yosef *et al*., 2009). (AL-Janabi and Aswad, 2012) and on the crude protein .Mohammed *et al*.(2014) in an investigation showed that different harvesting times also had a significant impact on crude protein content. The crude protein contents were decreased as the period before harvest was extended. According to AL-Fahdawi (2011) and AL-Dulimi (2012) the crude protein percentage is highest during the early stages of plant development, and then decreases as the plant matures. Ahmed *et al*.(2019) appeared that forage quality is influenced by a number of factors, including forage cultivars and environmental conditions such as fertility. A study was done by Shivprasad and Singh, (2017) the effect of two cuttings on quality fodder sorghum was included, and the results confirmed a significant difference between the two cutting dates on (crude protein and crude fiber); the maximum percentage for crude protein was in the first cutting, while the maximum percentage for crude fiber was in the second cutting. Asal, (2019) reported that the effect of different cutting stages on sorghum quality. The result showed that the vegetative period had the lowest percentage of crude protein and crude fiber. Rana *et al*. (2013) analyzed the effect of cutting time on sorghum quality. Ziki *et al*. (2019) carried out an experiment set up an experiment to see how cutting affects the quality of feed sorghum. Afzal *et al*. (2013) conducted an experiment the effect of three cutting methods on forage quality. The results revealed that the second cutting had the highest crude protein level, while the first had the highest ash content. Mohammed, *et al*.(2014) conducted an experiment showed that the use of nitrogen had a significant impact on the neutral detergent fiber. The greatest concentration of neural detergent fibers was measured in the control, and it declined as nitrogen levels increased. As a result, it appears that nitrogen fertilizer application improves the quality of sweet sorghum forage due to a reduction in fiber content, as has also been reported by (Almodares *et al*., 2009). (Khan *et al*., 2007) and percentage of fiber (Al- Fahdawi, 2011). But decrease in percentage of crude fiber (AL-Dulimi, 2012). These results are comparable with Choi *et al*. (1991) also Khrbeet and Jasim (2015) have an explanation for the higher fiber percentage they discovered that as plant life progresses, the percentage of cellulose, hemicelluloses, and lignin, which are essential components of fiber, increases. Mohammed *et al*. (2014) reported that that higher nitrogen levels enhanced the concentration of ether extractable fat. Ether extract decreased as maturity progressed, and all harvests differed significantly from one another. Bajwa *et al*. (1983) studied that decrease in fat content with delayed harvesting. Ayub *et al*. (2002) who found that the effect of nitrogen application on ash percent contents shows a significant effect on sorghum forage nitrogen application at the rate of 100 kg N ha^{-1} has the highest ash percent contents followed by nitrogen application at the rate of 50 kg N ha^{-1} ash percent contents. The increase or decrease in ash content (percent) could be attributed to an increase or decrease in dry matter production. Increased nitrogen levels were also linked to an increase in ash content, harvesting causes a rise in ash content. Nitrogen application causes an increase in ash (Ayub *et al* 1999). Mohammaed *et al*.(2014) informed that delayed harvesting resulted in a lower ash percentage .As well as, Mohammed, *et al*. (2014) investigated that nitrogen levels and harvesting had a significant impact on total ash percent. The results resemble to those of Chattha *et al*. (2017) delayed.AL-Janabi *et al*.(2014) AL-Fahdawi (2011), described how delaying cutting had a substantial impact on carbohydrate percentage increases. Crawford *et al*.(2018) illustrated that cutting time is an important management practice that affects forage quality. Afzal *et al*. (2012) noticed that cutting sorghum crops earlier would improve fodder quality. Mohammed *et al*. (2014) were explaining that cutting stage had an effect on forage quality and cutting at the vegetative stage resulted in forage with a high nutritional value.Atis *et al*. (2012) compared forage sorghum cultivars to determine the effects of harvesting at four different growing stages on the change in forage quality; they discovered that physiologic maturity stage (PM) is the best harvesting time for high fodder quality.

5. CONCLUSIONS

According to the results generally the quality characters (Protein, Fiber, Ether extracts, Ash and Carbohydrate,) significantly influenced by nitrogen, cutting frequency, varieties and their interaction. There more, N3 and N2 recorded highest protein and fat respectively. C2 recorded height carbohydrate. V1 recorded highest crude protein fat and ash, while V2 recorded lowest fiber and heigher carbohydrate. Thereby, it is suggested that nitrogen fertilizer might be applied when planting different sorghum cultivars for green forage purpose are 100 kg ha^{-1} because the highest protein content and multi-cut highest carbohydrate content are essential components of increased fodder for the animal.

Acknowledgements

Authors would like to thank the all staffs at the both researching fields, Grdarasha Field, College of Agricultural Engineering Sciences, Salahaddin University – Erbil and also Kurshaxlu Field, for preparing the field and equipment during the research.

Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

A. O. A. C. (1975). Association of Official Agricultural Chemists and Horwitz, W.,*Official methods of analysis* (Vol. 222). Washington, DC: Association of Official Analytical Chemists.

A. O. A. C. (1980). Association of Official Analytical Chemists and Association of Official Agricultural Chemists (US. *Official methods of analysis* (Vol. 13).

A.O.A.C, C., 1990. Xanthophylls in Dried Plant Materials and Mixed Feeds. Method 970.64. *Official Methods of Analysis of the Association of Official Analytical Chemists, 15th ed., Association of Official Analytical Chemists, Inc. Arlington, VA, USA*, pp.1048-1049.

Afzal, M., Ahmad, A. and Ahmad, A.H., 2012. Effect of nitrogen on growth and yield of sorghum forage (Sorghum bicolor (L.) Moench CV.) Under three cuttings system. *Cercetări Agronomice in Moldova*, *45*(4), pp.57-64.

Afzal, M.A.U.H., Ahmad, A.U.H. and Zamir, S.I., 2013. Performance of multicut forage sorghum under various sowing methods and nitrogen application rates. *The Journal of Animal & Plant Sciences*, *23*(1), pp.232-239.

Ahmed, S.E.E., Naim, A.M.E. and Jabereldar, A.A., 2019. Some quality aspects of different sorghum forage (sorghum bicolor L. moench) genotypes grown under rain-fed and irrigation condition. *Adv Plants Agric Res*, *9*(1), pp.101-104.

Al-Dulimi, N.M.A., 2012. *The effect of seed soaking with pyridoxine, height and stage cutting in yield, forage quality and HCN content of sorghum* (Doctoral dissertation, Ph. D. Thesis. Coll. of Agric. Univ. of Al-Anbar).

Al-Fahdawi, O.A.K., 2011. *Effect of sowing dates and cutting stages on forage yield and quality of two cultivars of sorghum* (Doctoral dissertation, M. SC. Thesis. Coll. of Agric. Anbar Univer-sity).

AL-Janabi, M.A. and Aswad, I.K., 2012. Effect of sowing and cutting dates in quality characters of (Sorghum bicolor) sorghum in Autumn season. *Tikrit Journal for Agricultural Sciences*, *12*(1).

AL-Janabi, M.A.A. and AL-Fahdawi, B.A.S., 2014. Effect of some levels of Nitrogen fertilizer and Cutting dates in some quality traits on green forage of Sorghum bicolor L. *Tikrit Journal for Agricultural Sciences*, *14*(2).

Almodares, A., Jafarinia, M. and Hadi, M.R., 2009. The effects of nitrogen fertilizer on chemical compositions in corn and sweet sorghum. *American-Eurasian Journal of Agricultural & Environmental Sciences*, *6*(4), pp.441-44.

Asal, S.T., 2019. Effect of Cutting Stages and Sowing Dates on Forage Yield and Quality of Sorghum (Sorghum bicolor L.). *Tikrit Journal for Agricultural Sciences*, *19*(2), pp.93-99.

Atis, I., Konuskan, O., Duru, M., Gozubenli, H. and Yilmaz, S., 2012. Effect of harvesting time on yield, composition and forage quality of some forage sorghum cultivars. *International Journal of Agriculture and Biology*, *14*(6).

Ayub, M., Nadeem, M.A., Sharar, M.S. and Mahmood, N., 2002. Response of maize (Zea mays L.) fodder to different levels of nitrogen and phosphorus. *Asian Journal of Plant Sciences*, *1*(4), pp.352-354.

Ayub, M., Nadeem, M.A., Tanveer, A. and Husnain, A., 2002. Effect of different levels of nitrogen and harvesting times on the growth, yield and quality of sorghum fodder. *Asian J. Plant Sci*, *1*(4), pp.304-307.

Ayub, M., Tanveer, A., Kahmud, K., Ali, A. and Azam, M., 1999. Effect of nitrogen and phosphorus on the fodder yield and quality of two sorghum cultivars (Sorghum bicolor L.). *Pakistan Journal of Biological Sciences (Pakistan)*.

Bajwa, M.S., Hussain, M.R. and Akhtar, M., 1983. Effect of different nitrogen levels and harvest stages on the yield and quality of sorghum fodder. *Pakistan Journal of Scientific and Industrial Research*, *16*(3), pp.148-151.

Barnaud, A., Deu, M., Garine, E., Chantereau, J., Bolteu, J., Koïda, E.O., McKey, D. and Joly, H.I., 2009. A weed–crop complex in sorghum: the dynamics of genetic diversity in a traditional farming system. *American Journal of Botany*, *96*(10), pp.1869-1879.

Carmi, A., Umiel, N., Hagiladi, A., Yosef, E., Ben-Ghedalia, D. and Miron, J., 2005. Field performance and nutritive value of a new forage sorghum variety 'Pnina'recently developed in Israel. *Journal of the Science of Food and Agriculture*, *85*(15), pp.2567-2573.

Chattha, M.U., Iqbal, A., Hassan, M.U., Chattha, M.B., Ishaque, W., Usman, M., Khan, S., Fayyaz, M.T. and Ullah, M.A., 2017. Forage yield and quality of sweet sorghum as influenced by sowing methods and harvesting times. *Journal of Basic and Applied Sciences*, *13*, pp.301-306.

Choi, S.J., Lee, S.S. and Back, J.H., 1991. Forage productivity of silage corn and sorghum at different planting dates in rice black-streaked dwarf virus prevalent area. *Journal of the Korean Society of Grassland Science (Korea Republic)*.

Crawford, S.A., Shroff, J.C. and Pargi, S.B., 2018. Effect of nitrogen levels and cutting management on growth and yield of multicut forage sorghum [Sorghum bicolor (L.) Moench] variety cofs-29. *International Journal of Agricultural Sciences*, *14*(1), pp.118-122.

De Wet, J.M., Harlan, J.R. and Price, E.G., 2011. Variability in Sorghum bicolor. In *Origins of African plant domestication* (pp. 453-464). De Gruyter Mouton.

Doggett, H., 1988. Sorghum. Harlow, Essex, England New York: Longman Scientific & Technical. *Wiley*, *18*, p.512.

Duraisami, V.P., Raniperumal, M.A. and Mani, A.K., 2002. Grain quality as influenced by fertilizer nitrogen, coir pith and bio fertilizer in sole and intercropped sorghum-maize-soybean sequence. *Mysore J Agric Sci*, *36*, pp.97-103.

FAO, F.E., 2008. Disponível em :< http://faostat. Fao. Org>. *Acesso em*, *6*.

Ghani, A., Saeed, M., Hussain, D., Arshad, M., Shafique, M.M. and Shah, S.A.S., 2015. Evaluation of different sorghum (Sorghum bicolor L. moench) varieties for grain yield and related characteristics. *Sci. Lett*, *3*, pp.72-74.

HUANG, R.D., 2018. Research progress on plant tolerance to soil salinity and alkalinity in sorghum. *Journal of Integrative Agriculture*, *17*(4), pp.739-746.

Karthika, N. and Kalpana, R., 2017. HCN content and forage yield of multi-cut forage sorghum under different organic manures and nitrogen levels. *Chem. Sci. Rev. Lett*, *6*(23), pp.1659-1663.

Kaur, R., Goyal, M. and Tiwana, U.S., 2016. Influence of seasonal variation on oxalate accumulation in Napier Bajra hybrid under different nitrogen nutrition. *Range Management and Agroforestry*, *37*(1), pp.62-68.

Khan, S.H., Khan, A.G., Sarwar, M. and Azim, A., 2007. Effect of maturity on production efficiency, nutritive value and in situ nutrients digestibility of three cereal fodders. *International Journal of Agricultural Research*, *2*(11), pp.900-906.

Khrbeet, H.K. and Jasim, A.M., 2015. Effect of sowing dates and cutting stages on forage yield and quality of sorghum (Var. Abu-Sabeen) 1- growth traits and green forage yield. *Iraqi Journal of agriculture sciences, 46*(4), pp.475-483.

Kumar, D.U.R.G.E.S.H. and Chaplot, P.C., 2015. Effect of fertility levels on quality of multi-cut forage sorghum genotypes. *Forage Research*, *40*(4), pp.251-253.

Mahfouz, H., Ali, A.M.M., Megawer, E.A. and Mahmoud, A.S., 2015. Response of growth parameters, forage quality and yield of dual-purpose sorghum to re-growth and different levels of FYM and N fertilizers in new reclaimed soil. *International Journal Current Microbiology and Applied Science*, *4*(11), pp.762-782.

Mahmud, K., Ahmad, I. and Ayub, M., 2003. Effect of nitrogen and phosphorus on the fodder yield and quality of two sorghum cultivars (Sorghum bicolor L.). *International Journal of Agriculture and Biology*, *5*(1), pp.61-63.

Malik, H.P.S., Singh, H. and Singh, O.P., 1992. Response of multicut fodder sorghum (Sorghum bicolor) cultivars to nitrogen and cutting management. *Indian Journal of Agronomy*, *37*(3), pp.470-473.

Malik, M.F.A., Hussain, M.A.N.Z.O.O.R. and Awan, S.I., 2007. Yield response of fodder sorghum (Sorghum bicolor) to seed rate and row spacing under rain-fed conditions. *Journal of Agriculture and Social Sciences*, *3*(3), pp.95-97.

Minitab, I. (2014). MINITAB release 19: statistical software for windows. *Minitab Inc, USA*.

Miron, J., Solomon, R., Adin, G., Nir, U., Nikbachat, M., Yosef, E., Carmi, A., Weinberg, Z.G., Kipnis, T., Zuckerman, E. and Ben‐Ghedalia, D., 2006. Effects of harvest stage and re‐growth on yield, composition, ensilage and in vitro digestibility of new forage sorghum varieties. *Journal of the Science of Food and Agriculture*, *86*(1), pp.140-147.

Mohammed, M.I. and Zakaria, Z.A., 2014. Quality attributes in Sudanese sorghums improved for forage yield. *American Journal of Experimental Agriculture*, *4*(2), p.171.

Neylon, J.M. and Kung Jr, L., 2003. Effects of cutting height and maturity on the nutritive value of corn silage for lactating cows. *Journal of Dairy Science*, *86*(6), pp.2163-2169.

Neylon, J.M., Ebling, T.L., Taylor, C.C., Lynch, M.P., Reddish, M.A., Endres, M.I. and Kung, L., 2002. The effects of height of cutting, hybrid, and stage of maturity at harvest on the nutritive value of corn silage for lactating dairy cows. *J. Dairy Sci*, *85*(Suppl 1), p.383.

Oberoi, H.K., Kaur, M. and Agrawal, R.K., 2020. Hydrocyanic acid, fodder quality and yield variation in sorghum genotypes grown under varying fertilizer levels. *Range Management and Agroforestry*, *41*(2), pp.322-327.

Rana, D.S., Singh, B., Gupta, K., Dhaka, A.K. and Arya, A.K., 2012. Response of multicut forage sorghum genotypes to different fertility levels. *Forage Res*, *37*(4), pp.251-254.

Rana, D.S., Singh, B., Gupta, K., Dhaka, A.K. and Pahuja, S.K., 2013. Effect of fertility levels on growth, yield and quality of multicut forage sorghum [Sorghum bicolor (L.) Moench] genotypes. *Forage Research*, *39*(1), pp.36-38.

Reddy, S.S., Shivaraj, B., Reddy, V.C. and Ananda, M.G., 2005. Direct effect of fertilizers and residual effect of organic manures on yield and nutrient uptake of maize (Zea mays L.) in groundnut-maize cropping system. *CROP RESEARCH-HISAR-*, *29*(3), p.390.

Shivprasad, M. and Singh, R., 2017. Effect of planting geometry and different levels of nitrogen on growth, yield and quality of multicut fodder sorghum (Sorghum bicolor (L.) Monech). *Journal of Pharmacognosy and Phytochemistry*, *6*(4), pp.896-899.

Singh, P. and Sumeriya, H.K., 2012. Effect of nitrogen on yield, economics and quality of fodder sorghum genotypes. *Annals of plant and soil Research*, *14*(2), pp.133-135.

Yang, G.D., Hu, Z.Y., Huang, R.D., Hao, Z.Y., Li, J.H., Wang, Q., Meng, X.X. and Zhou, Y.F., 2020. Effect of nitrogen on the starch formation and yield high-density sorghum [sorghum bicolor (L) MOENCH] in northern china. Applied ecology and environmental research, *18*(4), pp.5727-5741.

Yosef, E., Carmi, A., Nikbachat, M., Zenou, A., Umiel, N. and Miron, J., 2009. Characteristics of tall versus short-type varieties of forage sorghum grown under two irrigation levels, for summer and subsequent fall harvests, and digestibility by sheep of their silages. *Animal feed science and technology*, *152*(1-2), pp.1-11.

Zerbini, E. and Thomas, D., 2003. Opportunities for improvement of nutritive value in sorghum and pearl millet residues in South Asia through genetic enhancement. *Field Crops Research*, *84*(1-2), pp.3-15.

Ziki, S.J.L., Zeidan, E.M.I., El-Banna, A.Y.A. and Omar, A.E.A., 2019. Influence of cutting date and nitrogen fertilizer levels on growth, forage yield, and quality of sudan grass in a semiarid environment. *International Journal of Agronomy*, *2019*.

Zou, M.L., Moughan, P.J., Awati, A. and Livesey, G., 2007. Accuracy of the Atwater factors and related food energy conversion factors with low-fat, high-fiber diets when energy intake is reduced spontaneously. *The American journal of clinical nutrition*, *86*(6), pp.1649-1656.

Zulfiqar, A.M. and Asim, M., 2002. Fodder yield and quality evaluation of the sorghum varieties. *Journal of Agronomy*.