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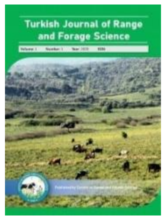

Effect of Nitrogen Fertilization on Growth and Forage Yield of Sorghum [*Sorghum bicolor* (L.) Moench.] under Takhar Agro-Ecological Conditions

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A B S T R A C T

A field experiment was carried out at Bagh-e-Zakhera research station, Takhar province of Afghanistan during 2020 to assess the effects of nitrogen (N) fertilization on growth and forage yield of sorghum under Takhar agro-ecological conditions. The experiment was laid out in randomized complete block design, using 4 replications. There were four levels of nitrogen N1 (control), N2 (50 kg N ha^{-1}), N3 (75 kg N ha^{-1}), and N4 (100 kg N ha^{-1}). The result of this research indicated that N fertilization significantly increased all growth parameters and forage yield of sorghum over control. Among the different levels of N fertilizer, application of N4 significantly enhanced the growth parameters such as plant height (245.26 cm), number of leaves (10.15 $plant^{-1}$), leaf area (3536.80 cm^2 $hill^{-1}$), dry matter accumulation (240.10 g $plant^{-1}$) at 90 days after sowing. Forage yield was significantly enhanced with increase in level of N fertilization and application of N4 resulted in the production of highest forage yield (6217.55 kg ha^{-1}). Whereas, no significant differences were detected with N4 and N3 treatments for stover yield. The crop growth rate of sorghum was significantly influenced by N fertilization, and the highest value for crop growth rate (69.09 g $plant^{-1}$ day^{-1}) was obtained with N4 treatment. From the results of this study, it was concluded that the growth and forage yield of sorghum can be enhanced with the application of 100kg of N ha^{-1} under agro-ecological conditions of Takhar province of Afghanistan.

1. Introduction

Sorghum forage is the basic feed for livestock and especially valuable for feeding in all regions of the world. Sorghum fodder, with a little protein supplement, maintains cattle in good condition throughout the winter with little or no gain supplement.

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Sorghum contains a reasonable amount of protein (7.5 10.8%), ash (1.2–1.8%), oil (3.4–3.5%), fiber (2.3–2.7%), and carbohydrate (71.4– 80.7%) with a dry matter ranging from 89.2% to 95.3% (AbdelRahaman et al., 2005). Sorghum stover contains 6.0-6.4% crude protein and 32-36% crude fiber (Sunil Kumar et al., 2012). It is widely grown in the semiarid regions of the world as animal feed, human food, or bioenergy feedstock. Its tolerance to drought and superior adaptation to marginal environments make it an attractive crop in rainfed production systems. Sorghum has adaptive traits for stressful environments and wide genetic variability for traits including tolerance to low nutrient supplies and efficiency in utilizing water and nutrients (Mahama et al., 2014). The great advantage of sorghum is that it can become dormant under adverse conditions and resume growth after a relatively severe drought (Bimbraw, 2013).

Sorghum is also consumed as staple food grain and is used for a variety of products like alcohol, edible oil, sugar, and waxes, etc. It is quite a soft, palatable, and fast-growing annual fodder crop adapted to areas up to 1500 m altitude. However, it remains green and palatable over a longer period than maize and pearl millet fodders (Bimbraw, 2013). High-quality forage is obtained from sorghum under good fertilizer management and a package of practices (Mukherjee and Maiti, 2008). The maximum nutrients in the fodder are available when the crop is cut at 50% flowering to the milk stage. The quality of fodder crop also partly depends on the amount of fertilizer applied to the crop. The Hydrogen cyanide (a poisonous compound to animals) contents in the dried or ensiled sorghum reduce sharply and silage or hay presents no danger to animals (Gupta and Singh, 2018).

Nitrogen (N) fertilizer is known to boost the aboveground biomass yield (Anderson et al., 2013). It plays a critical role in cell division during plant growth (Stals and Inzé, 2001) and the deficit of soil nitrogen leads to lower sorghum biomass due to reductions in leaf area, chlorophyll index, and photosynthetic rate (Mahama et al., 2014). Production of forage sorghum with applying a little amount of N fertilizer is manageable, but this crop displays a great deal of reaction in response to applied nitrogen (Ram and Sing, 2001). In irrigated areas, N fertilizer is very important and is the main factor affecting the dry matter yield of sorghum cultivars; N fertilizers are easily soluble and leachable in most of the soils and increase the forage yield of sorghum varieties (Rahman et al., 2001). Forage sorghum displayed a positive reaction to increasing nitrogen to about 200 kg ha^{-1} but the further application had no effect on yield increase (Gupta and Sing, 1988). Although, sorghum utilizes nitrogen more efficiently than corn and is more resistant to drought and higher temperatures (Young and Long, 2000) inadequacy of N fertilizer reduces the congregation of dry matter and leads to growth reduction (Zhao et al., 2005). Previous research has demonstrated that the application of N increased biomass and productivity of sorghum (Kaizzi et al., 2012). The nitrogen doses 50-200 kg ha-1 contributed to an increase in the crude protein together with an increase in dry matter and/or protein concentration and crude protein increased 59.5-312.9% (Melo et al., 2017).

Takhar province is located in the north-eastern region of Afghanistan. More than half of the province (57%) is mountainous or semi-mountainous terrain, while more than one third (37%) is flat. Double cropping systems of wheat, rice, and cotton in rotation with fodder (alfalfa, maize), legumes (bean), and vegetable crops (potato, tomato) are common in this province. Years of the crisis have led to the loss of markets and households are forced into subsistence farming. The most common livestock in this province is cattle (Sharifi and Bell, 2011).

Research activities have been focused on important cereals in Afghanistan, but less attention was given to the forage crops, particularly sorghum. However, legume forages such as lucerne and clovers were grown in different parts of Afghanistan for centuries. Therefore, the present experiment was carried out to ascertain the effects of nitrogen fertilization rates on growth and forage yield of sorghum under agro-ecological conditions of Takhar province of Afghanistan.

2. Materials and Methods

This research was conducted at Bagh-e-Zakhera Research Station, department of agriculture, Takhar province of Afghanistan during the growing season 2020, to examine the effects of different levels of N fertilization on sorghum growth and forage yield under Takhar agro-ecological conditions. In Takhar, the temperature typically varies from 2°C to 37°C and is rarely below -4°C or above 40°C. The rainy period of the year lasts for 5.2 months (December 3 to May 10), with a sliding 31-day rainfall of at least 13 millimeters. The most rain falls during the 31 days centered around March 20, with an average total accumulation of 34 millimeters. The physical and chemical characteristic of soil is given in table 1.

Table 1. Chemical and physical characteristics of soil.

Physical characteristics			**Chemical properties**				
Texture class	**Clay (%)**	**Sand (%)**	**pH**	**EC (dS/m)**	**Potassium (ppm)**	**Phosphorus (ppm)**	**Nitrogen (%)**
Silty loam	19	24	7.92	0.250	84.66	15.96	0.089

The experiment was carried out in a randomized complete block design with four replications. The experiment was comprised of 4 rates of Nitrogen: N1 (no N application), N2 (50 kg N ha^{-1}), N3 (75 kg N ha^{-1}), and N4 (100 kg N ha^{-1}). The source of N was urea fertilizer. Phosphorus (60 kg P_2O_5 ha^{-1}) was applied to each plot at the time of land preparation.

The area of the experiment was divided into 16 plots (4 x 3.6 m) each. The row spacing was 45cm, and 15 cm distance was kept between the plants. The seeding rate was 10 kg h^{-1}, and seeds of a local variety of sorghum were sown to a depth of 5 cm by hand in the first week of May 2020. Weed control was carried out using a recommended dose of Pendimethalin herbicide. All other agronomic practices were kept uniform for all the treatments. The sampling was done at 45, 60, and 90 days after sowing (DAS). Five plants were taken from each replication randomly to measure plant height, number of leaves per plant, leaf area, and dry matter accumulation.

The height of the plant (cm) was measured from the soil surface to the top of the plant. The number of leaves per plant was counted manually in the field. The area of leaf was measured manually using a ruler and the obtained value was calculated as leaf area (cm^2) hill^{-1}. Dry matter accumulation was measured as increase in accumulation of total dry matter (g plant^{-1}) over the time.

Forage yield was measured as total fresh weight of plant (kg ha^{-1}) at 90 DAS. To measure the stover yield, samples were collected at 90 DAS and panicles were remove from plants and the leaves and stalks were dried under the sunlight of hot summer for one week and weighed to obtain the stover yield (kg ha^{-1}). Crop growth rate (CGR) was calculated as the plant's dry weight increase per unit of time (Nogueira et al., 1994).

$$CGR= (W2 - W1) / (T2 - T1)$$

Where: W1 and W2 = total dry weight of plant at first and second sampling; T1 and T2= time of first and second sampling.

Statistical analyses were performed using the SPSS statistics package (student version 22). Analysis of variance (ANOVA) was carried out to evaluate the effects of the main factor (Nitrogen levels) on growth and forage yield of sorghum. Less Significant Difference (LSD) was used to estimate the least significant range between means at the probability level of 0.05.

3. Results and Discussion

The response of sorghum plants to different levels of N was significant ($P < 0.05$). Application of N fertilizer significantly affected growth and forage yield of sorghum, and a higher dose of nitrogen enhanced all growth characteristics. Analysis of variance for plant height at 45, 60, and 90 DAS revealed that the effect of N fertilization was significant ($p < 0.05$), and the highest plant height was observed with the application of 100 kg of N ha^{-1} (N4). The significant differences were recorded with the application of various doses of N fertilizer in samples collected at 45, 60, and 90 DAS (Table 2). The increase in plant height by application of higher rates of nitrogen might be due to the increase in the number of nodes and internodal distance (Afzal et al. (2012). Uchino et al. (2013) also reported that plant height enhanced with increased N fertilizer level reported.

The effect of different levels of N fertilization on the number of leaves per plant is presented in Table 2. Significant differences among the various levels of N application were observed during the growing season. The number of leaves per plant gradually increased with an increase in the rate of N fertilizer, and a higher number of leaves was recorded with N4 treatment. The age of the plant also influenced the number of leaves, and more leaves were recorded at 90 DAS. The same trend was reported by Abuswar and Mohammed (1997) who revealed that nitrogen fertilization significantly affects the number of green leaves of fodder sorghum. In another research, Afzal et al. (2012) found that the number of leaves per plant increased steadily with a progressive increase in growth and an increasing dose of N fertilizer.

Table 2. Effects of N fertilization of sorghum plant height and number of leaves (plant^{-1}). [a]

Treatments	Plant height (cm)			Number of leaves per plant		
	45 DAS	60 DAS	90 DAS	45 DAS	60 DAS	90 DAS
N_1	43.30d	156.70c	182.74d	5.96b	6.42b	7.19c
N_2	52.55c	180.10b	208.15c	6.18b	7.81a	8.22b
N_3	59.07b	186.07b	229.41b	6.85b	8.03a	8.77b
N_4	66.55a	201.33a	245.26a	8.00a	8.66a	10.15a
LSD ($p \leq 0.05$)	4.01	7.36	4.01	0.98	0.90	0.60

[a] *Means followed by the same letters are not significantly different from each other at 5% probability level. LSD (0.05): least significant difference at 5% probability level*. DAS: days after sowing

Analysis of variance showed that N fertilization significantly increased the leaf area of sorghum (Table 3). The increase in the dose of N fertilizer enhanced the leaf area, and a significantly higher leaf area was recorded with N4 treatment. The progress in crop growth also highly affected leaf area as higher leaf area was observed on 90 DAS (Table 3). The application of nitrogen fertilizer was shown to enhance the growth of sorghum as observed in the plant leaf area and leave area index (Olugbemi and Ababyomi, 2016). Application of N fertilizer increased the green leaf area of sorghum but decreased the time of flowering by 5 days (Mahama et al., 2014).

Application of N fertilizer significantly enhanced dry matter accumulation (g plant^{-1}) in sorghum. Plant dry matter gradually increased with an increase in N rate and age of the plant, as the highest dry matter accumulation was recorded with the application of 100 kg N ha^{-1} (N4) at 90 DAS, while the lowest dray matter accumulation was noted with N1 or control (Table 3). Ashiono et al., (2005) revealed that N deficiency can result in reduced dry matter of dual-purpose sorghum. Bebawi (1987) reported that with increasing nitrogen levels in forage sorghum the number of tillers and the leaf area of plants increases and this ultimately leads to a rise in dry matter accumulation. Melo et al., (2017) also found that a higher level of N fertilization contributed to an increase in dry matter.

Mean comparison of nitrogen levels revealed that increasing nitrogen application resulted in an increase in the forage yield. A progressive increase in the forage yield was observed with increase in the rate of N application. The highest forage yield was recorded with the application of 100 kg N ha^{-1} (N4), while, the N1 treatment resulted in the lowest forage yield (Table 4). Nitrogen is a crucial component of plant nutrition, and its deficiency limits the productivity of crops more than any other element. Previous researches have shown that the application of N increased the forage yield of sorghum (Kaizzi et al., 2012; Reza et. al., 2013). Likewise, Mahama et al., (2014) found that grain and forage yield of sorghum increased linearly with increasing N rates from 0 to 90 kg N ha^{-1}.

Statistical analysis of data showed that N fertilization significantly increased the stover yield of sorghum according to control. Stover yield of N4 and N3 treatments was statically similar, however, it was significant compared to N2 and N1 (control). The lowest stover yield was observed with N1 treatment (Table 4). The application of nitrogen fertilizer improves the growth and forage yield of sorghum compared with the control (Olugbemi and Ababyomi, 2016) which in turn increases the stover yield of sorghum.

Table 3. Effects of N fertilization on leaf area and dry matter accumulation (g plant^{-1}). [a]

Treatments	Leaf area (cm^2) hill^{-1}			Dry matter accumulation (g plant^{-1})		
	45 DAS	60 DAS	90 DAS	45 DAS	60 DAS	90 DAS
N_1	225.42b	552.17d	1109.16c	11.21b	27.69c	64.63d
N_2	342.ab	708.31c	1628.28c	12.14b	38.46b	131.94c
N_3	703.25ab	895.08b	2445.41b	13.50a	40.98b	195.94b
N_4	822.37a	1058.94a	3536.80a	13.83a	47.93a	240.10a
LSD ($p \leq 0.05$)	500	64.37	606	1.17	5.1	42.24

[a] *Means followed by the same letters are not significantly different from each other at 5% probability level. LSD (0.05): least significant difference at 5% probability level*. DAS: days after sowing

Crop growth rate (CGR) was significantly affected by N fertilization, and a higher level of N fertilizer enhanced CGR. The maximum value of CGR was recorded with application of 100 kg N ha^{-1} (N4). The lowest crop growth rate was observed with N1 treatment where no N fertilizer was applied (Table 4). Application of N fertilizer enhances cell division during plant growth (Stals and Inze, 2001), it increases the aboveground biomass yield (Anderson et al., 2013), which consequently boosts crop growth rate. These findings are in line with Olugbemi and Ababyomi (2016) who reported that the highest CGR values were obtained with the application of a higher rate of N.

Table 4. Effects of N fertilization on forage yield, stover yield and crop growth rate of sorghum. [a]

Treatments	Forage yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Crop growth rate (g plant^{-1} day^{-1})
N_1	1742.22d	594.44c	19.36d
N_2	3480.00c	1433.33b	38.67c
N_3	5659.11b	2201.33a	62.18b
N_4	6217.55a	2467.55a	69.09a
LSD ($p \leq 0.05$)	519.88	470.44	6.87

[a] *Means followed by the same letters are not significantly different from each other at 5% probability level. LSD (0.05): least significant difference at 5% probability level*

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4. Conclusion

Forage and fodder crop production is a very important component of farming systems, as it provides adequate feed for the livestock. The outcome of this study shows that N fertilization can significantly enhance the growth and forage yield of sorghum. Application of 100 kg N ha^{-1} significantly increased plant height, the number of leaves per plant, leaf area, dry matter accumulation, forage yield, stover yield, and crop growth rate during growing period under Takhar province agro-ecological conditions. The study however also revealed that application of 75 kg N ha^{-1} would also result in the production of reasonable stover yield of sorghum.

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