Journal of Agriculture and Ecology Research International

20(3): 1-8, 2019; Article no.JAERI.53427
ISSN: 2394-1073

Effects of Spacing and Nitrogen Fertilizer on Growth and Biomass Yield of Mechello Grass (*Sorghum aethiopicum*) under Rain Fed Condition in Western Tigray, Northern Ethiopia

Gebreslasie Gebrekidan[1*] and Gebrekiros Maru[1]

[1]Humera Agricultural Research Center, P.O.Box 62, Humera, Ethiopia.

Authors' contributions

This work was carried out in collaboration between both authors. Author GG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author GM managed the analyses of the study. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2019/v20i330108
Editor(s):
(1) Dr. Ahmed Esmat Abdel Moneim, Department of Zoology, Egypt And Slovak Academy of Medicine, Helwan University, Bratislava, Slovakia.
Reviewers:
(1) Ana Maria Arambarri, National University of La Plata (Universidad Nacional de La Plata), Argentina.
(2) Angela N. Kathuku-Gitonga, Kenya Agricultural and Livestock Research Organization, Kenya.
Complete Peer review History: http://www.sdiarticle4.com/review-history/53427

Original Research Article

Received 15 October 2019
Accepted 19 December 2019
Published 27 December 2019

ABSTRACT

Field study was conducted at Humera, Kebabo, Banat, Zerbabit, Division and Ruwasa, western zone of Tigray, northern Ethiopia in 2018 under rain fed condition to determine effects of six nitrogen fertilizer levels (0, 11.5, 23.0, 34.5, 46.0 and 57.5 kg Nha^{-1}) applied in the form of urea and four spacing (30, 45, 60 and 75 cm) on growth and biomass yield of Mechello grass (*Sorghum aethiopicum*). The experiment was arranged in a split-plot design with three replications. Data on dry matter yield (DMY, $tonha^{-1}$), onset of flowering date (days), plant height (cm) and the number of tillers at harvest were recorded. A significant difference ($p<0.001$) due to nitrogen fertilizer was noted on DMY ($tonha^{-1}$), onset of flowering date (days) and plant height (cm) at harvest. Similarly, spacing had a significant effect on DMY ($p<0.001$), plant height ($p<0.002$) and the number of tillers at harvest ($p<0.001$). Higher values on DMY and plant height at harvest were recorded at 23.0, 34.5, 46.0 and 57.5 kg N ha^{-1}. Similarly, higher values of DMY and number of tillers at harvest were obtained from the denser (30 cm) and less dense (75 cm) spacing's, respectively. The study

**Corresponding author: E-mail: gebre077@gmail.com;*

suggested that application of 23.0 kgNha^{-1} and 30 cm spacing improved biomass yield of *Sorghum aethiopicum* under rain fed condition and recommended to be implemented. Therefore, application of 23.0 kgNha^{-1} and 30cm spacing to boost biomass yield of *Sorghum aethiopicum* should be demonstrated and popularized in the study area and other similar agro-ecologies of the country.

Keywords: Sorghum aethiopicum; dry matter yield; nitrogen fertilizer; spacing; tillers.

1. INTRODUCTION

Because of rapid human population and income growth, together with urbanization, the demand for livestock products is increasing throughout the world [1,2]. According to [3], the world meat production and consumption has been increased especially by the increasing living standards in developing countries. People in developed countries currently consume about 3 to 4 times as much meat and fish, and 5 to 6 times as much milk products per capita as in developing Asia and Africa. Meat, milk, and fish consumption per capita has barely grown in developed countries as a whole over the past 20 years [4]. According to Christopher et al. [4], yet poor people everywhere clearly desire to eat more animal protein products as their incomes rise above the poverty level and as they become urbanized. Regardless of this, because of health problem, low management, and low genetic potential and together with the shortage of feed, animal productivity is still too low; as a result, it cannot satisfy the available demand.

Feed both in terms of quantity and quality is a major bottleneck for livestock production in Ethiopia [5,6]. Feed resources can be classified as natural pasture, crop residue, agro-industrial byproducts [7], and improved forage of which the first two contribute the largest share [6]. Moreover, according to Gizaw et al. [5], crop residue is the major livestock feed in Oromia, Amhara and Tigray, whereas in the South Nations, Nationalities and Peoples (SNNP) region grazing lands and crop residues are the major sources of livestock feed. Besides, the overall contribution of crop residues exceeds 50% of the livestock feeds currently used by smallholder farmers [8]. However, crop residues are fibrous byproducts and their feeding value are limited by their poor voluntary intake, low digestibility and low nitrogen, energy, mineral and vitamin contents [9,6]. Moreover, with the rapid increase of human population and increasing demand for food, grazing lands are steadily shrinking by being converted to arable lands [9], and are restricted to areas that have little value [5,6].

Thus, to address this situation, the use of indigenous forage grasses such as Mechello grass (*Sorghum aethiopicum*) as a feed source is one option. Mechello grass (*Sorghum aethiopicum*) is one of the promising grass varieties that intended to contribute paramount role in addressing feed shortage in the western zone of Tigray, northern Ethiopia. It was registered in the national variety release in 2017 Gregorian calendar (G.C) as best feed resources of the area and recommended for relatively low to high moisture areas of lowland Tigray and other similar agro-ecologies of Ethiopia. Being native to the area, drought-resistant, having 13.56% crude protein (CP) and 17.67 tonha^{-1} of forage yield makes it an important grass for the area [10]. However, there is no evidence regarding the appropriate agronomic practice like spacing between row and optimum rate of N fertilizer on growth and biomass yield of Mechello grass (*Sorghum aethiopicum*) in the study area and other similar agro-ecologies in Ethiopia. Therefore, the study was conducted to intend to determine the effects of appropriate spacing and nitrogen fertilizer on growth and biomass yield of Mechello *grass* (*Sorghum aethiopicum*).

2. MATERIALS AND METHODS

2.1 Description of the Study Area

This study was conducted at Kafta Humera (Humera, Zerbabit, Ruwassa and Banat sites) and Tsegede (Kebabo and Yekatit sites) Districts of Western Zone of Tigray (WZT), Northern Ethiopia (Fig. 1). Western Zone of Tigray (WZT) is located at 570 and 991 km far from Mekelle and Addis Ababa, respectively [11]. It lies at 13° 42′ to 14°28′ north latitude and 36°23′ to 37°31′ east longitude [12] and shares borders with Tahtay Adiyabo Woreda, Sudan, Amhara region and Eritrea in the East, West, South and North, respectively. Similarly, its altitude ranges from 500-3000 m.a.s.l for Humera and Ketema Nugus, respectively. Moreover, it consists of three agro-ecological zones (lowland, midland and highland) in which *kola* (lowland), *weynadegga* (midland) and *dega* (highland) account for 75%, 15.7% and 9.3%, respectively of the land coverage. Its annual rainfall ranges from 600 to 1800 mm with maximum and minimum temperatures of 45 and 12ºC, respectively [11].

Moreover, WZT covers a total area of 1.5 million hectares, of which grazing lands cover 116921.88 hectares (10.4%) [11]. Likewise, the livestock sector is the predominant economic activity of the area in which 95% of the total population engaged directly or indirectly on it [12]. Local *Arado* (in both high land and midland areas) and *Begait* cattle (in lowland areas) are the main cattle breeds reared in the study area. Similarly, major livestock feed resources in the study area include natural pasture, crop residues, woody browses (shrubs, bush and tree) and others such as stubble, hay and tree foliages, of which natural pasture and followed by crop residues are the main ones [13].

2.2 Plot Preparation, Planting Method and Fertilizer Application

Mechello grass (*Sorghum aethiopicum*) was planted in a well-prepared plot in row planting method at the beginning of July 2018. Each plot had a size of 2.5 m length and 4 m width with 1.5 and 1 m spacings between each block and plot, respectively. The grass was planted in drilling method at a depth of about 2.5 cm and lightly covered with soil to ensure adequate emergence. Moreover, urea fertilizer was applied after the grass was well established by placing near root slips depending on the treatments.

2.3 Methods of Data Collection

Data were recorded from the sample plants during the experiment. Three plants were selected from each of the unit plots for the collection of data. The plants in the outer rows and the end of the middle rows were excluded from the random selection to avoid the border effect. Moreover, fresh biomass yield was taken by harvesting the middle rows at the onset of the flowering stage. Consequently, dry matter yield was calculated after drying a sub-sample of green forage in an oven at 105ºC for 24 hours in Humera Agricultural Research Center which was converted into a hectare.

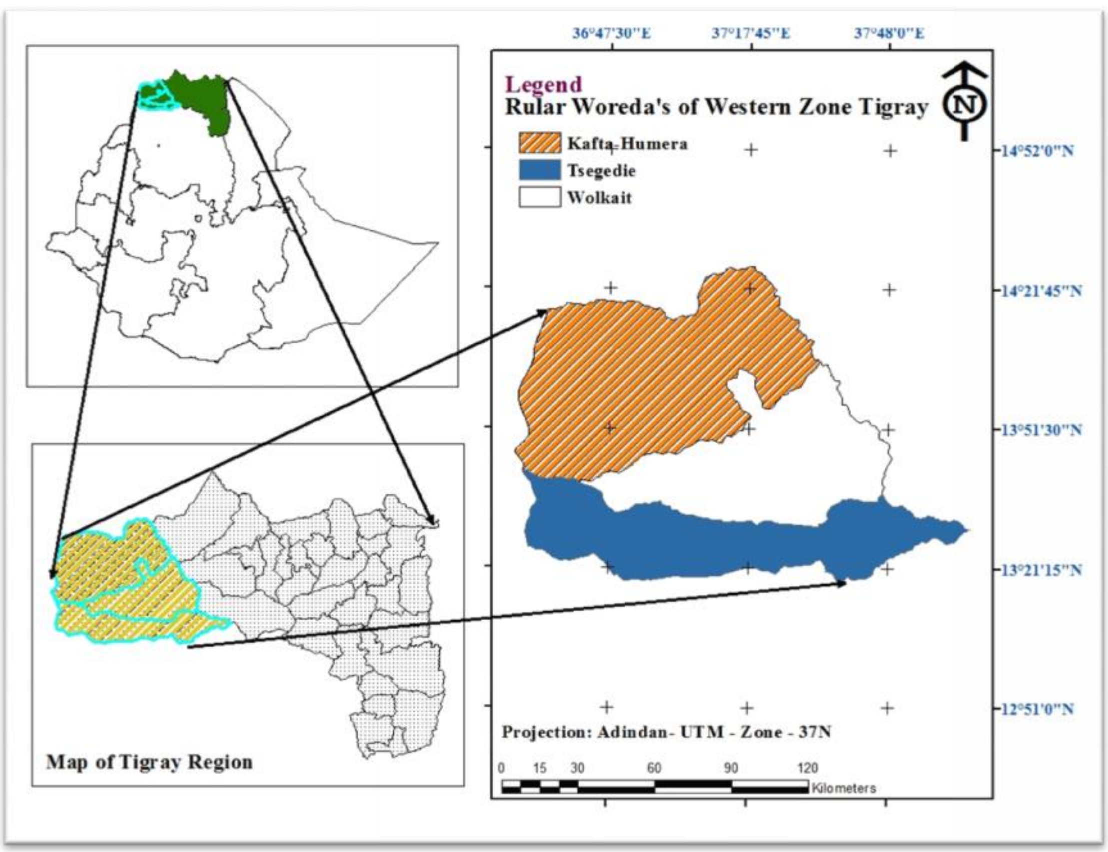

Fig. 1. Location map of the study area, western zone of Tigray region, Northern Ethiopia using ARC GIS 10.1 [14]

2.4 Experimental Design and Treatments

The experiment was arranged in a split-plot design with six nitrogen fertilizer levels (0, 11.5, 23.0, 34.5, 46.0 and 57.5 kg Nha^{-1}) and four spacing (30, 45, 60 and 75 cm). Nitrogen fertilizer rates and spacing were used as main-plot and sub-plot treatments, respectively. Two separate randomization process was used, one for the main plot and another for the subplot. In each replication, main plot treatments were first randomly assigned to the main plots followed by a random assignment of the subplot treatments within each main plot.

2.5 Data Analysis

Data were analyzed by Genstat eighteenth edition and subjected to analysis of variance (ANOVA). As well as means were separated by Fisher's unprotected least significant difference test at 5% probability level.

3. RESULTS AND DISCUSSION

3.1 Effect of Nitrogen Fertilizer on Dry Matter Yield (DMY)

There was a significant difference in DMY due to nitrogen fertilizer (Table 1). Based on the over al mean result, higher ($p<.001$) DMY was obtained from 23.0, 34.5, 46.0 and 57.5 kg N ha^{-1}, and the lower value were obtained from the control. The observed higher DMY record at 23.0, 34.5, 46.0 and 57.5 kg N ha^{-1} could be due to relatively higher plant height in these treatment groups. On the contrary, the lower value in the control group could partly be due to the lower plant height. The increase in yield of forage due to nitrogen application can be attributed to the positive effect of nitrogen on all the growth parameters.

3.2 Effect of Spacing on DMY

Higher and lower DMY was obtained from the denser (30 cm) and less dense (75 cm) spacing, respectively and intermediate for the others (Table 1). Because of the higher plant height (Table 2) and population density in the denser (30 and 45 cm) spacing groups, DMY decrease as spacing increase. The current finding was in line with the previous findings [15,16], but in contrary with that of the findings of Genet et al. [17] and Worku et al. [18] who reported that DMY was not affected by plant spacing and was increased with spacing, respectively.

3.3 Effect of Nitrogen Fertilizer on Plant Height at Harvest

There was a significant difference ($p<.001$) on plant height at harvest (PH) due to nitrogen fertilizer application (Table 2), and higher values were recorded at 23.0, 34.5, 46.0 and 57.5 kg N ha^{-1} and lower values were at 11.5 and 0 level of fertilizer. The increase in plant height with nitrogen fertilizer can be attributed to the fact that nitrogen promotes plant growth, increases the number and length of the internodes which results in a progressive increase in plant height [19].

3.4 Effect of Spacing on Plant Height at Harvest

According to the overall mean result, relatively higher ($p<0.002$) plant height at harvest was recorded at the narrow (30 and 45 cm) spacing as compared with the wide ones (Table 2). The higher plant height at the narrow spacing could be due to narrow spacing increased interplant competition, causing individual plants to grow taller with longer internodes, plus slender, thin and weak stalks due to poor light exposure and hence poor photosynthetic output [20].

3.5 Effect of Nitrogen Fertilizer on Number of Tillers per Plant at Harvest

There was no significant ($p>0.433$) difference in the number of tillers per plant due to nitrogen fertilizer application (Table 3).

3.6 Effect of Spacing on Number of Tillers per Plant at Harvest

As shown from the result (Table 3), the tillering ability is more significant due to spacing as compared with the level of fertilizer. The number of tillers per plant increases as spacing increase and was comparable with the previous studies [16,17,18], and higher and lower values were recorded at 75 and 30 cm, respectively. Under wider spacing competition for nutrients (moisture, nitrogen) is less, so individual plants can support more tillers per plant [17].

Table 1. Means ± SE of dry matter yield (tonha^{-1}) of *Sorghum aethiopicum* at six locations

LF (kgNha^{-1})	Locations						Overall mean
	Banat	Humera	Kebabo	Ruwasa	Zerbabit	Division	
0	11.59^{b}	8.39^{b}	5.350^{d}	5.323^{c}	5.945^{e}	4.625^{d}	6.971^{c}
11.5	11.72^{b}	9.81^{a}	7.462^{cd}	4.418^{c}	9.344^{ab}	6.283^{c}	8.173^{b}
23.0	13.84^{a}	10.67^{a}	9.122^{bc}	6.486^{b}	9.407^{a}	8.669^{b}	9.700^{a}
34.5	12.48^{ab}	10.38^{a}	10.547^{b}	8.083^{a}	8.520^{bc}	7.612^{b}	9.645^{a}
46.0	13.98^{a}	10.84^{a}	11.202^{ab}	7.009^{b}	8.421^{c}	10.130^{a}	10.263^{a}
57.5	13.10^{ab}	11.03^{a}	12.804^{a}	6.604^{b}	7.064^{d}	10.216^{a}	10.135^{a}
SE	0.945	0.625	0.980	0.462	0.370	0.596	0.472
CV (%)	9.1	7.5	12.7	9.0	5.6	9.2	6.3
P-value	0.116	0.016	<.001	<.001	<.001	<.001	<.001
IRS(cm)							
30	15.04^{a}	11.31^{a}	10.774^{a}	6.684^{ab}	9.739^{a}	10.707^{a}	10.803^{a}
45	12.06^{b}	10.15^{b}	9.659^{ab}	6.874^{a}	8.672^{b}	7.473^{b}	9.148^{b}
60	12.00^{b}	9.85^{b}	8.296^{b}	5.722^{c}	7.111^{c}	7.259^{bc}	8.373^{bc}
75	12.05^{b}	9.42^{b}	8.929^{ab}	6.002^{bc}	6.944^{c}	6.250^{c}	8.267^{c}
SE	0.758	0.506	0.983	0.539	0.407	0.606	0.389
CV (%)	6.3	2.6	4.0	3.5	2.6	5.5	4.9
P-value	<.001	<0.001	0.064	0.024	<.001	<.001	<.001

Means with the same letter(s) in a column are not significantly different; LF (kg Nha^{-1}): level of fertilizer; IRS (cm): inter-row spacing; CV (%): Coefficients of variation; SE: Standard errors of the mean

Table 2. Means ± SE of plant height at harvest (cm) of *Sorghum aethiopicum* at six locations

LF (kgNha^{-1})	Locations						Overall mean
	Banat	Humera	Kebabo	Ruwasa	Zerbabit	Division	
0	139.1^{c}	80.9^{b}	118.4^{e}	104.6^{c}	89.66^{c}	149.5^{d}	113.7^{c}
11.5	166.3^{ab}	106.4^{a}	153.0^{d}	125.0^{b}	94.76^{bc}	167.9^{c}	135.7^{c}
23.0	177.8^{a}	109.1^{a}	166.2^{c}	132.2^{ab}	98.38^{b}	187.1^{ab}	145.1^{ab}
34.5	170.0^{a}	113.0^{a}	183.1^{b}	142.6^{a}	93.73^{bc}	198.1^{a}	150.1^{a}
46.0	174.2^{a}	112.5^{a}	193.8^{a}	131.9^{ab}	99.22^{b}	178.3^{bc}	148.3^{a}
57.5	152.4^{bc}	110.2^{a}	193.7^{ab}	128.5^{b}	108.70^{a}	176.5^{bc}	145.0^{ab}
SE	7.56	5.14	4.80	5.21	3.74	7.06	4.60
CV (%)	5.7	6.0	3.5	5.0	4.7	4.9	4.0
P-value	0.003	<.001	<.001	<.001	0.008	<.001	<.001
IRS(cm)							
30	157.9^{b}	111.4^{a}	173.9	138.3^{a}	102.37	188.9^{a}	145.5^{a}
45	174.7^{a}	109.1^{a}	167.5	132.0^{ab}	94.82	184.0^{a}	143.7^{a}
60	160.0^{b}	101.2^{b}	166.6	122.2^{bc}	97.95	170.6^{b}	136.5^{b}
75	160.7^{b}	99.6^{b}	164.2	117.4^{c}	94.49	161.4^{c}	133.0^{b}
SE	6.10	3.79	5.56	6.98	5.32	6.00	3.55
CV (%)	5.4	2.5	1.6	2.6	3.8	2.1	4.8
P-value	<.001	0.002	0.352	0.019	0.196	<.001	0.002

Means with the same letter in a column are not significantly different; LF (kg Nha^{-1}): level of fertilizer; IRS (cm): inter-row spacing, CV (%) = Coefficients of variation, SE = Standard errors of the mean

3.7 Effect of Nitrogen Fertilizer on Onset of Flowering

There was a significant difference (p<.001) on the onset of flowering date due to nitrogen fertilizer between the treatment groups with fertilizer and the one without fertilizer (Table 4). The treatment groups with fertilizer reached the onset of flowering earlier than the control. This could be because nitrogen application promoted vigorous growth and hence early 50% flowering. A similar finding was observed by Worku et al. [18] in his study on Desho grass (*Pennisetum pedicellatum*).

Table 3. Means ± SE of number of tillers per plant at harvest (number) of *Sorghum aethiopicum* at six locations

LF (kgNha^{-1})	Locations						Overall
	Banat	Humera	Kebabo	Ruwasa	Zerbabit	Division	mean
0	10.51^{bc}	11.80^{bc}	4.525^{b}	10.08	12.69^{ab}	9.39^{d}	9.81
11.5	11.24^{bc}	12.82^{a}	5.175^{b}	11.89	11.20^{c}	9.98^{cd}	10.37
23.0	10.38^{c}	13.16^{a}	4.992^{b}	11.00	12.78^{ab}	12.69^{b}	10.83
34.5	12.23^{a}	10.94^{c}	5.133^{b}	10.13	12.29^{b}	15.44^{a}	11.00
46.0	11.45^{ab}	10.97^{c}	6.050^{a}	10.18	13.07^{a}	11.68^{bc}	10.57
57.5	10.99^{bc}	12.30^{ab}	6.583^{a}	11.11	13.43^{a}	11.23^{bcd}	10.93
SE	0.438	0.424	0.314	1.338	0.351	0.875	0.614
CV (%)	4.8	4.3	7.1	15.3	3.4	9.1	7.1
P-value	0.017	0.001	<.001	0.709	0.001	<.001	0.433
IRS(cm)							
30	9.76^{b}	10.71^{b}	5.200^{b}	10.46	10.28^{b}	9.16^{c}	9.26^{c}
45	11.79^{a}	11.58^{b}	5.206^{b}	11.13	11.47^{b}	11.47^{b}	10.40^{bc}
60	11.93^{a}	12.69^{a}	4.728^{b}	10.36	14.07^{a}	12.02^{b}	10.97^{ab}
75	11.05^{ab}	13.01^{a}	6.506^{a}	10.98	14.49^{a}	14.29^{a}	11.71^{a}
SE	0.847	0.460	0.323	0.865	0.683	1.360	0.575
CV (%)	3.0	1.5	4.9	2.0	2.1	10.1	7.2
P-value	<.001	<.001	<.001	0.695	<.001	<.001	<.001

Means with the same letter in a column are not significantly different; LF (kg Nha^{-1}): level of fertilizer; IRS (cm): inter-row spacing; CV (%): Coefficients of variation; SE: Standard errors of the mean

Table 4. Means ± SE of onset of flowering date (days) of *Sorghum aethiopicum* at six locations

LF (kgNha^{-1})	Locations						Overall
	Banat	Humera	Kebabo	Ruwasa	Zerbabit	Division	mean
0	68.92^{a}	70.42^{a}	78.00^{a}	73.25^{a}	68.08^{a}	75.92^{a}	72.43^{a}
11.5	64.67^{b}	65.42^{b}	73.83^{b}	68.58^{b}	63.50^{bc}	70.92^{b}	67.82^{b}
23.0	65.83^{b}	65.33^{b}	73.58b^{c}	68.33^{b}	63.42^{bc}	70.92^{b}	67.90^{b}
34.5	65.58^{b}	65.67^{b}	73.58^{bc}	68.50^{b}	63.67^{bc}	70.83^{b}	67.97^{b}
46.0	65.00^{b}	65.58^{b}	73.67^{bc}	68.17^{b}	63.92^{b}	70.67^{b}	67.83^{b}
57.5	64.75^{b}	65.58^{b}	73.33^{c}	68.50^{b}	63.25^{c}	70.83^{b}	67.71^{b}
SE	0.8105	0.2386	0.1581	0.2030	0.1566	0.3199	0.159
CV (%)	1.5	0.4	0.3	0.4	0.3	0.5	0.3
P-value	0.003	<.001	<.001	<.001	<.001	<.001	<.001
IRS(cm)							
30	65.61	66.33	74.50	69.17	63.94 b	71.56	68.52
45	65.83	66.50	74.28	69.33	64.61 a	71.61	68.69
60	65.72	66.17	74.22	69.06	64.50 a	71.78	68.57
75	66.00	66.33	74.33	69.33	64.17ab	71.78	68.66
SE	0.2202	0.1838	0.1632	0.2061			0.082
CV (%)	1.9	0.2	0.1	0.2	0.2	0.6	0.2
P-value	0.298	0.359	0.380	0.462	0.002	0.636	0.142

Means with the same letter(s) in a column are not significantly different; LF (kg Nha^{-1}): level of fertilizer; IRS (cm): inter-row spacing; CV (%): Coefficients of variation; SE: Standard errors of the mean

4. CONCLUSION AND RECOMMENDATIONS

This study indicated that spacing and nitrogen fertilizer influenced DMY and plant height at harvest. A significant difference ($p<0.001$) due to nitrogen fertilizer was noted on DMY (tonha^{-1}), the onset of flowering date (days) and plant height (cm) at harvest. Similarly, the study also indicated that spacing had significant ($p<0.05$) effect on DMY, plant height and number of tillers at harvest. Higher values on DMY and plant height at harvest were recorded at 23.0, 34.5, 46.0 and 57.5 kgNha^{-1}. Similarly, higher values of DMY and number of tillers at harvest were obtained from the denser (30 cm) and less dense

(75cm) spacing, respectively. The study suggested that application of 23.0 $kgNha^{-1}$ and 30cm spacing improved biomass yield of *Sorghum aethiopicum* under the rainfed condition and recommended to be implemented. Therefore, application of 23.0 $kgNha^{-1}$ and 30 cm spacing to boost biomass yield of *Sorghum aethiopicum* should be demonstrated and popularized in the study area and other similar agro-ecologies of the country. Also, further investigation should be conducted on the effect of N fertilizer on the chemical composition of feed harvested at the different maturity stage of *Sorghum aethiopicum.*

DECLARATION

Authors declare and affirm that this is our work. The authors have followed all principles of the scholarship in the preparation, data collection, data analysis and compilation of the activity. Any scholarly matter that is included in the activity has been given recognition through citation.

ACKNOWLEDGEMENTS

The authors would like to thank the Tigray Agricultural Research Institute (TARI) for financial support. Moreover, deepest appreciation goes to Humera Agricultural Research Center (HuARC) for giving material support during conducting the research project.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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