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Agronomic Performance of Forage Sorghum Genotypes as Affected by Watering Interval in Semi-arid Environment

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Abstract In the latest years, scarcity of rainfall in North Kordofan of Sudan led to the search for irrigation water for cultivation of fodder crops to fill the gap in fodder production, hence the North Kordofan state characterized by a limited water situations. Therefore, efficient use of irrigation water seems to be of vital importance. This situation emphasizes the need for using earlier variety and scientifically sound methods for deciding when and how much to irrigate the crops. A field experiment was carried out during two successive seasons (2014/2015) and (2015/2016), to investigate the effect of ten genotypes and two watering intervals (seven and ten days) on growth and yield of forage sorghum. The treatments were arrange in a split plot design with three replications. The results showed that there were significant differences among watering intervals and genotypes for the most characters measured. The Watering interval of seven days significantly improved growth and forage yield of sorghum. Hybrid Pioneer was superior in plant height, leaf to stem ratio (LSR), fresh and dry forage yield (ton/ha) compared to other genotypes.

Keywords: *fodder crop, hay, irrigation, pasture*

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1. Introduction

Sorghum (Sorghum bicolor (L.) Moench) is a cereal plant member of the family of Poaceae. Sorghum crop adapted to drought areas is a crop of hot, semi-arid tropical environment with 400–600 mm rainfall areas [1,2]. Sorghum plant has a potentiality of quick growth to produce grain yield and good fodder [3,24]. It is an excellent pasture plant with no danger of bloat. It can produced under irrigated in dry farming conditions [4]. These advantages include high water use efficiency and could be a good alternative to maize under limited water in the semi-arid conditions [5]. In Sudan, sorghum forage production is primarily concentrated in the central and eastern states. Its production system is mainly under irrigation. Sudan average yield of dry sorghum forage ranges between 6.55 and 10.08 ton/hectare. The irrigated green forage production in the Sudan is about 4 million tons per year. Sorghum forage production is small compared with other forages, it, production is only about 4% of the total forage produced in the Sudan [6]. In North Kordofan State, where its characterized by a large numbers of animal wealth, the demand for forage and fodder is continuously increasing due increasing numbers of animals. Moreover, very few efforts, with regard to selection or evaluation of known forage sorghum were exerted. This imposed a crucial need to practice evaluation and selection for good forage sorghum suitable for the state to be cultivated under irrigation condition.

One of the most important factors affecting plant growth and yield is watering intervals [7]. El Naim et al [8] mentioned that moisture stress significantly affect stomata closure, decline in growth rate and photosynthesis. It has negative effect on plant growth and development. Water stress in plants led to leaf area reduction, leaf senescence and reduction in cell development [9]. Thus, the aim of this work was to evaluate the productivity of ten genotype of forage sorghum under different irrigation intervals.

2. Materials and Methods

2.1. Experimental Site

This study was carried at the Experimental Farm of crop Sciences Department, Faculty of Natural Resources and Environmental Studies, University of Kordofan, Sudan, Latitude (11-15° N) and longitude (27-32°E). The climate of the area is arid and semi-arid with sandy soil, annual rainfall ranges between 350-450 mm [10]. Average maximum daily temperature ranges between 30-40°C throughout the year

2.2. Experimental design and field layout

Two field experiments were conducted during winter season (2015/2016) and (2016//2017). It based on

randomized complete block design (RCBD) in a split - plot design arrangement with three replications. The treatments consisted of two irrigation intervals (every 7 and 10 days) designated as W_1 and W_2 respectively and the ten genotypes (Taqqat.7B, Taqqat. 9A Taqqat.5A, Gasabi, Geshaish, Nabig, Aish-Baladi, Pioneer (introduced hybrid), Abu70-Aliab and Grawia). Irrigation interval treatments assigned to the main plot whereas genotypes treatments assigned to the sub –plot. Land was disc ploughed and leveled. The individual plot size was (2×2 m) and 70 cm apart consisted of three rows. The main plots were isolated by the guard area of 1.5 m apart to avoid lateral movement of irrigation water or lateral precipitation to adjacent experimental plots. The irrigation was adopted in this trial was surface irrigation, and was applied by using pumping machine through valve and tube of 2-inches diameter and the amount of irrigation water was added at rate of 50 mm /irrigation, according to F.A.O, [11] recommendation. The crop sown manually on first of February 2015 and 2016. Manual weeding practiced two times during the both seasons; the first one was after two weeks from sowing and the second weeding after a month from the first. All experimental plots received similar amounts of water applied at seven days interval for the first 21 days after sowing to establish the plants. Irrigation intervals treatments were applied thereafter. Table 1 shows the number of irrigations, amount of water per irrigation and total water applied during the season.

2.3. Character Studied

2.3.1. Growth Attributes

Growth attributes play an important role in the proper stand establishment of the growing crop, which ultimately affect the productivity and quality of forage crop at the end of the growing season. The following vegetative growth attributes were carried on sample size of ten plants chosen randomly from the inner rows when plants reached 50% flowering in each plot:

Plant height (cm): measured from base to the tip of the plant.

Stem diameter (cm): measured by using a Vernier (Caliper) at the third internodes. Number of leaves: it was determined by counting all number of leaves per plant at flowering stage.

Leaf /stem ratio: plant leaves dry weight (g)/ stem dry weight (g).

2.3.2. Yield Atributes

Fresh forage yield (ton/ha): was calculated by harvesting one meter long from central rows in area of (0.7 m^2) in each plot; cut was practiced at 15 cm above soil surface in each plot, and then weighed immediately in the field by using spring balance, and final fresh weight expressed in ton/ha. The fresh forage was sun dried to constant weight. Then converted to get final dry forage weight (ton/ha).

2.4. Statistical Analysis

The collected data subjected to the statistical analysis of variance according to Gomez and Gomez [12] for spilt–plot design, by using computer program (MSTATC). Duncan multiple range tests used to separate the differences between means.

3. Results and Discussion

The results of plant height as affected by genotypes and irrigation interval shown in Table 2. Significant differences among genotypes were found. Genotype Pioneer had the highest plant height during the two seasons. While the lowest value (82.1 cm) was recorded by genotype Gassabi during season (2015/2016). This variation in plant height might be attributed to genetic make of the genotypes. Sartaj, *et.al.* [13], reported similar results. The irrigation interval (every seven days) had a highest value during both seasons. This result confirmed the report of El Naim and Ahmed (2010). They found that the irrigation interval every seven days had the highest plant height. This result might be due to increase of moisture with less frequent interval, which generally enhance the growth of sorghum. These results matched with those of El Naim et al. [14] who reported that plant height of sorghum increased with increasing soil moisture and tillage depth. The results are in confirmation with those of Saeed and El-Nadi [15] who reported that, plant height of forage sorghum decreased with increasing irrigation intervals.

Statistical analysis indicated that, there were significant differences between genotypes in stem diameter (Table 2), the highest values (1.48 and 1.43 cm) recorded by genotypes Taqqat.7B and Taqqat.5A respectively, whereas minimum value was (1.13 cm) registered by genotype aish-Baladi.. Water treatment had significant effect on the of stem diameter (cm) during season 2015/2016; watering interval (irrigation every seven days) gave the highest value. The significant difference among genotypes could be attributed to genetic makeup of cultivars, differences in genotypes with respect to stem diameter under taken by Naeem *et.al* [16] who observed great differences among sorghum forage cultivars, generally ranged from 1.1 to 1.67 cm. Watering interval treatments were not significant during season 2016/2017. These results coincide with Abdelmula and Salih [17] found significant differences among genotypes in stem diameter under well water conditions. Similarly, Asgharipour and Mahmood [18] reported maximum stem diameter at different irrigation regimes. The genotype T.5A had the highest number (12.3) of leaves (Table 2) followed by genotype Abu70, while the lowest value (7.2) recorded by the local cultivar aish-Baladi. Variation of genotypes could be attributed to environmental factors and water regime. These results disagreed with Abdelmula and Salih [17].

The results of leaf to stem ratio showed in Table 3. Hybrid genotype, Pioneer had the highest leaf to stem ratio. However, genotype Geshaish had the minimum values. This variation might be due to fact that, availability of moisture in closer watering interval, which favoured highest growth rate of leaves. These results in accordance of those investigated by Atem [19], who suggested that, irrigation every seven days favoured production of more leaves during the different stages of growth. The variation between irrigation water intervals statistically was not significant during both seasons. Moosavi, *et.al*, [20] confirmed that, the irrigation intervals had a significant effect on the leaf to stem ratio. The effect of irrigation intervals and genotypes on green forage yield (ton/ha) is shown in Table 3. There were significant differences among genotypes on fresh forage yield (ton

per hectare) during both seasons, the highest value (9.66 ton/ha) was obtained by genotype Pioneer. In addition, cultivar Pioneer had the highest fresh weight during winter season (2016/2017). The differences in fresh forage yield among genotypes could be attributed to the performance and potential of different genotypes grown in the same condition. Sarafa, *et.al* [21] recorded that, there were a considerable variations in the performance of varieties with respect to green forage yield, and this variation due to varietal potential. There was a significant difference due to watering interval treatments, the greater values in both seasons recorded by watering interval treatment (W_1). The highest fresh yield of watering interval (every seven days). This may be attributed to that, the closer water interval 7 days had highest vegetative growth attribute such as plant height, stem diameter, leaf/stem ratio and leaf area. These results are in line with those of Moosavi, *et.al*, [20] who reported that, the irrigation intervals had a significant effect on the yield and yield component of forage sorghum. Data regarding the dry forage yield (ton/ha) recording during the two seasons, showed significant differences among genotypes (Table 3).

Table 1. Number of irrigations, amount of water per irrigation and total water applied for each treatment during the season

Pre-experimental period	Amount per irrigation (mm)	Treatment	Number of irrigations per season	Amount /irrigation (mm)	Total amount of water applied during the season (mm)
1st irrigation	50	W_1	8	50	550
2nd irrigation	50	W_2	4	50	350
3rd irrigation	50				
Total	150				

Table 2. Effect of genotypes and watering interval on plant height (cm), stem diameter (cm) and number of leaves /plant of forage sorghum (*Sorghum bicolor* L. Moench) grown during (2015/2016-2016/ 2017) seasons

Treatments	2015/ 2016			2016/ 2017		
	Plant height (cm)	Stem diameter (cm)	Number of leaves/plant	Plant height (cm)	Stem diameter (cm)	Number of leaves/plant
Tagat.9A	93.5 ^{c}	1.40 ^{abc}	9.2	92.6 ^{j}	1.60 ^{e}	8.9 ^{f}
Pioneer	120.4^{a}	1.42 ^{ab}	8.2	159.9^{a}	1.63 ^{d}	9.8 ^{e}
Tagat.7B	93.7^{c}	1.48 ^{a}	8.0	117.5 ^{h}	1.70 ^{a}	10.06^{c}
AishBaladi	87.0^{cd}	1.13 ^{f}	7.3	114.0 ^{i}	1.21 ^{i}	7.2 ^{j}
Abu70	93.1^{c}	1.28 ^{bcde}	8.5	132.9 ^{d}	1.66 ^{b}	10.2 ^{b}
Tagat.5A	85.2^{cd}	1.43 ^{a}	8.0	120.0 ^{g}	1.70 ^{a}	12.3 ^{a}
Nabig	111.3 ^{b}	1.25 ^{def}	8.2	144.9 ^{b}	1.38 ^{h}	7.9 ^{i}
Grawia	105.7 ^{b}	1.38 ^{abcd}	7.3	139.7 ^{c}	1.65 ^{c}	9.8 ^{d}
Geshaish	87.6 ^{cd}	1.27 ^{cdef}	7.2	124.6 ^{e}	1.46 ^{g}	8.7 ^{g}
Gasabi	82.1^{a}	1.20 ^{ef}	7.3	123.7 ^{f}	1.51 ^{f}	8.5 ^{h}
SE±	0.41	0.021	0.85	1.71	0.02	0.13
W_1	100.3	1.34^{a}	7.8	135.6^{a}	1.56	9.6
W_2	91.8^{b}	1.31^{b}	8.0	118.4^{b}	1.55	9.1
SE±	0.50	025	0.10	2.09	0.02	0.16
C.V%	7.98%	8.05%	8.37%	8.58%	4.71%	9.30%

Similar letters are not significantly different at the 0.05 level of probability according to Duncan Multiple Range.

Table 3. Effect of genotypes and watering interval on leaf /stem ratio, dry forage yield (ton/ha), and fresh forage yield (ton/ha) of forage sorghum (*Sorghum bicolor* L. Moench) grown during (2015/16-2016/17) seasons

Treatments	2015/ 2016			2016/ 2017		
	Leaf / stem ratio	Fresh forage yield (ton/ha)	Dry forage yield (ton/ha)	Leaf / stem ratio	Fresh forage yield (ton/ha)	Dry forage yield (ton/ha)
Tagat.9A	0.78^{bc}	5.6^{cd}	1.8^{c}	0.87 ^{f}	8.0 ^{e}	2.4 ^{h}
Pioneer	0.97^{a}	9.7 ^{a}	4.6^{a}	1.40 ^{a}	11.3 ^{a}	3.3 ^{b}
Tagat.7B	0.80^{a}	7.9^{ab}	2.9^{ab}	0.86 ^{g}	7.4 ^{f}	2.9 ^{e}
AishBaladi	0.65^{de}	4.5^{d}	1.5^{c}	0.79 ^{I}	4.7 ^{j}	1.6 ^{j}
Abu70	0.95 ^{a}	8.0^{ab}	2.7^{ab}	1.07 ^{c}	6.9^{h}	3.3 ^{d}
Tagat.5A	0.75 ^{c}	5.0 ^{d}	1.9 ^{c}	1.23 ^{b}	10.0 ^{b}	3.8 ^{a}
Nabig	0.92 ^{b}	7.5 ^{bc}	2.5 ^{ab}	0.98 ^{d}	9.4 ^{d}	3.3 ^{c}
Grawia	0.82^{ab}	5.7 ^{cd}	1.9^{bc}	0.93^{e}	9.6 ^{c}	3.1 ^{e}
Geshaish	0.55 ^{e}	5.8 ^{cd}	2.0^{bc}	0.78 ^{j}	6.9^{g}	2.2^{i}
Gasabi	0.83^{ab}	4.3 ^{d}	1.7 ^{c}	0.83^{h}	6.7^{i}	2.8^{g}
SE±	0.04	0.24	0.11	0.04	0.18	0.06
W_1	0.82	7.4^{a}	2.6^{a}	1.07^{a}	9.1^{a}	3.1^{a}
W_2	0.78	5.3^{b}	2.1^{b}	0.89^{b}	7.1^{b}	2.3b
SE±	0.05	0.29	0.14	0.05	0.21	0.07
C.V %	16.9%	24.8 %	23.1 %	17.07%	16.31%	25.4 %

Similar letters are not significantly different at the 0.05 level of probability according to Duncan Multiple Range.

Genotype Pioneer had produced higher (4.62) weight ton per hectare during season (2015/2016) than the other genotypes. Irrigation watering intervals significantly were different, watering interval W_1 gave the highest value in both seasons. The increased in dry forage yield might be due availability of moisture which enhanced rapid growth and caused a high green forage yield, which reflect in high dry weight similarly decreased in dry yield due to the reduction occurring to fresh yield. These findings are similar in accordance with Mustafa, *et al*. [22], who reported that dry matter of forage sorghum increased with the decrease in irrigation interval, which means enough moisture, was available in plant roots. Also Miron *et al.* [23] reported significant differences in dry matter yields of different sorghum cultivars.

4. Conclusion

The results indicated that the irrigation interval of seven days had a better growth performance and the highest forage yield. Pioneer cultivar was a superior in all irrigation intervals and expected to be cultivated for forage purposes in marginal area in North Kordofan environments. Further study needed with different irrigation quantities and intervals proposed to determine whether there are greater benefits or yield, increases at other levels than those observed in this study.

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