Effect of Different Nitrogen Levels on Yield and Quality of Forage Sorghum (*Sorghum bicolor* L. Moench cv. Abusabien)

Abstract

The present study was conducted at the Experimental Farm of the Department of Crop Science, Faculty of Natural and Environmental Studies, University of Kordofan, Elobeid, Sudan. To evaluate the effect of different nitrogen fertilizer levels on growth, yield and quality of Sorghum forage (*Sorghum bicolor* L. Moench. cv Abusabien). The treatments consisted of four levels of nitrogen: control, 43, 86 and 120 kg N/ha (0N, 1N, 2N and 3N). The treatments were arranged in a Randomized Complete Block Design (RCBD) with five replications. The parameters measured were: plant population, plant height (cm), number of leaves/ plant, fresh weight (ton/ha), dry weight (ton/ha), crude protein (%) content, fat (%) content, fiber (%) content, ash (%) content and carbohydrates (%) content. the results revealed that there were significant differences among the treatments in most characters under study. Nitrogen fertilizer resulted in an increase in growth attributes as well as forage yield. Nitrogen fertilizer dose (120 kg N/ha) produced higher fresh and dry forage at harvest compared to the other treatments. Also the results showed that nitrogen fertilizer significantly increased the percentage (%) content of crude protein, fat, ash and carbohydrates while decreased fiber percentage (%) concentration compared to the control. The treatment 120 kg N/ha (3N) had highest values of protein (13.68), fat (2.04), ash (12.18) (%) content, while the lowest values (9.73, 1.32 and 10.07) % content respectively, were obtained in the control. Then, based on these findings we recommended that to obtain high growth, forage yield and quality from sorghum forage Abu-Sabeen, nitrogen at the level of (120 kg/ha) should be applied.

Keywords: Nitrogen Levels, Growth, Yield, Quality, Sorghum Forage

1. Introduction

"Sorghum (*Sorghum bicolor* L. Moench) it is a member of the Poaceae family, is an essential annual plant that ranks fifth in the world's-wide cereal crops after maize, rice, wheat and barley" [1]. "Sorghum forage is a drought-resistant crop in the family of Poaceae" [2]. "Sorghum fodder is well-known for its high stress resistance and adaptability, and one of its most important characteristics is salt stress tolerance leading to increasing sorghum production on saline-alkaline soil so it is best preferences for making the most of marginal land" [3]. "Sorghum is largely cultivated in arid, semiarid, tropical, subtropical, and temperate areas. It is an important supply of feed and food" [3]. "In Sudan the main fodder crops produced was (*Sorghum bicolor* L. Moench cv. Abusabien) represent about 43% of the total annual yield and take up an area 70 thousand hectares, also it is most important annual cereal forage crop for Livestock production because of the facts that Sudan has a huge numbers of animal wealth, wild fire, overgrazing of natural pasture, and drought leading to reduction of range land" [4, 5]. "Application of Fertilizer is the most important factor clearly influences the forage yield. Nitrogen is an important nutrient for growth, physiological and yield point of view" [6]. However at the same time an optimum plants stand establishment is similarly important to get high yield [7]. Several factors affected quality of sorghum forage including fertilization, genotype irrigation, and plant population.. Use of nitrogen application has a direct affect on fodder quality [8]. [9] mentioned that "the enhance in protein concentration with increasing the nitrogen rate might be due to nitrogen use improving amino acid creation and consequently increasing protein concentration".

[10]. reported that higher levels of nitrogen improved the content of ether extractable fat. [11] mentioned that "the influence of nitrogen application on ash concentration demonstrates a considerable influence on sorghum fodder nitrogen application at the level of 100 kg N/ha has the highest ash percent concentrations followed by application of nitrogen at the level of 50 kg N/ha ash percent concentrations"..

Therefore, Kordofan sandy soil lack in nitrogen level and other nutrients elements so optimum levels of nitrogen fertilizer would be of great significant for high fodder yield and quality. The objective of this study was to investigate the effect of different level of nitrogen fertilizer on growth, yield and forage quality of Abusabien cultivar

2. Materials and methods

2.1 Experimental site

Afield experiment was conducted at the Experimental Farm of Crop Science, Faculty of Natural Resources and Environmental Studies, University of Kordofan, El-Obeid, Sudan during the period (March-June 2023) to study the effect of different nitrogen levels on growth, yield and quality of sorghum forage. The site is located in the arid and semi arid (latitude 11 - 15 and 16 - 30 N and longitude 27 - 32 E). The soil of experimental site is sandy, annual rain fall is about 350 - 450 mm [12], and maximum daily temperature is about 30 - 50 C^0 throughout the year.

2.2. Experimental Design

Treatments consisted of four levels of nitrogen, control (0N), 43, 86 and 120 kg N/ha, designed as (0N, 1N, 2N and 3N). The treatments were arranged in a Randomized Complete Block Design (RCBD) with five replications. Urea (46% N) was applied as the source of nitrogen. Seed of Sorghum forage cultivar (Abusabien) used in this experiment was obtained from the local market. The experiment was sown on the 20th of March 2023 (summer).The experimental site was plot leveled and ridged into 70 cm. The size of each experimental unit was 4 x 5 meters consisting of 6 ridges of 4 meters in length. In each plot, 2nd and5th ridges were used for sampling. The spaces between experimental units were one meter and between replication was two meter. Sowing was done manually on one side of the ridge (eastern side of ridge) and it was done on 20-3-2023 the seed rate applied was 45 kg/ha. The crop was irrigated immediately after sowing and then at 5 -7 day intervals according to the crop needs. Each plot was irrigated separately to avoid nitrogen movement to adjoining plots. Nitrogen fertilizer was applied after ridging. The experimental plots were weed free by hand weeding

2.3. Studied characters:-

2.3.1 Plant population

An area of one-meter row ($0.7m^2$) was permanently marked in each treatment in one of the two middle ridges. Plants were calculated after 7, 21 days after planting, and at harvest.

2.3.2 Plant height (cm)

Plant height was measured as an average height of ten plants per plot at the 30, 60 days after sowing and at harvest taken from the soil surface to the tip of the flag leaf.

2.3.3 Number of leaves/ plant

It was obtained by calculating all leaves of ten randomly selected plants after 30, 60 days after planting and at harvest and then the average number of leaves per plant was determined.

2.3.4 Fresh forage yield (ton/ ha)

First and second cuts of the fresh forage of the one meter row ($0.7m^2$) was chosen from one ridge as destructive samples and cut after 30, 60 days after sowing. At the harvest the whole plot for each treatment was clipped by A sickle, weighted immediately by a spring balance in the field to get the fresh weight. Final fresh yield was measured in ton per hectare.

2.3.5 Dry forage yield (ton/ ha)

The fresh forage of one meter row ($0.7\ m^2$) was left to dry in an oven at 80 ^{0}C for 36 hours until a constant weight was reached then final dry yield was measured in tons per hectare .

2.4 Forage quality parameters

samples of quality characteristics were taken from leaves and stem when it was oven dried for 2 days at 80 ^{0}C, were calculated for all samples after drying and grinding the samples were ground to small portion then mixed together to be utilized in chemical analysis.

2.4.1 Protein percentage (%)

The % of nitrogen was measured by micro Kjeldal apparatus using the method of [13]. Protein (%) was calculated using the following equation:

Protein (%) = Nitrogen (%) × 6.25

2.4.2 Fiber percentage (%)

"2 gram (fat free) sample was dissolved in 200 ml of 1.25(%) H_2SO_4 and putted in 500 ml capacity beaker. The mixture was heated for 30 minutes with constant stirring; also the water level was complemented, 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". [31] 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)

[14].

2.4.3 Ash percentage (%)

A. 2 gram (stems and leaves) samples were putted into crucible, ignited, cooled in desiccators and weighed at room temperature.

"B. after that sample was transferred to muffle furnace at 605°C but steadily from 100°C, incinerated until light grey ash was funded. The sample was placed in desiccators and weighed at room temperature" [15].

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

2.4.4 Ether extraction (%): Fat was extracted using Soxhlet apparatus. By method of [13].

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

2.4.5 Total carbohydrates percentage (%)

After the calculation of the protein, fiber, ash and ether extracts percentage the percentage of the total carbohydrates was measured according to [16] using the following equation:

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

2.4 Statistical analyses

Data were collected and analyzed using analysis of variance (ANOVA) and SPSS (SPSS Inc, Chicago, IL). Significant different means of the measured data were separated at the 0.05 probability level by the Least Significant Different (LSD).

3. Results

3.1 Effect of different nitrogen levels on growth attributes

3.1.1 Plant population

Effect of different nitrogen levels on plants density of forage sorghum is shown in table (1). Number of plants per unit area (0.7 m^2) showed a steady increase with time, regardless of treatment used, up to second counting occasions. Thereafter, a drop in number of plants per unit area was observed (count 3 Table 1). The results showed significant differences among treatments for number of plants per unit area.

Nitrogen fertilizer significantly increased the number of plants per unit area over the control throughout different sampling occasions. The lowest number of plants per unit area was recorded for control, where the highest number was recorded for the highest level of nitrogen (120 kg N/ha)

3.1.2 Plant height

Plant height data shows considerable differences among the different fertilizer treatments (Table 2). Plants fertilized with various nitrogen levels were significantly taller than those of the control. Moreover, 120 kg N/ha treatment resulted the tallest plant followed by 86 kgN/ha, 43 kgN/ha treatments and the control, which resulted in the shorter plants.

3.1.3 Number of leaves/ plant

The effect of different nitrogen levels on number of leaves / plant of forage sorghum (Abusabien) is presented in table 3.

Significant differences for 3N and 2N of nitrogen levels treatments over the control were obtained for the trait during the third count but the first and second count the difference was not significant. For all treatments, the number of leaves per plant increased slightly. The 3N (120 kg N/ha) gave higher number of leaves per plant in the different counting occasions compared to other treatments.

Table 1. Effect of different nitrogen levels on number of plants / m^2 at different counts during growing season.

Treatments	1 st count at 7 days	2 nd count at 21 days	3 rd count at harvest
0N	30.16d	33.16d	29.05d
1N	35.07c	38.02c	33.06c
2N	40b	43.05b	37.09b
3N	47a	51.07a	45.08a
LSD	2.93	2.65	3.96
CV%	3.10	6.80	11.64
SE±	1.55	1.41	2.1

Different small letters in the same column refer to significant differences between treatments at $P < 0.05$ level.

Table 2. Effect of different nitrogen levels on plant height (cm) at different counts during growing season.

Treatments	1 st sampling at 30 days	2 nd sampling at 60 days	3 rd sampling at harvest
0N	20.15c	100.03c	112.15d
1N	22.33c	112.27b	132.11c
2N	26.17b	116.05ab	140.23b
3N	31.12a	121.16a	146.21a
LSD	3.52	5.62	4.08
CV%	15.07	5.31	3.26
SE±	1.87	2.98	2.16

Different small letters in the same column refer to significant differences between treatments at $P < 0.05$ level.

Table 3. Effect of different nitrogen levels on number of leaves/plant at different counts during growing season.

Treatments	1 st count at 30 days	2 nd count at 60 days	3 rd count at harvest
0N	6.18b	9.02c	9.26c
1N	7.08a	9.33bc	10.03bc
2N	7.2a	9.62b	10.63ab
3N	7.18a	10.25a	11.01a
LSD	0.29	0.34	0.87
CV%	4.51	3.78	11.64
SE±	0.15	0.18	0.04

Different small letters in the same column refer to significant differences between treatments at $P < 0.05$ level.

3.2 Effect of different nitrogen levels on yield attributes

3.2.1 Fresh forage yield

Effect of different nitrogen levels on fresh forage yield of forage sorghum is shown in figure 1. The results showed that there were significant differences between the control and the other treatments. All treatments during first and second sampling

resulted in higher fresh yield compared to the control (Fig. 1). On the other hand, all treatments had a significant effect on final fresh yield when compared to the control. At harvest, the nitrogen level 3N (120 kg N/ha) scored the highest yield compared to the control followed by 2N (86 kgN/ha) and 1N (43 kg N/ha).

3.2.2 Dry forage yield

Figure 2 showed that there was significant different on dry yield between nitrogen fertilizer treatments and the control during the first and second sampling. On the other hand, all treatments had a significantly higher final dry yield (ton/ ha) when compared to the control (Fig. 2). At harvest nitrogen level (120 kg N/ha) resulted in the highest dry yield, followed by (86 kg N/ha) and (43 kg N/ha). Generally, higher dry matter yield was obtained at final harvest during the growing period compared to the first and second samplings (Fig. 2)

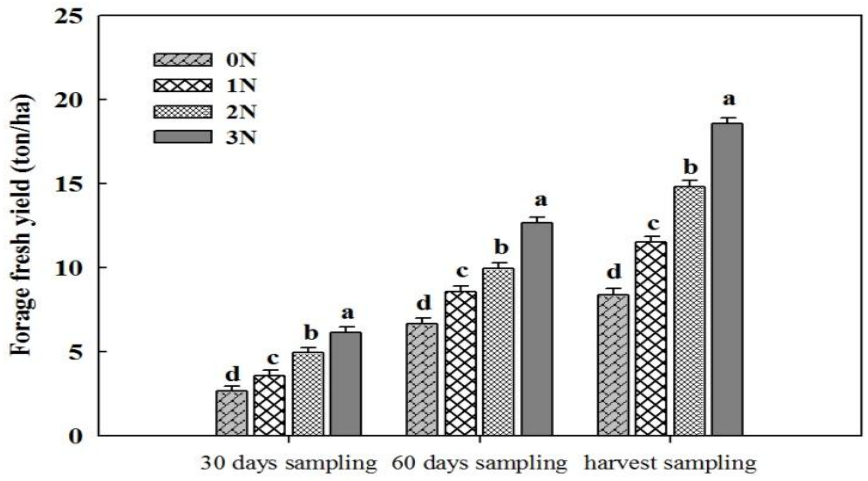

Fig.1. Effects of different nitrogen levels on forage fresh yield during growing season in sorghum forage abusabien. Data are mean +SD (n=3). Different small letters indicate significant differences between treatments at $P < 0.05$

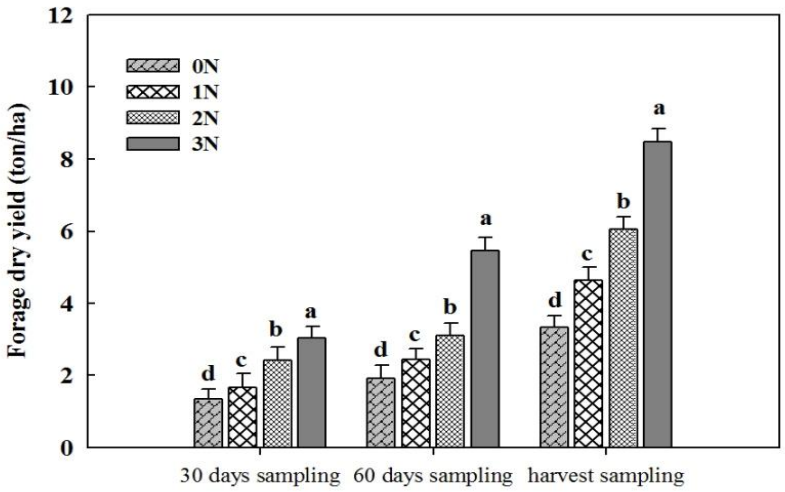

Fig.2. Effects of different nitrogen levels on forage dry yield during growing season in sorghum forage abusabien. Data are mean +SD (n=3). Different small letters indicate significant differences between treatments at $P < 0.05$

3.3 Effect of different nitrogen levels on quality attributes

3.3.1 Protein percentage (%)

The results of Figure 3 showed that the percentage of crude protein contents increased with increasing the rate of nitrogen. Plants fertilized with 120 kg N/ha demonstrated highest crude protein (%)) (13.68) which was considerably higher than all other treatments, and lowest value was obtained in control (9.73) crude protein (%).

3.3.2 Fat (%)

The results showed that fat percentage extremely affected by different level of nitrogen (Fig. 4). Fat (%) improved when the plants were fertilized by 43 to 120 kg N/ha. The highest percentage of fat (2.04) was recorded when the plants was fertilized by 120 kg N/ha, and lowest (%) (1.32) was obtained in the control (Fig. 4).

3.3.3 Fiber percentage (%)

As shown in Figure 5, all fertilizer treatments significantly reduced the fiber percentage (%) compared to the control. On the other hand, the results of nitrogen treatments showed that 120 kg N/ha recorded lowest fiber (%) (18.52) and the highest value was obtained in 0N kg N/ha (24.71) fiber (%) of control.

3. 3. 4 Ash percentages (%)

The results of Figure 6 showed that nitrogen levels treatments considerably difference in ash content percentage when compared with control. Treatment 120 kg N/ha recorded highest ash percentage (%) (12.18) followed by 86 kg N/ha (11.59) ash (%) and 43 kg N/ha (11.19) ash percentage (%).

3.3.5 Carbohydrate percentage (%)

Figure 7 reported that there were considerably differences between the fertilizer treatments for carbohydrate percentage (%) when compared to control. The results showed that carbohydrates content was highest in 86 kg N/ha (51.23) percentage (%) where the lowest was obtained in 0N kg N/ha (43.74) carbohydrate (%) in the control.

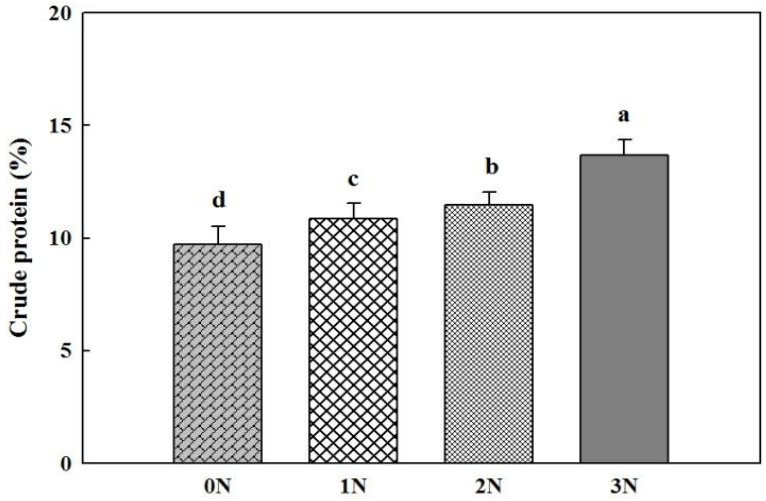

Fig.3. Effects of different nitrogen levels on crude protein (%) in sorghum forage abusabien. Data are mean +SD (n=3). Different small letters indicate significant differences between treatments at $P < 0.05$

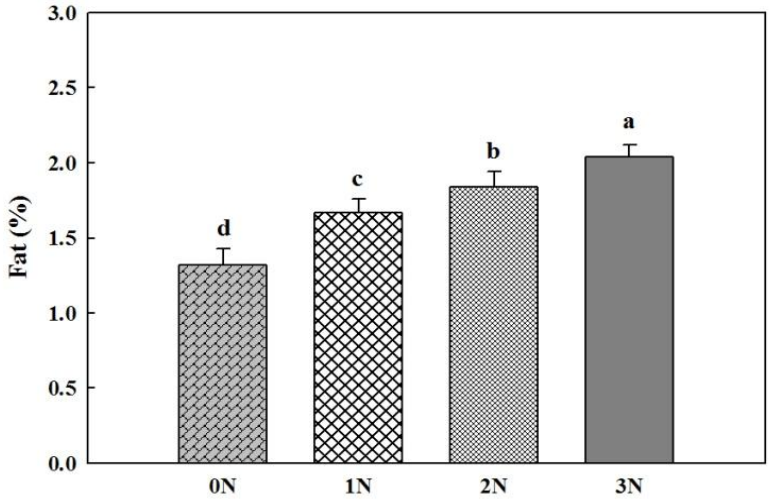

Fig.4. Effects of different nitrogen levels on fat (%) in sorghum forage abusabien. Data are mean +SD (n=3). Different small letters indicate significant differences between treatments at $P < 0.05$

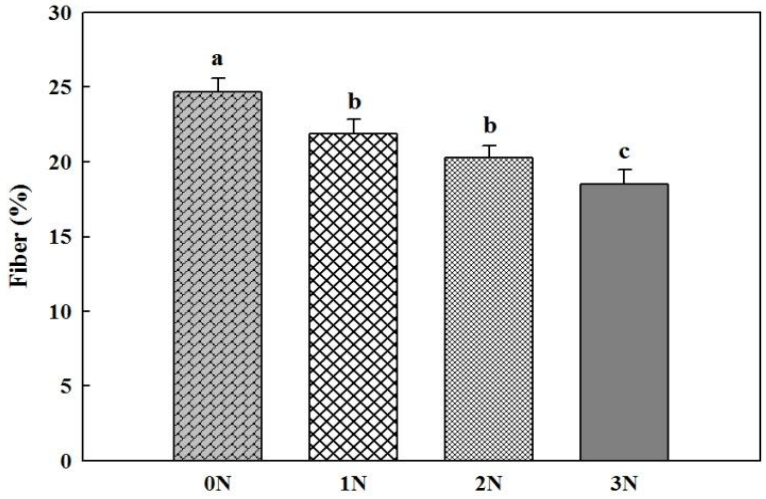

Fig.5. Effects of different nitrogen levels on fiber (%) in sorghum forage abusabien. Data are mean +SD (n=3). Different small letters indicate significant differences between treatments at $P < 0.05$

4. Discussion

In this study, the growth traits of forage sorghum (Abusabien) studied included plant population, plant height, number of leaves per plant. The change in these parameters is very significant aspect for fodder production, because they are vegetative characteristics that contribute components of herbage yield. The treatments of nitrogen fertilizer scored higher number of plants population, taller plants, and higher number of leaves per plant compared to the control. This result was consistent with the early study that nitrogen level 86 kg N/ha increased the number of plants population in sudan grass [17]. [18], reported that nitrogen fertilizer application improved the plant height. [19] also established that nitrogen fertilizer considerably increased plant height in forage sorghum. [20], reported that "nitrogen fertilizer application up to 100 kg/ha enhanced the plant height and numbers of leaves per plants of sudan grass". "These responses may refer to its that this crop as it is non – leguminous, may have obtained high nitrogen supply from the soil directly" [21].

Forage yield in terms of fresh and dry matter was investigated in this study. Forage yield is constantly related to growth characteristics. All nitrogen fertilizer treatments had a significant influence on forage yield (fresh and dry), as compared to the control. Generally Fertilization increased fodder yield during the growing season. Nitrogen fertilizer resulted in an increase in growth parameters as well as forage yield. Nitrogen level 3N (12o kg N/ha) produced higher fresh and dry fodder at harvest compared to the control. The results were also in agreement with mentioned by [22] who found that the highest yield of sorghum forage was obtained under nitrogen fertilizer while the lowest yield was obtained with control. In the Sudan the use of 88 kg N/ha considerably increased the dry matter yield of sorghum forage "Abusabien" and *Sorghum sudanense* [23].

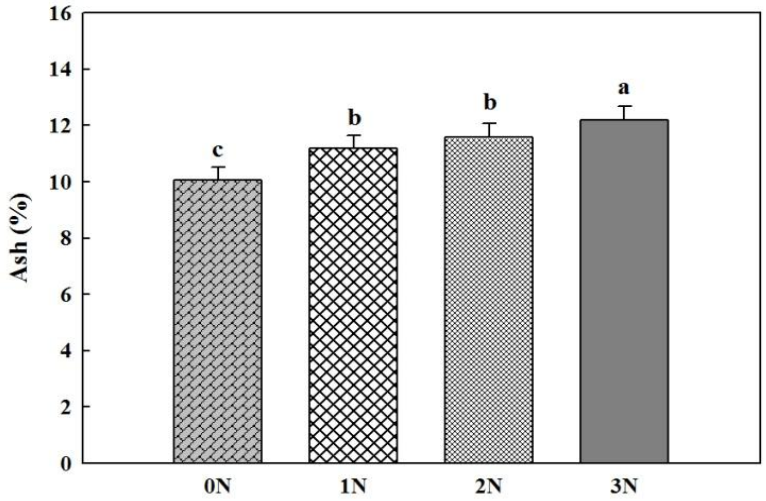

Fig.6. Effects of different nitrogen levels on ash (%) in sorghum forage abusabien. Data are mean +SD (n=3). Different small letters indicate significant differences between treatments at $P < 0.05$

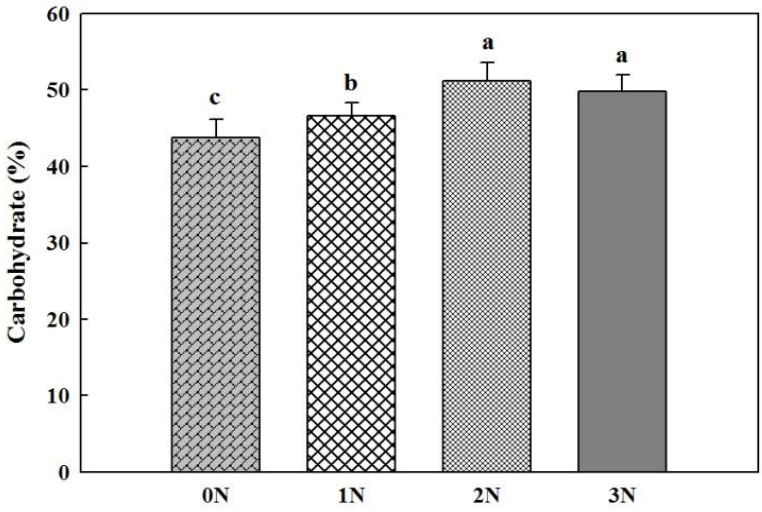

Fig.7. Effects of different nitrogen levels on carbohydrate (%) in sorghum forage abusabien. Data are mean +SD (n=3). Different small letters indicate significant differences between treatments at $P < 0.05$

The findings in this study were in agreement with [24] who found that "the most significant factors influencing the nutritional value of forage crop is protein content. The highest crude protein content was found in (120 kg N/ ha), while the lowest crude protein content was obtained in (0 kg N/ ha)". Significant differences for crude protein concentrations among the sorghum cultivar mentioned by [25], who found that "nitrogen fertilizer significantly, increased the crude protein concentration (%). The increase in protein content with increasing the nitrogen level might be due to nitrogen fertilizer enhancing the formation of amino acid and so increasing protein concentration". Comparable results were also found by [26]. Our results demonstrated that the fat percentage was increased with nitrogen fertilizer compared to the control. [27], reported that the higher level of nitrogen improved the ether extractable fat content. The higher fat percentage in fertilized plants with higher levels of nitrogen was maybe due to more synthesis of glycerol. These findings area in agreement with those of [28]. [27], conducted "an experiment demonstrated that the nitrogen fertilizer had a significant effect on the neutral detergent fiber. The higher content of neural detergent fibers was calculated in the control, and it decreased with increased in nitrogen level". "In this study, nitrogen fertilizer clearly reduced the fiber percent content as compared to the control. As a result, it shows that application of nitrogen fertilizer improves sweet sorghum forage quality due to a reduction in fiber concentration, as has also been mentioned" by [29]. Also [30] have "an elucidation for the higher fiber percentage they revealed that progress of plant life, the percentage of cellulose, hemicelluloses, and lignin, which are important components of fiber, enhances". [11] who found that "the effect of nitrogen fertilizer on ash percent concentrations illustrates a significant effect on sorghum forage, nitrogen fertilizer at the rate of 100 kg N/ ha has the highest percent contents of ash followed by nitrogen fertilizer at the rate of 50 kg N/ha ash percent contents. Our finding also appeared that nitrogen application enhances the ash content when compared to the control. The increase or decrease in content of ash might be attributed to an increase or decrease in production of dry matter". [30], mentioned that nitrogen fertilizer had a significant impact on carbohydrate percentage increases. Our results also showed that the application of nitrogen fertilizer improves carbohydrate percentage content.[24] found that application of nitrogen fertilizer to sorghum crops improve forage quality.

5. Conclusions

The results of this study clearly demonstrated that nitrogen fertilizer increased the growth attributes as well as forage yield (fresh and dry). Generally the quality characters protein, fat, fiber, ash and carbohydrate significantly influenced by nitrogen. There more, 3N recorded highest (%) of protein, fat and ash respectively. 2N registered height carbohydrate (%), while 0N (control) recorded lowest protein, fat, ash and carbohydrate and higher fiber. Based on these results, it is suggested that to obtain high forage growth, yield and quality nitrogen fertilizer at rate of 120 kg N/ha should be applied when planting sorghum forage abusabien for green forage purpose because the highest contents of protein and carbohydrate are essential components of increased quality of forage for the animal.

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