J Bangladesh Agril Univ 18(2): 373–378, 2020 https://doi.org/10.5455/JBAU.73998

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Effect of nitrogen fertilization on growth, yield and proximate composition of selected sorghum varieties

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ARTICLE INFO

Article history:
Received: 20 November 2019
Accepted: 28 March 2020
Published: 30 June 2020

Keywords:
Growth parameter,
Nitrogenous fertilizer,
Proximate composition,
Sorghum variety

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ABSTRACT

A field experiment was conducted at the Crop Botany Field Laboratory of Bangladesh Agricultural University, Mymensingh to study the effect of varieties and different doses of nitrogen on growth and yield parameters of sorghum. It was a two factorial experiment. Factor one consisted of three levels of nitrogen viz. 69, 92, 115 kg N ha^{-1} and factor two consisted of four varieties of sorghum viz. BD700, BD707, BD722 and Hybrid Sorgo. The experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. Result revealed that both variety and application of nitrogen doses had significant effect on all of the morphological and physiological characters (plant height, total number of leaves per plant, leaf length, leaf width, stem diameter, fresh and dry weight of shoot and root, relative greenness (SPAD value), Fv/Fm value); yield contributing characters (panicle length, branches per panicle, grain yield) at harvesting stage and proximate composition of grain and leaf (crude protein, crude fiber, ether extract, nitrogen free extract and total ash). The tallest plant, maximum fresh and dry weight of shoot, less crude fiber were recorded from BD722 when treated with 69 kg N ha^{-1}. The longest panicles, highest number of branches per panicle, maximum grain yield were produced from the same variety (BD 722) with 92 kg N ha^{-1}. The maximum SPAD value, nitrogen free extract and ash in leaf were found in the same variety (BD722) with 115 kg N ha^{-1}. The maximum crude protein and ether extract in leaf was recorded in Hybrid Sorgo with treatment combination 90 and 92 kg N ha^{-1}, respectively. The minimum plant height, fresh and dry weight of shoot, length of internodes, relative greenness of leaf, panicle length, grain yield, crude protein and ash was found in BD707. Among the varieties tested, BD722 was the best in terms of growth characters with 69 kg N ha^{-1} and in terms of physiological, yield and yield contributing characters with 92 kg N ha^{-1}. Both BD722 and Hybrid Sorgo showed the best performance in chemical composition with different N treatments. On the other hand, BD707 showed inferior performance in all plant characters.

Introduction

Sorghum bicolor L. is a self-pollinated diploid C_4 grass with a high photosynthetic efficiency. It is the 5th most important grain crop after wheat, maize, rice and barley (De Morais Cardoso *et al.*, 2017). It is indigenous to Africa. It is one of the promising and resilient crops that can adapt well to any climate change conditions. It is also able to grow with moderate salinity and contribute in enhancing food, nutrition and energy security of the country by cultivating it in the fallow land in the dry period (Roy *et. al.*, 2018 and Sagar *et. al.*, 2019). It is the dietary staple food of more than 500 million people in more than 30 countries. Sorghum is a principal source of energy, protein, vitamins and minerals for millions of the poorest people in the semi-arid regions (Khaton *et. al.*, 2016). Sorghum is mainly cultivated in drier areas, especially on shallow and heavy clay soils. It is an important crop due to its wide use as food, feed and energy crop. It is mostly used as food (55%) in Asia and Africa and as feed (33%) in America (ICRISAT, 2013). In Bangladesh, 254 tons of sorghum grains are produced annually from about 187 ha of land and average yield is 1.36 tons per hectare (FAOSTAT, 2013).

Sorghum in addition of being boor in quality is also low yielding due to non-rationing ability to improve yield and quality of sorghum. The application of nitrogen not only affects the yield but also improve quality from view point of its protein contents (Hamed and Knowles, 1988). Nitrogen is essential for plants growth (Mosier *et al.*, 2004) and it is still one of the major factors limiting crop yield (Zhao *et al.*, 2005). Variable responses to the application of nitrogen fertilizer have been observed in maize and in sorghum (Muchow, 1990). Application of nitrogen fertilizer increased sweet sorghum stem yield (Johnston *et al.*, 2000). Mahmud. *et al*. (2003) reported that the application of nitrogen increased crude protein, fodder and dry matter yield in forage sorghum. Fiber content has a negative relationship with palatability and

Cite this article

Tajkia, J.E., Sagar, A. and Zakir Hossain, A.K.M. 2020. Effect of nitrogen fertilization on growth, yield and proximate composition of selected sorghum varieties. *Journal of Bangladesh Agricultural University*, 18(2): 373–378. https://doi.org/10.5455/JBAU.73998

digestibility of forges (Stevens *et al*., 1996) and McDonald *et al*. (1991) reported that fiber content was decreased by application of nitrogen fertilizer.

Bangladesh is one of the most densely populated countries of the world of which 85% lives in rural areas and 80% of them are directly involved or dependent on agricultural production. Alleviating poverty and attaining food security for its fast growing population is the most critical challenges that Bangladesh has faced since its independence in 1971 as the economy is based largely on agriculture, especially, the cultivation of rice. Rice is a high nitrogenous fertilizer consumptive cereal while sorghum is a cereal that releases significant amounts of biologically active compounds that suppress soil nitrification (Subbarao *et al*., 2006, Zakir *et al*., 2008). Total annual demand of urea in Bangladesh is 2.7 million tons. Nitrogen requirement in Sorghum cultivation may less than other crops. Different rates of application of nitrogen fertilizer on different varieties of sorghum may have different responses on its growth, yield, chemical composition and other characters.

Therefore, the objectives of this study were to find out the efficient variety/varieties for being best performances on different morphological, growth attributes and yield contributing characters as well as the proximate composition due to the application of different doses of nitrogen fertilizers.

Materials and Methods

This field experiment to evaluate the effect of different Nitrogen levels on growth and morphological character of sorghum fodder was conducted at Crop Botany Field Laboratory, Bangladesh Agricultural University (BAU). The experiment was laid out in a Randomized Complete Block Design (Factorial Arrangement) with 3 replications having a net plot size of 1 m × 1 m. Seeds of four different sorghum varieties (BD700, BD707, BD722, and Hybrid Sorgo) were sown on 1st January, 2016 maintaining row to row and plant to plant distances of 50 and 25 cm respectively. Three different doses of N (92 kg ha^{-1}, 115 kg ha^{-1} and 69 kg ha^{-1}) were applied in the form of urea. The recommended fertilizer doses (TSP 65.6 Kg ha^{-1}, MOP 50.45 Kg ha^{-1} and Gypsum 110.75 Kg ha^{-1}) according to the consideration of the type of soil of the experimental site of Crop Botany Field Laboratory of Bangladesh Agricultural University and one third urea (of the treatments) was applied during the final land preparation and the rest urea was top dressed in equal splits at 25 DAS and 45 DAS.

Three plants were selected at random from each plot to record individual plant observations like plant height, number of leaves per plant, leaf area, stem diameter, root length, number of nodes per plant, number of tillers per plant, fresh weight and dry weight of shoot and root. Plant height was taken with measuring tape from ground level up to the highest leaf tip. Leaf length was measured with measuring tape from base to tip. Leaf width was measured with the help of measuring tape from top, middle and bottom portions and the averages were calculated. Stem diameter was measured with the help of vernier caliper from top, middle and bottom portions and then the averages were calculated. Number of leaves per plant was determined by counting all the leaves. Number of nodes per plant and number of tillers per plant was counted at harvest.

Length of panicle was measured in centimeter by a meter scale at 120 DAS. Number of branches per panicle was counted at the time of harvest. After harvesting, the grains were removed from the separated panicle and then dried in sun for 2–3 days. Finally, grain weights were taken on individual plot basis at moisture content of 12% and then converted into t ha^{-1}.

The index of the total leaf chlorophyll content was measured by a chlorophyll meter (SPAD-502, Konica Minolta, Japan). Data were taken along the middle section of the fourth leaves and flag leaves of three plants of each treatment and the mean values were used for analysis.

Chlorophyll fluorescence was measured with a MINI-PAM (Walz, Effeltrich, Germany). The maximal photochemical efficiency of PSII, $Fv/Fm= (Fm- Fo)/Fm$ was measured. The day before F*v*/Fm measurements, well developed leaves (2nd or 3rd) were selected and fixed with a big cable-string (7.5 mm wide slit for the leaf tip) to ensure even exposure to the actual light in the greenhouse. The fixed leaves were cut off (2–3 cm) and dark-adapted for 30 min with the leaf clip (DLC-8, Walz, Effeltrich, Germany). The leaf clips with leaf samples were kept at room temperature on a wet paper and covered with a plastic bag to protect them from drying during dark adaptation.

Proximate Analysis after harvesting of grain and leaves was analyzed in the Laboratory of the Department of Animal Science, BAU, Mymensingh. The analyses included proximate analysis showed crude protein (total nitrogen), crude fiber, ether extract, ash and nitrogen-free extract content of the sample. The samples were analyzed following the methods of AOAC (1984).

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using the statistical computer package program MSTAT-C.

Results

Results showed significant variation among the varieties due to different doses of nitrogen. We recorded the highest plant height from Hybrid sorgo at 30 (6.83 cm) and 90 (148 cm) DAS with 92 kg N ha^{-1} application and from BD 722 at 60 (30.33 cm) and 120 (238.00 cm) DAS with 69 kg N ha^{-1}. However, the lowest plant height at 30, 60, 90 and 120 DAS were observed in BD 707 with 92 kg N ha^{-1} (Table 1).

Combined effect between variety and nitrogen doses on leaf area was significant at 30, 60, 90 and 120 DAS. The highest leaf area was observed at 30, 60, 90 and 120 DAS in BD700 when 69 kg N ha^{-1} was applied (11.53, 102.99, 566.83, 629.36 cm^2 respectively) (Fig. 1). Combined effect between variety and nitrogen doses on stem diameter was significant at 90 and 120 DAS where the highest value was observed in BD 707 with 92 kg N ha^{-1} (Table 2). The maximum number of leaves per plant was observed in Hybrid Sorgo with 69 kg N ha^{-1} at 30, 60, 90 and 120 DAS. On the other hand the lowest values were recorded from BD 700 at the same day (Table 2). The highest length of internode (11.33 cm) and root (42 cm) were observed in BD 722 with 92 and 69 kg N ha^{-1} respectively (Table 2). The highest number of nodes (10) and tillers per plant (4) were observed in Hybrid Sorgo with 115 kg N ha^{-1} (Table 2).

The highest fresh weight and dry weight of shoot and root were observed in BD 722 with 69 kg N ha^{-1} and in all cases the lowest value was recorded from BD 707 (Table 3). The maximum Fv/Fm value was observed in BD707 with the treatment combination of 92 and 115 kg N ha^{-1} (0.77) (Table 3). The maximum greenness of flag and older leaf were observed in BD722 with 115 kg N ha^{-1} at flower initiation stage (60.33, 67.67 respectively) (Fig. 2). The highest crude protein (8.89), crude fiber (37.45), ether extract (4.00) of leaves were observed in Hybrid sorgo with 69,115 and 92 kg N ha^{-1} respectively. The highest nitrogen free extract (49.64) and ash (6.5) were observed in BD722 with 115 kg N ha^{-1}. The lowest crude protein (5.90) was observed in BD700 with 69 kg N ha^{-1}. The lowest crude fiber (31.89) was observed in BD722 and Hybrid Sorgo with 69 kg N ha^{-1}. The lowest nitrogen free extract (44.90) was observed in Hybrid Sorgo with 115 kg N ha^{-1}. The lowest ash (6.50) was observed in BD707 with 92 kg N ha^{-1} (6.50) (Fig. 3).

Table 1. Effect of N doses on plant height of different sorghum varieties

Treatment	Plant Height			
	30 DAS	60 DAS	90 DAS	120 DAS
V1N1	3.00d-f	15.33bc	98.00b	178.67a-d
V1N2	3.17de	18.00b	74.00cd	160.33b-d
V1N3	3.00d-f	16.67bc	100.00b	194.67a-d
V2N1	3.00d-f	14.67bc	87.67bc	179.67a-d
V2N2	2.40f	10.00d	64.00d	138.67cd
V2N3	2.47f	15.33bc	74.67cd	147.00cd
V3N1	2.80ef	30.33a	86.67bc	238.00a
V3N2	4.17c	15.00bc	133.33a	206.67a-c
V3N3	3.00d-f	16.33bc	95.67b	211.00a-c
V4N1	5.00b	31.00a	131.67a	211.67a-c
V4N2	6.83a	17.33bc	148.00a	215.00ab
V4N3	3.50d	13.67c	102.67b	212.67ab
SE	0.19	1.10	5.56	19.36
CV (%)	35.90	35.63	26.00	15.96
Level of sig.	*	*	*	*

N.B.: SE= Standard error of means; CV=Co-efficient of variation; ** = Significant at 1% level; * = Significant at 5% level; NS= Non-significant; Treatments with different letters in a column differ significantly according to DMRT test at p<0.05; V_1 = BD 700, V_2=BD 707, V_3= BD 722, V_4 =Hybrid Sorgo; N_1= 69 Kg N ha-1(25% lower than control), N_2= 92 Kg N ha-1 (Control), N_3= 115 Kg N ha-1 (25% higher than control)

Table 2. Effect of N doses on growth and morphological parameters of different sorghum varieties

Treatment	Stem Diameter(cm)				Number of Leaves Plant-1				Internode length (cm)	Root length (cm)	No. of nodes /plant	Tillers/ plant
	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS				
V1N1	1.33ab	2.67a-c	7.33a	8.33a	7ab	9c	15c-e	20b-d	5.67cd	37.33	8.00ab	1.67c
V1N2	1.67ab	3.00ab	7.00ab	7.00ab	6ab	11a-c	12de	14d	8.33a-d	47.67	7.67b	1.33c
V1N3	1.33ab	2.33bc	7.00ab	7.33ab	6ab	7c	11e	15cd	6.00b-d	49.00	7.67b	1.00c
V2N1	1.00b	2.00c	5.67a-d	5.33b	6ab	9c	14c-e	24b	7.33b-d	35.00	7.00b	1.33c
V2N2	2.00a	3.00ab	7.33a	8.67a	5b	7c	19cd	21b-d	7.33b-d	41.33	6.67b	1.33c
V2N3	2.00	3.33a	5.67a-d	6.67ab	6ab	15a	20c	21b-d	5.00d	32.33	7.33b	2.00c
V3N1	1.67ab	2.67a-c	5.00b-d	7.33ab	6ab	12a-c	16c-e	22b-d	9.67a-c	42.00	8.00ab	2.33bc
V3N2	2.00a	3.33a	6.67a-c	7.33ab	6ab	8c	14c-e	17b-d	11.33a	40.00	7.00b	2.33bc
V3N3	2.00a	3.00ab	6.67a-c	8.00ab	6ab	12a-c	14c-e	17b-d	7.00b-d	40.67	7.00b	2.00c
V4N1	1.33ab	2.33bc	4.67cd	7.67ab	7a	16a	38a	43a	10.00ab	34.00	8.67ab	4.33a
V4N2	1.33ab	3.33a	4.33d	7.00ab	6ab	14ab	30b	37a	9.00a-d	32.00	6.67b	3.00a-c
V4N3	1.33ab	3.33a	5.67a-d	6.67ab	6ab	12a-c	21c	23bc	6.00b-d	40.00	9.67a	4.00ab
SE	0.23	0.22	0.63	0.88	0.55	1.67	2.49	2.83	1.17	4.94	0.61	0.61
CV (%)	22.31	16.04	17.3	12.02	9.94	27.49	43.28	38.69	25.42	13.96	11.64	48.03
Level of sig.	**	**	**	**	**	**	*	**	**	NS	**	**

N.B.: SE= Standard error of means; CV=Co-efficient of variation; ** = Significant at 1% level; * = Significant at 5% level; NS= Non-significant; Treatments with different letters in a column differ significantly according to DMRT test at p<0.05; V1 = BD 700, V2=BD 707, V3= BD 722, V4 =Hybrid Sorgo; N1= 69 Kg N ha-1(25% lower than control), N2= 92 Kg N ha-1 (Control), N3= 115 Kg N ha-1 (25% higher than control)

Effect of nitrogen fertilization on four sorghum varieties

Table 3. Effect of N doses on growth and yield parameters of different sorghum varieties

Treatment	Shoot weight (gm)		Root weight (gm)		Fv/Fm value	Panicle Length (cm)	Branches/ panicle	Grain yield (ton/ha)
	Fresh weight	Dry weight	Fresh weight	Dry weight				
V1N1	596.7a-c	463.3a-c	180.0	130.0	0.72b	32.00a	42.00	1.67ab
V1N2	616.7a-c	486.7a-c	183.3	116.6	0.75ab	28.00a-c	45.00	1.33ab
V1N3	606.7a-c	520.0a-c	191.67	103.3	0.75ab	29.33ab	43.00	1.67ab
V2N1	356.7c	303.3bc	123.3	90.0	0.77a	27.67a-d	44.00	1.00b
V2N2	366.7c	273.3c	120.0	86.6	0.72b	23.33d	39.00	1.00b
V2N3	416.7bc	350.0a-c	186.7	100.0	0.76a	32.00a	45.00	2.00ab
V3N1	733.3a	616.7a	233.3	156.7	0.75ab	25.00b-d	39.00	1.33ab
V3N2	566.7a-c	440.0a-c	163.3	120.0	0.77a	32.00a	53.00	2.67a
V3N3	366.7c	280.0c	133.3	90.0	0.75ab	25.00b-d	41.00	1.33ab
V4N1	646.7ab	590.0ab	203.33	118.3	0.76a	24.33cd	37.00	1.00b
V4N2	430.0bc	330.0a-c	120.0	93.3	0.76a	30.33a	52.00	1.33ab
V4N3	516.7a-c	383.3a-c	166.7	133.3	0.75ab	28.67a-c	40.00	1.67ab
SE	80.74	87.35	40.11	36.18	0.01	1.41	4.84	0.37
CV (%)	24.61	28.13	21.82	19.26	2.09	11.18	11.06	32.13
Level of sig.	**	**	NS	NS	**	**	NS	**

N.B.: SE= Standard error of means; CV=Co-efficient of variation; ** = Significant at 1% level; * = Significant at 5% level; NS= Non-significant Treatments with different letters in a column differ significantly according to DMRT test at $p<0.05$; V_1 = BD 700, V_2=BD 707, V_3= BD 722, V_4 =Hybrid Sorgo; N_1= 69 Kg N ha-1(25% lower than control), N_2= 92 Kg N ha-1 (Control), N_3= 115 Kg N ha-1 (25% higher than control)

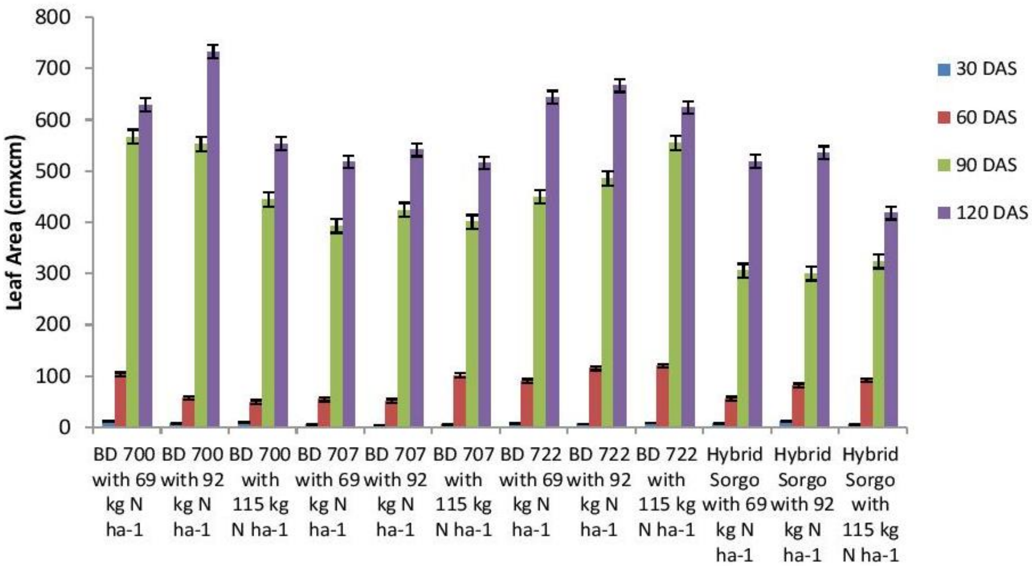

Fig. 1. Combined effect of varieties and N doses on leaf area

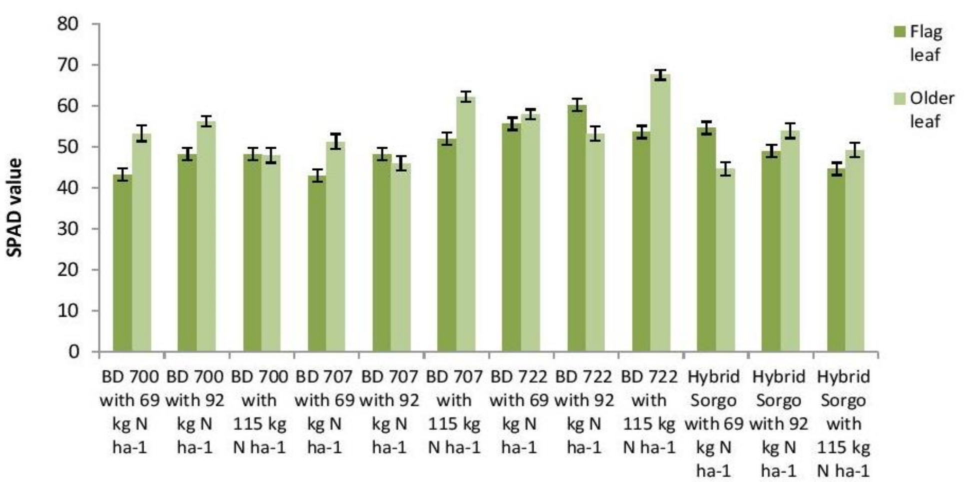

Fig. 2. Combined effect of varieties and N doses on relative greenness (SPAD value) of flag leaf and older leaf

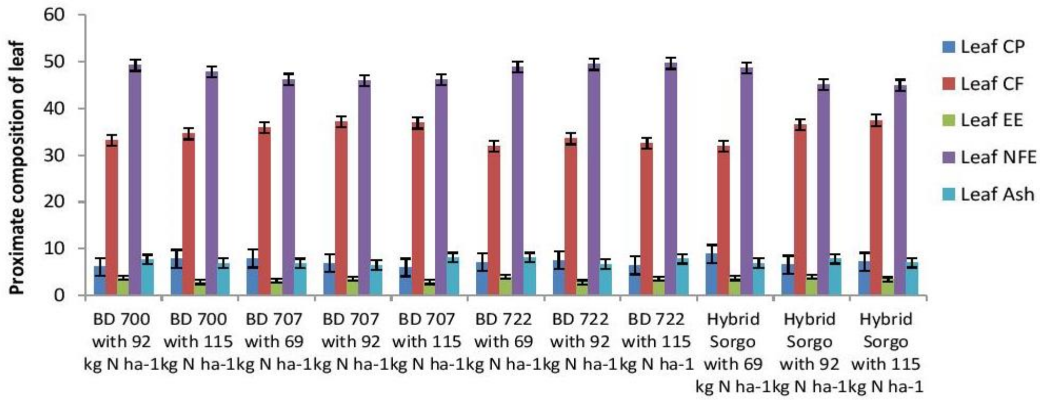

Fig. 3. Combined effect of varieties and N doses on proximate composition of leaf

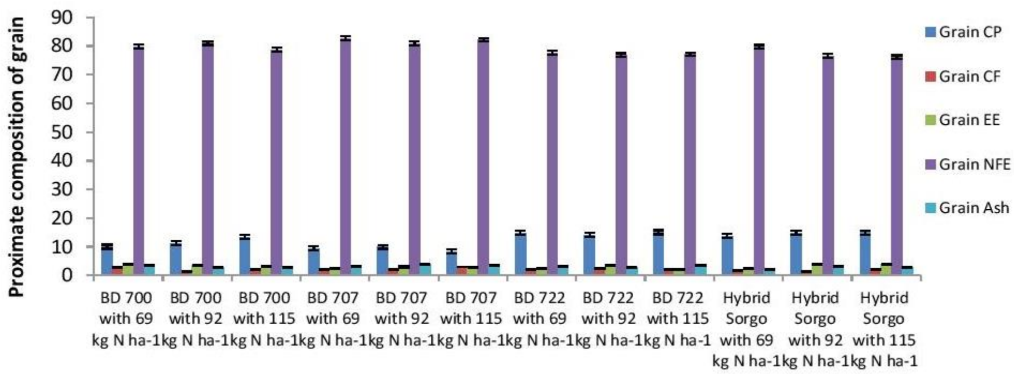

Fig. 4. Combined effect of varieties and N doses on proximate composition of grain

The highest crude protein (15.10) of grain was observed in BD722 with 115 kg N ha^{-1}. The highest crude fiber (14.70) and ether extract (3.90) of grain were observed in Hybrid Sorgo with 92 kg N ha^{-1}. The highest nitrogen free extract (82.16) and ash (4.00) of grains were observed in BD 707 with 115 and 92 kg N ha^{-1} respectively (Fig. 4). The highest panicle length (32.00 cm), branches per panicle (53.00) and yield (2.67 ton ha^{-1}) were observed in BD722 with 92 kg N ha^{-1} and the lowest length of panicle, branches per panicle and yield were observed in the variety BD707 with 92 kg N ha^{-1} (Table 3).

Discussion

Nitrogen fertilizer is one of the most important elements which has a great impact on growth and yield of sorghum. Scientific information on sorghum in relation to the effect of N is very limited in the world. Nitrogen is a major element that is essential for synthesis of amino acids, nucleic acids and some organic acids etc. which are necessary for plant growth and development and its limits reduce yield (Zhao *et al*., 2005). Our findings reveal that significant changes occur in different varieties of Sorghum due to the application of different doses of nitrogen fertilizers. We observed different parameters like morphological, growth, yield contributing and proximate composition and recorded significant changes among the varieties and in the same varieties due to the changes of nitrogen doses. Our findings are comparable with several other researches. The faster rate of sorghum development when subjected to higher N rates supports the report of Uchino *et al.* (2013) who evaluated sweet sorghum in the semi-arid tropical zone of India. From an experiment on nitrogen fertilization effect on grain sorghum, application of N-fertilizer significantly increased plant height, LAI, panicle length, yield per panicle, 1000 grain weight, grain yield, stover yield and harvest index over the control (Gebremariam and DerejeAssefa, 2015). Our results showed that variety and nitrogen rates had significant effect on growth and physiological parameters. At 120 DAS, the highest plant height, fresh and dry weight of shoot was found in BD722 with treatment of 69 kg N ha^{-1}, highest length of internodes was recorded from the same variety with 92 kg N ha^{-1}. The maximum relative greenness was also found from the same variety (BD722) with 115 kg N ha^{-1} treatment combination. On the other hand, the minimum plant height, fresh and dry weight of shoot, length of internodes and relative greenness of leaf was found in BD707 with treatment combination 92 kg N ha^{-1}.

The interaction effect of variety and nitrogen rates was significant for all yield and yield contributing characters. The combination of BD 722 with 92 Kg N ha^{-1} produced the highest panicle length, branches per panicle, maximum grain yield. On the other hand, the minimum panicle length, grain yield was found in BD707 with treatment combination 92 kg N ha^{-1}. Mengel *et al.* (2001) mentioned that corn and sorghum yield would have dropped by 41% and 19%, respectively, without nitrogen fertilizer application.

Interaction effect of variety and nitrogen rates was significant for the proximate composition of Sorghum. The maximum crude protein and ether extract in leaf was recorded in Hybrid Sorgo with treatment combination 69 and 92 kg N ha^{-1} respectively. Application of nitrogen increased crude protein, fodder and dry matter yield in forage sorghum (Mahmud *et al*., 2003). Crude protein contents were significant influenced by different nitrogen level. A significant increase in crude protein contents were observed at each increased levels of nitrogen has also been by Ayub *et al*. (2002). The lowest crude fiber in leaf was recorded in BD722 with 69 kg N ha^{-1}. Increasing level of nitrogen fertilizer decreased the crude fiber content was reported by Aman (2010). The maximum nitrogen free extract and Ash in leaf was found in BD722 with the treatment combination 115 kg N ha^{-1}. On the other hand, the minimum crude protein and ash were recorded in BD707 with 115 and 92 kg N ha^{-1} treatment combination respectively. The highest ether extract was observed in Hybrid sorgo with 92 kg N ha^{-1}. Ether extractable fat concentration was increase with increased nitrogen levels (Ayub *et al.* 2002).

Conclusion

Among the varieties tested BD722 was the best in terms of growth characters with 69 kg N ha^{-1} and in terms of physiological, yield and yield contributing characters with 92 kg N ha^{-1}. Both BD722 and Hybrid Sorgo showed best performance in chemical composition with different N treatments. On the other hand, BD707 showed inferior performance in all plant characters. It might be concluded that BD 722 and Hybrid Sorgo can be cultivated with minimum input of nitrogenous fertilizer. However, further research is needed including more varieties from home and abroad to identify efficient variety in terms of nitrogen use efficiency.

Acknowledgement

We acknowledge the National Science and Technology Fellowship, the Ministry of Science and Technology, Government of the People's Republic of Bangladesh.

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