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The Effects of Nitrogen Fertilizer on Chemical Compositions in Corn and Sweet Sorghum

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Abstract: This study was carried out to evaluate the effects of four nitrogen treatments (50, 100, 150 and 200 Kg urea / ha) on biomass, crude protein, soluble carbohydrates and crude fiber contents in three fodders (corn, sweet sorghum and sweet sorghum bagasse) at the filed experimental station. The results showed the effects of nitrogen treatments and fodders on the above measurements were significant. Treatment of 200 kg/ha urea had the highest biomass (64.80 t/ha) and protein content (8%) and it had the lowest soluble carbohydrates (12.80 %) and fiber contents (31.90%). Between fodders, corn had higher biomass and protein content (72.80 t/ha, 7.10 %) than sweet sorghum (66.50 t/ha, 5.90 %), respectively. Also both carbohydrate and fiber contents of sweet sorghum was higher than corn. Sweet sorghum bagasse had lower crude protein and carbohydrates content and higher crude fiber than both corn and sweet sorghum. In fodders as the nitrogen fertilizer increased, crude protein present increased while crude fiber present decreased which could increase palatability and digestibility of the both species. Thus, base on the results, it is suggested to apply 200 kg/ha urea for corn and sweet sorghum.

Key word: Sweet sorghum · Corn · Bagasse · Nitrogen fertilizer · Carbohydrate · Protein · Fiber

INTRODUCTION

Sorghum *[Sorghum bicolor* L. (Moench)] can be classified as sweet, grain and forage types [1]. It is well adapted to sub-tropical and temperate regions of the world and it is water efficient [2]. Sweet sorghum has many good characteristics such as a drought resistance [3], water-lodging tolerance, salinity resistance [4, 5] and with a high yield of biomass etc [6]. It is often grown in areas of low fertility and unpredictable rainfall [7]. Sweet sorghum usually is planted for sugar [8] and ethanol production [9, 10]. It is a C4 crop with a high biomass yield and good nitrogen used efficiency [11]. Nitrogen is essential for plants growth [12] and it is still one of major factors limiting crop yield [13]. To achieve economically viable returns, efficient use of available resources, like nitrogen, is necessary to maximize yields in all seasons. There is a need to use the minimum amount of nitrogen required for the maximum growth rate at any time during the growing season [14]. The nitrogen requirement for crop production has traditionally been determined from field experimentation involving different rates of application of nitrogen fertilizer [15]. Variable responses to the application of nitrogen fertilizer have been observed in maize and in sorghum [16] owing to differences in climatic, soil and genotypic factors across seasons and locations [15]. Who also mentioned that nitrogen requirement is dependent on the yield expectation in a given environment as determined by climate, management and cultivar. Depending on soil nitrogen fertility, farmers apply anywhere between 45 and 224 kg Nha^{-1} in sorghum production [13]. Although adequate supply of nitrogen to crops is fundamental to optimize crop yields, mismanagement of nitrogen, such as excessive nitrogen application, can result in contamination of groundwater [17]. Mengel and Kirkby [18] mentioned that corn and sorghum yield would have dropped by 41% and 19%, respectively, without nitrogen fertilizer application. Application of nitrogen fertilizer increase sweet sorghum stem yield [19] and corn fodder [20]. Mahmud *et al*. [21] reported that application of nitrogen increased crude protein, fodder and dry matter yield in forage sorghum. They also mentioned that plant nutrition may not only affect the forage production but also improve the quality of forage from view point of its protein contents. Also, Mullins *et al*. [22] reported that, nitrogen fertilizer increased forge protein content in corn. Where nitrogen levels are limiting, photosynthesis is not fully used in the synthesis of organic nitrogen compounds and sugars are accumulated [23]. Fiber

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content has a negative relationship with palatability and digestibility of forges [24] and as McDonald *et al*. [25] reported that fiber content was decreased by application nitrogen fertilizer. Application of nitrogen fertilizer decreased soluble carbohydrates content in sorghum [26] and in corn [27]. The purpose of this study was to determine the effects of different nitrogen levels on biomass, protein, soluble carbohydrates and fiber content in corn, sweet sorghum and sweet sorghum bagasse.

MATERIAL AND METHODS

The experiment was carried out at Isfahan University Research Station (31º, 31'N, 5º, 51' E, altitude 1550 m above sea level) Isfahan, Iran in 2007. Four rates of nitrogen fertilizer (50, 100, 150 and 200 Kg Urea ha^{-1}) and one corn and one sweet sorghum cultivar (704 and keller, respectively) were assessed in split plot design with three replications. The fertilizers assigned to main plots and the species to subplots. The area was plowed in the pervious season and in the spring 300 Kg/ ha of ammonium phosphate was broadcasted and disked in the soil. Then 75 cm furrows were prepared. Seeds were planted in furrows with 10 m long. Following establishments, the plants were thinned to 10 cm apart. At three to four leaf stages, the urea treatments were added to the furrows. Plants were harvested at dough stage and the plants were taken from to central rows and their biomass was determined. To extract the juice, part of sweet sorghum plants were passed through the mill. The dry weight of corn, sweet sorghum and sweet sorghum bagasse (it is the fibrous residue remaining after sorghum stalk are crashed to extract its juice) were determined. The crude protein present of day samples were determined according to Listra *et al*., [28]. The soluble carbohydrates were determined according to Dubois *et al*. [29]. The crude fiber content was determined according to Goering and Van- Soest, [30]. Statistical analyses were performed using SAS computer program. The means were compared according to Duncan multiple rang test.

RESULTS AND DISCUSSION

The results showed the effect of nitrogen treatments on biomass, species and their interactions were significant at 1% level (Table 1). Also the results showed the effect of nitrogen treatments and fodders on percentage of crude protein, soluble carbohydrates and crude fiber, were significant at 1% level (Table 2). Their interactions on protein and soluble carbohydrates content were significant at 1% level and on crude fiber at 5% level. Table 3 showed that biomass was increased significantly by increasing nitrogen fertilizer level. Biomass in nitrogen treatment (200 kg/ha urea) was higher (64.80 t/ha) than other nitrogen treatments and it was the lowest (55.50 t/ha) at 50 kg/ha urea. The results are quite in line with those of Johnston [19], Mahmud *et al*. [21] and Almodares *et al*. [31]. Nitrogen is a major element [12] that is essential for synthesis of amino acids, nucleic acids and some organic acids etc… which is necessary for plant growth and development and its limits reduce yield [13]. Although, the amount of nitrogen application is depend on soil fertility, soil texture, plant species and environmental factors. The comparison for biomass between species is presented Table 4. The biomass of corn (72.80 t/ha) was significantly higher than sweet sorghum (66.50 t/ha). Generally, the biomass of corn is higher than sweet sorghum in suitable condition.

Table 1: Mean squares of Biomass

Treatments	d.f	df	Biomass
Replication	2	2	218.42 ns
Nitrogen (N)	3	3	2723.129 **
Error a	6	6	68.431
Species (S)	1	1	20883.05 **
NxS	3	3	205.944 **
Error b	8	9	705.644
Total	23		

* *: Significant at 1 percent level, ns: non significant

Table 2: Mean squares of protein, carbohydrate and fiber content

Treatments	d.f	df	Crude Protein	Soluble Carbohydrates	Crude Fiber
Replication	2	2	0.72 ns	12.14 ns	18.63 ns
Nitrogen (N)	3	3	835.778 **	320.795 **	458.130 **
Error a	6	6	1.438	0.673	5.333
Fodder (F)	2	2	347.692 **	68736.52 **	97476.861 **
NxF	6	6	6.57 **	28.588 **	9.491 *
Error b	16	14	1.209	0.782	16.694
Total	35				

* * Significant at 1 percent level, * Significant at 5 percent level, ns: non significant

Table 3: Mean comparisons* among nitrogen treatments for biomass, protein, carbohydrates and fiber content

Nitrogen Fertilizer (Kg/ha)	Biomass (t/ ha)	Crude Protein %	Soluble Carbohydrates %	Crude Fiber %
50	55.50 d	4.30 d	17.80 a	35.80 a
100	59.10 c	5.40 c	15.40 b	33.10 b
150	62.10 b	7.10 b	13.60 c	32.40 b
200	64.80 a	8.00 a	12.80 d	31.90 b

* Values within one column followed by the same letter are not significantly different at $P<0.05$.

Table 4: Mean comparisons* among fodders for biomass, protein, carbohydrates and fiber content

Fodder	Biomass (t/ ha)	Crude Protein %	Soluble Carbohydrates %	Crude Fiber %
Corn	72.80 a	7.10 a	10.40 b	23.50 c
Sweet Sorghum	66.50 b	5.90 b	26.50 a	35.70 b
Sorghum Bagasse	-------------	5.40 b	7.70 c	40.60 a

* Values within one column followed by the same letter are not significantly different at P<0.05.

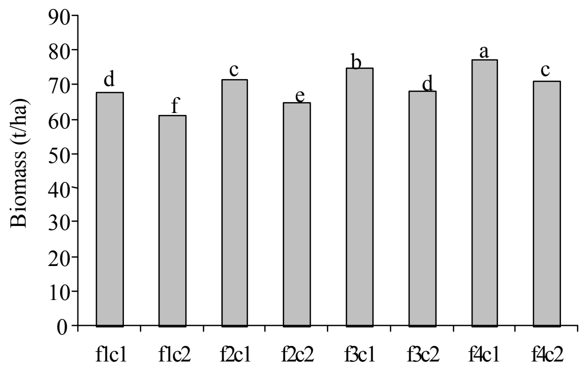

Fig. 1: Interaction between levels of nitrogen treatments and species on biomass; f1 (50 kg/ha urea), f2 (100 kg/ha urea), f3 (150 kg/ha urea) and F4 (200 kg/ha urea); C1 (corn) and C2 (sweet sorghum) and C3 (sweet sorghum bagasse).

However under stress conditions such as heat and drought and salinity, sweet sorghum is better adapted and produce more yield than corn [32]. The interaction between of nitrogen fertilizes and species is shown in Fig. 1. In all nitrogen treatments, corn had higher biomass than sweet sorghum. Also, biomass of corn and sweet sorghum steadily increased from 50 kg / ha urea to 200 kg / ha urea. It seems that in suitable climatic conditions, corn can use nitrogen better than sweet sorghum. Because under favorite conditions, corn can grown better than sweet sorghum and utilize more nitrogen for its growth and development. As mention before, the effect of nitrogen treatments and fodders and their interactions on percentage of crude protein were significant at 1% level (Table 2). Table 3 showed that crude protein content was increased significantly by increasing nitrogen fertilizer level. The highest crude protein (8 %) was at 200 kg/ha urea and the lowest (4.3 %) at 50 kg/h urea. The increase in protein content with nitrogen fertilization is in line with the finding of Shinde *et al*. [33], Ayub *et al*. [34] and Mahmud *et al*. [21]. The increase in protein contents with increasing in fertilizer levels may be the result of enhancement in amino acid formation due to fertilization.

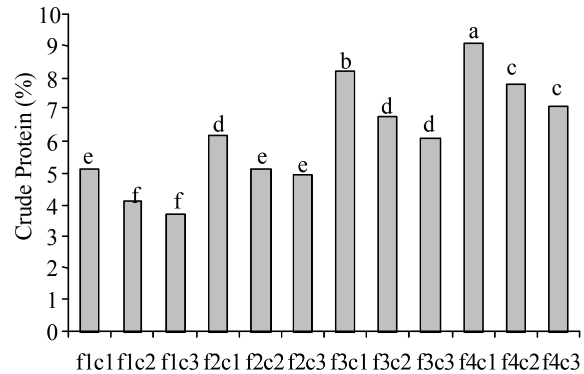

Fig. 2: Interaction between levels of nitrogen treatments and fodders on crude protein (%); f1 (50 kg/ha urea), f2 (100 kg/ha urea), f3 (150 kg/ha urea) and F4 (200 kg/ha urea); C1 (corn) and C2 (sweet sorghum) and C3 (sweet sorghum bagasse).

The nitrogen application not only affects sorghum forage production but also improve its quality from view point of protein contents [35]. The results showed that corn had higher crude protein content (7.1 %) than both sweet sorghum (5.9 %) and its bagasse (5.4%). The amount of protein was no significant different between sweet sorghum and its bagasse. McDonald *et al*. [25] and NRC [36] reported that protein content of forge corn is higher than sorghum which is in agreeable with our results. Adgola-Bessa and Qwen [37] reported that as the age of the plant increases, the amount of protein content decreased. It seems that, because in this experiment the plants were harvested at dough stage and sweet sorghum reached to that stage latter than corn therefore its may be cause to reduce protein content in sweet sorghum than corn. The Interaction between levels of nitrogen treatments and fodders on protein content were significant at 1% level (Table 2) and at 200 kg/ha urea, corn had the highest protein content (Fig. 2). Sweet sorghum and its bagasse had the lowest protein content at 50 kg/ha urea although corn in this treatment had higher protein content than sweet sorghum and its bagasse. It seems that corn can be produce higher protein content than sweet sorghum at these nitrogen treatments. As indicated in Table 2, the effect of nitrogen treatments, fodders and their interactions on soluble carbohydrates were significant at 1% level. Mean comparison among for level of urea application indicates that as the amount of nitrogen increased from 50 kg/ha urea to 200 kg/ha urea, soluble carbohydrates decreased significantly (Table 3). It was 17.8% at 50 kg/ha urea and 12.8 % at 200 kg/ha urea. Soluble carbohydrates content (invert sugar) in

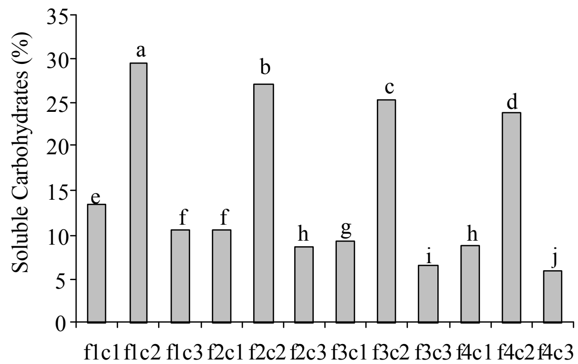

Fig. 3: Interaction between levels of nitrogen treatments and fodders on soluble carbohydrates (%); f1 (50 kg/ha urea), f2 (100 kg/ha urea), f3 (150 kg/ha urea) and F4 (200 kg/ha urea); C1 (corn) and C2 (sweet sorghum) and C3 (sweet sorghum bagasse)

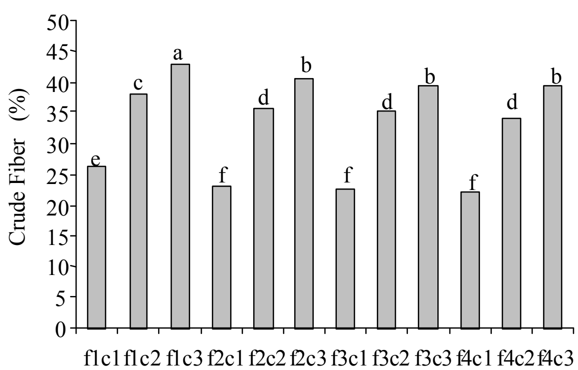

Fig. 4: Interaction between levels of nitrogen treatments and fodders on crude fiber (%); f1 (50 kg/ha urea), f2 (100 kg/ha urea), f3 (150 kg/ha urea) and F4 (200 kg/ha urea); C1 (corn) and C2 (sweet sorghum) and C3 (sweet sorghum bagasse)

Allium porrum had no relationship with the level of nitrogen that was applied [23]. On the other hand, Biczak *et al*. [38] observed that in celery, increasing pre-sowing and top-dressing doses of nitrogen fertilizers cause a decrease of the sugars in vegetables. In contrary, Galani *et al*. [39] reported that nitrogen fertilizer increased soluble carbohydrates content (sucrose) in sweet sorghum. This relationship between nitrogen fertilizer and consumption of soluble carbohydrates in plants may be due to metabolism nitrogen fixation. Since some of the intermediate metabolic in TCA cycle is used for amino acids and protein synthesis, so the amount of carbohydrates is reduced specially in sugar crops such as sweet sorghum. Table 4 showed that sweet sorghum and its bagasse had the highest (26.5 %) and lowest (7.7 %) soluble carbohydrates, respectively. The lowest carbohydrates content in bagasse is due to the extraction of carbohydrates from sweet sorghum stalk. Corn soluble carbohydrates (10.4 %) were lower than sweet sorghum. The results of corn soluble carbohydrate content are in line with Zhao *et al*. [40]. Fig. 3 showed the interaction between levels of nitrogen treatments and fodders on carbohydrate content. Sweet sorghum and its bagasse at 50 Kg/ha urea and at 200 Kg/ha urea had the highest and the lowest soluble carbohydrate content, respectively (Fig. 3). In all treatments, sweet sorghum had higher soluble carbohydrate content than corn and bagasse however in all fodders the carbohydrate content was decreased as the level of nitrogen increased. Table 2 showed that nitrogen treatments and species and their interactions on stalk fiber content were significant at 1% level. Stalk fiber content at 50 Kg/ ha urea (35.80 %) was higher than other nitrogen treatments (Table 3). There was no significant different amount other nitrogen treatments. As the amount of nitrogen increased the amount of fiber content decreased but the reduction at 100-200 Kg/ha urea was not significant. It seem that the trend of fiber content reduction similar to the trend of carbohydrate content reduction although this effect of nitrogen treatments on fiber content was not clear as their effects on carbohydrate content. The fodder having less crude fiber percentage is considered a good quality because higher the crude fiber percentage lesser will be digestibility. Therefore, because the application of nitrogen decreased fiber content, so it increased digestibility of the plants. In addition, the amount of protein was increased with application of nitrogen (Table 3) which increased the quality of the fodders. Thereby, by application of nitrogen both quality and digestibility of the fodder increased. Table 4 showed that corn had the lowest fiber content (23.50 %) than sweet sorghum (35.7 %) and its bagasse (40.6 %). The results are in agreeable with NRC [36] and Burns and Kimbrough [41]. It seems that, part of lower fiber content of corn than sorghum could be due to the species differences between them. Interaction between levels of nitrogen treatments and fodders on crude fiber (%) showed that sweet sorghum bagasse at 50 Kg/ha urea had the highest fiber content (Fig. 4). Corn had the lowest fiber content regardless nitrogen treatments. Sweet sorghum fiber content decreased as the amount of nitrogen increased. Therefore, it seems that application of nitrogen fertilizer improves the quality of sweet sorghum forage due to reduction of fiber content.

CONCLUSION

In crop plants, protein and fiber content could be suitable parameters for determining forage quality. Fonsca *et al*. [42] reported that protein content in corn forage has a positive relationship with palatability and digestibility. In contrary, fiber content has a negative effect on forage quality [24]. Application of nitrogen fertilizer increased the amount of forage protein content and decreased the fiber content in sweet sorghum and corn. Therefore, it seems that application of nitrogen fertilizer could increase palatability and digestibility of the both species. On the other hand, amount of soluble carbohydrates also could alter the quality of the forages. In crop plants, as the soluble carbohydrates have increased within some limits both forage palatability and digestibility increased. Since, application of nitrogen fertilizer could be decreased soluble carbohydrate in sorghum and corn. Thereby, optimum nitrogen fertilizer should be applied to increased protein and soluble carbohydrates contents and also decreased fiber content in these two spices. Thus, base on the results, it is suggested to apply 200 kg/ha urea because the highest biomass and protein content and the lowest fiber content will be achieved with at this amount of nitrogen fertilizer. Although, this amount of nitrogen will decreased soluble carbohydrates content but it seems this reduction dose not effect on forage palatability and digestibility considerably.

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