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CHEMICAL COMPOSITION AND METHANE YIELD OF SORGHUM AS INFLUENCED BY PLANTING METHODS AND CULTIVARS

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ABSTRACT

Bio-fuel produced by plant biomass is considered to be cheap, sustainable and more environmental friend owing to lower green house gas emissions. Management considerations including sowing method and suitable cultivar have considerable effect on the biomass yield which in turns influences the bio-fuel yield. Field experiments were executed during 2016 and 2017 to determine the impact of sowing methods and cultivars on biomass yield, composition and methane yield. The experiments were designed in randomized compete block design in split plot arrangement with sowing methods (broadcasting, line, bed and ridge sowing) in main plot and sorghum cultivars (Hagari and JS-2002) in sub-plot. Results revealed better performance of ridge sowing for LAI, LAD, CGR, dry matter yield and methane yield ha^{-1} as compared to other sowing methods. Moreover, the all sowing methods exhibited comparable protein, sugar, acid detergent, and neutral detergent fiber, lignin and ash contents. Amongst cultivars Hagari exhibited higher LAI, LAD, CGR, plant height, leaves per plant, diameter yield, protein, ADF, NDF, lignin concentration and methane yield ha^{-1} basis as compared to the JS-2002. It may be concluded that sowing on ridges would produce higher dry matter yield resulting in higher methane production per unit area. Moreover, Hagari is promising cultivar owing to higher dry matter production for maximizing its potential for methane production.

Keyword: Sowing methods, Cultivars, Biomass quality, Methane yield.

INTRODUCTION

The energy demand and consumptions are rapidly increasing globally owing to development of economy and blooming population (Zhou *et al.,* 2011). Amongst energy sources fossil fuels are the major source of fuel (Kibazohi and Sangwan, 2011) nonetheless, these resources are continuously depleting and major source of green house gas emissions (Petersson *et al.,* 2007). Hence, all over the world scientists are looking and exploring the potential of alternate, sustainable and environmental friendly energy sources. Amid the alternate sources bio-fuels made from plant biomass are sustainable and environmental friendly as compared to the traditional fossil fuels. Moreover, they can also conquer the challenges of energy security and climate changes due to burning of fossil fuels (Zhuang *et al.,* 2011).

Among biomass sources, energy crops are being grown globally for the production of bioenergy. Sorghum (*Sorghum bicolor L.*) is one of the indispensible crops cultivated globally for bio-energy production (Hassan *et al*., 2018c). Although sorghum is the native crop of tropical regions, however, it is also well adopted to temperate regions (Kangama and Rumei, 2005). The versatile characteristics, including low water, and nutrient requirements and drought, water logging and salinity tolerance makes it more suitable energy crop (Vasilakoglou *et al.,* 2011). Moreover, sorghum can also perform remarkably well in marginal environments (Amaducci *et al.,* 2004).

Management considerations including the sowing methods and selection of suitable cultivars have considerable influence on the final biomass production which consequently affects the biomass yield, hence biogas production. Majority of farmers in the country use broadcasting as method of sowing which have many disadvantages including, more use of seed, uneven seed distribution, picking of seeds by birds, poor germination, thus results in poor stand establishment and final yield (Bakht *et al.,* 2007). In this regard improved sowing methods including ridge and bed sowing can play a significant role to improve the crop productivity. Ridges and beds provide the loose layer of soil that results in better root development and proliferation, more uptake of water and nutrient, thus resulting in increased the final yield (Khan *et al.,* 2012). Various researchers reported the considerable differences among the sowing methods for biomass yield. Likewise, Khan *et al.* (2012) reported the maximum grain and biomass yield in ridge and bed sowing as compared to flat and broadcasting. Similarly, Bakht *et al.* (2011) also reported the maximum grain and biomass yield from ridge and raised bed sowing as compared to conventional broadcast sowing. Similarly, Bakht *et al.* (2007) also observed the maximum biological yield in ridge sowing as compared to the flat and broadcasting sowing.

Similarly, selection of suitable cultivar also plays a considerable role in the final biomass production and methane yield. Cultivars differed in the context of growth, biomass yield, and chemical composition including protein, fiber and fat contents (Ayub *et al.,* 2001) which consequently affects the methane yield (Mahmood *et al.,* 2015: Hassan *et al*., 2018a). The chemical composition of cultivars i.e. protein, sugars, fibers, and lignin content considerably influenced the digestibility of biomass (Miron *et al.,* 2005) which resultantly influenced the methane yield (Mahmood and Honermeier, 2012). In the light of above mentioned evidences it can be concluded that management practices i.e. sowing methods and cultivars had considerable influence on the biomass production which resultantly influence the biomass composition and methane yield. In, Pakistan no study is available regarding the effect of sowing methods and cultivars on biomass production and methane yield of sorghum. Thus, this study was conducted to determine the influence of sowing methods and cultivars on biomass yield, composition and methane yield of sorghum.

MATERIALS AND METHODS

Study site: The current study was performed during 2016 and 2107 at Post Graduate Agriculture Research University of Agriculture Faisalabad Pakistan (longitude 73·8°E, latitude 31·8°N, and altitude 184·4 masl). The study sites fall in subtropical regions, moreover, the prevailed conditions during the study are given in Table 1. The composite soil samples were collected from the depth of 0-30cm and various physio-chemical characteristics (Table 2) were determined by the standard procedures of Homer and Pratt, (1961) and are given in Table 2.

Experimental design and treatments: The experiment was performed in randomized compete block design with split plot arrangement. The study was composed of two factors, i.e., sowing methods, (broadcasting, line, ridge and bed sowing) and sorghum cultivars (Hagari and JS-2002).

Crop management: After harvesting of wheat crop a pre soaking irrigation was applied to field. Afterwards when field came in workable moisture condition two ploughing followed by planking was done to prepare the seedbed. In broadcast method seeds were broadcasted manually in the field, while in line sowing method sowing was done with the hand drill. Ridges and beds were prepared by the ridge and bed shaper. Fertilizers, nitrogen (N) and phosphorus (P) was used at the of 60:40 NP kg ha^{-1} in the form of urea and diammonium phosphate. All the P and fifty percent of N was applied at sowing whilst rest dose of N was applied with first irrigation. Three irrigations were applied during both years including soaking irrigation. Weed control was done by using Atrazine at the rate of 2.5-liter ha^{-1} with additional manual practices. Furadan at the rate of 15 kg ha^{-1} was also used to control the attack of shoot fly. The crop was sown on 2nd May and 6th May and harvested on 16th and 20th August during 2016 and 2017 respectively.

Collection of data: Leaf area was determined by using leaf area meter (CI-202, CID Bio-Science). Furthermore, leaf LAI was measured by standard procedures of Watson (1952), whilst, LAD and CGR was measured standard procedures as detailed by (Hunt 1978). First LAI, LAD and CGR were measured post forty days after sowing, while subsequent measurements were taken after ten-day interval. Twenty plants from each plot were selected and their height, stem diameter were measured and leaves per plant was counted and then average was taken. At the end plots were harvested and dried to determine the dry matter yield and converted mathematically into ton ha^{-1} basis.

Chemical analysis: After drying, sorghum samples were grinded with grinder and passed through 1mm sieve. The contents of protein and ash in sorghum samples were measured by the methods of AOAC (1990). Moreover, sugar concentration was measured by the procedures of Dubois *et al.,* (1956), whilst ADF, NDF and lignin was worked out by the protocols of Georing and Van-Soest, (1970) and Van-Soest *et al.,* (1991) respectively. Methane produced by the sorghum samples was measured by the Bioprocess Control's AMPTS equipment. Cattle manure was used as a source of bacteria for an-aerobic digestion of sorghum samples. The digester had the capacity of 400 ml. In every digester 16 g substrate was add and then the volume was made upto 400 ml. Afterwards, digesters were perched with nitrogen gas in order to create the an-aerobic conditions. The temperature of digesters was maintained at 37^{0}C by standing them in water bath. The sorghum samples were allowed to digest for 28 days. Methane produced by the sorghum samples was recorded every day with the help of computer operated system. At the end by using the amount of volatile solids, specific methane produced by each sorghum sample was calculated and later on converted into per ha^{-1} basis mathematically.

Statistical analysis: Fisher's analysis of variance techniques was practiced to analyze the data; moreover, least significant difference test at 5% probability was used to compare the treatment means. In addition, graphs were prepared by using sigma plot 9 software.

RESULTS

Growth attributes: The results revealed that sowing methods had significant effect on the growth attributes i.e., LAI, LAD and CGR. LAI increased progressively and maximum LAI was reported 70 days after sowing (DAS). At 70 DAS, the maximum LAI was recorded from ridge sowing followed by bed sowing, whereas the lowest LAI was recorded in broadcast sowing (Fig 1 ab). Likewise, maximum LAD and CGR was observed at 60-70 DAS which was again from ridge sowing, whereas the lowest was observed in broadcast sowing (Fig c,d and e,f). Similarly, cultivars also had considerable effect on the LAI, LAD and CGR. Both the cultivars exhibited the maximum LAI after 70 DAS, however the highest LAI was observed in Hagari as compared to the JS-2002. Likewise, the maximum LAD and CGR was observed at 60-70 DAS, nonetheless, highest LAD and CGR was recorded in Hagari as compared to the JS-2002. The interactive effect between sowing methods and cultivars for LAI, LAD and CGR was found non-significant. The planting methods and cultivars remarkably affected the plant height, stem girth and leaves count per plant. In case of sowing methods maximum plant height, stem girth and leaves count per plant was observed in ridge sowing, followed by bed sowing, whereas the lowest plant height, stem girth, and leaves count was reported in broadcast sowing (Table 3). Amongst the cultivars Hagari, had more plant height, stem girth and leaves as compared to the JS-2002 (Table 3). The interactive effect was significant for stem diameter. In interactive maximum stem diameter was observed in Hagari sown on ridges whereas the lowest was recorded in JS-2002 sown by broadcasting method (Fig 3).

Biomass yield: Sowing methods and tested cultivars had significant effect on the dry matter yield. The maximum dry matter yield was recorded with ridge sowing, followed by bed sowing that was comparable with line sowing, whereas the lowest dry matter yield was observed in broadcast sowing (Table 3). In case of cultivars Hagari produced significantly higher biomass yield as compared to the JS-2002 (Table 3).

Biomass quality: The results revealed that sowing methods had non-significant effect on the quality attributes i.e., protein, sugar, ADF, NDF, lignin and ash contents (Table 4, 5). However, tested cultivars had significant effects on the quality attributes (Table 4, 5). The maximum protein content was exhibited by the Hagari, whilst minimum protein content was shown by JS-2002. Conversely, maximum sugar content was recorded in the DM of JS-2002, whilst lowest was recorded in Hagari. Moreover, cultivar Hagari was characterized with maximum ADF, NDF, lignin and ash content, whereas the cultivar JS-2002 exhibited the lowest ADF, NDF, lignin, and ash content.

Specific methane yield and methane yield ha^{-1}: Sowing methods produced comparable specific methane yield (SMY), while cultivars differed significantly for specific methane yield (Table 6). Cultivar JS-2002 was characterized with maximum specific methane yield as compared to Hagari (Table 6). On the other hand, sowing method and cultivars had significant effect on the methane yield ha^{-1}. Maximum methane yield ha^{-1} was recorded with ridge sowing followed by bed sowing, while lowest was observed in broadcast sowing. In case of cultivars Hagari produced highest methane yield ha^{-1} than the cultivar JS-2002 (Table 6).

Table 1. Prevailing climatic conditions for the experimental site during year 2016 and 2017.

Months	Monthly mean maximum temperature (^{0}C)		Monthly mean minimum temperature (^{0}C)		Monthly average temperature (^{0}C)		Rainfall (mm)		Relative Humidity (%)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
May	39.8	41.1	25.6	26	32.7	33.5	25	10.1	28.8	29.8
June	40.2	39.8	28.5	27.3	34.4	33.5	39.9	41.6	38.9	44.5
July	36.6	38.5	27.4	28.9	32	33.7	193.5	161.4	59.6	70
August	35.7	38.1	26.5	28.6	31.1	33.4	48.1	66	62.2	68.9

Table 2. Physio-chemical properties of experiment site.

Soil Properties	2016	2017
Texture	Sandy loam	Sandy loam
Soil pH	7.9	8.0
Ec (mS/cm)	1.17	1.24
Organic matter (%)	0.86	0.92
Available N (%)	0.031	0.029
Available P (ppm)	6.3	6.56
Available K (ppm)	180	192

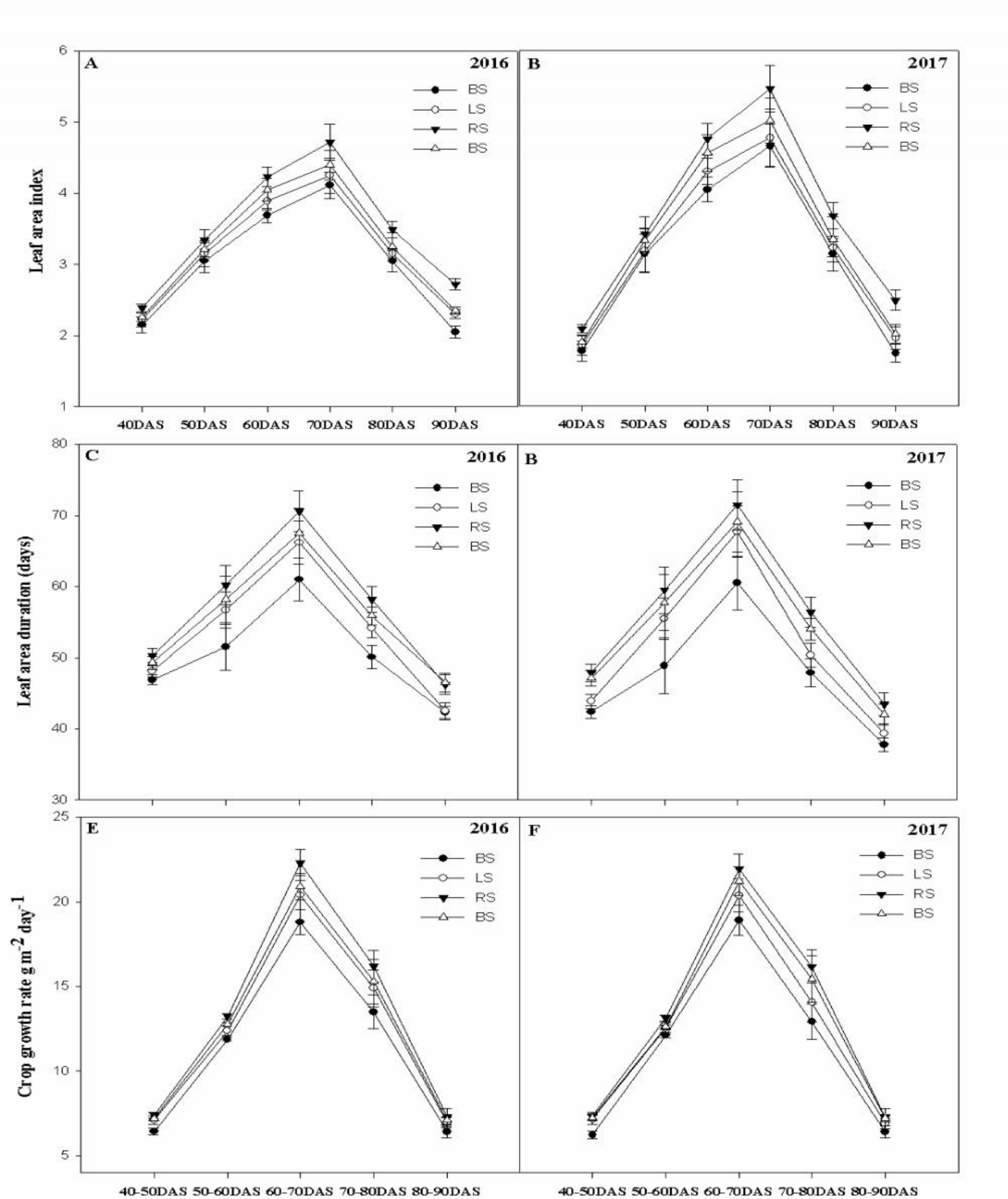

Fig 1: Effect of different planting methods on LAI (A, B), LAD (C, D) and CGR (E, F) of sorghum bicolor

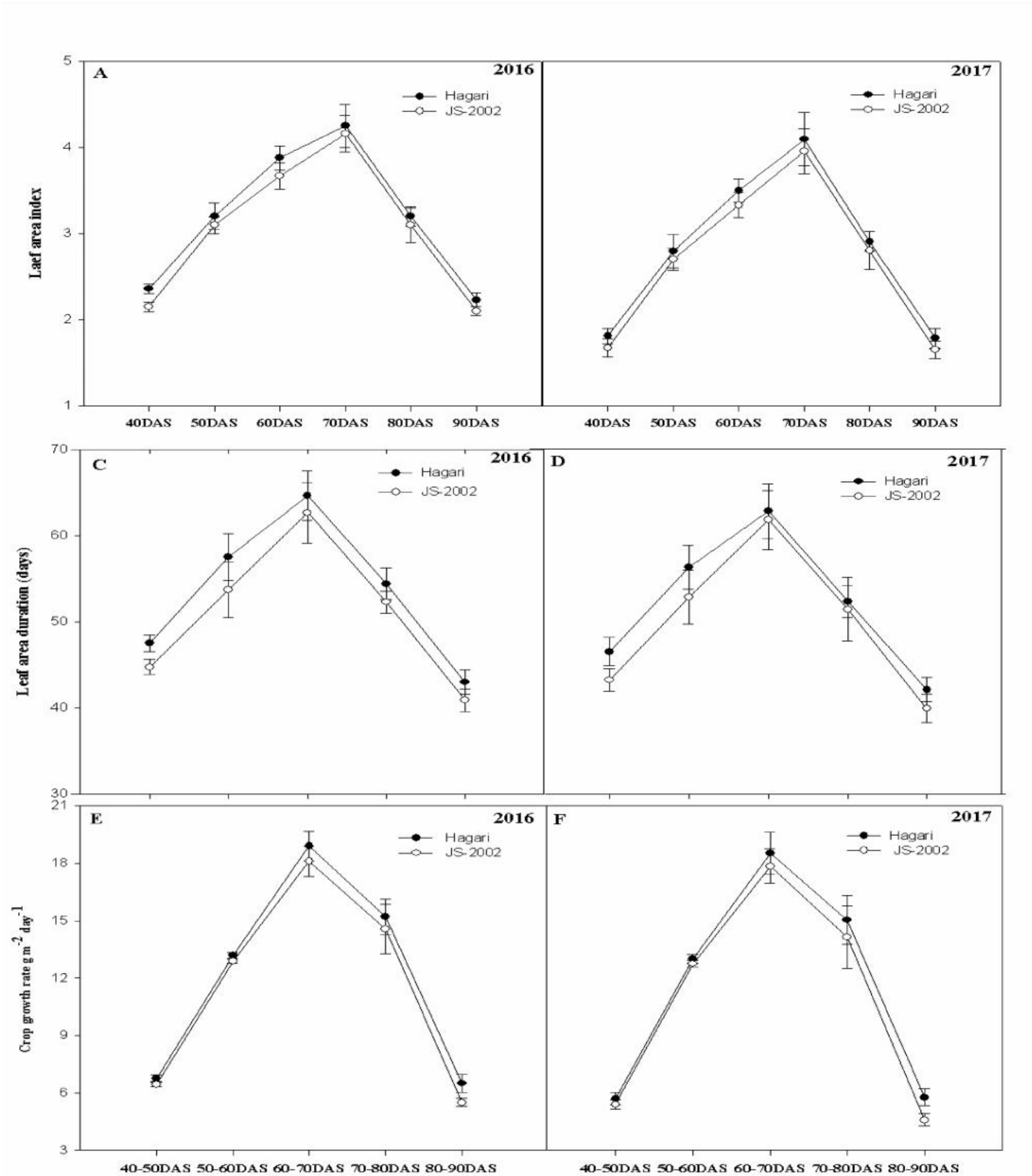

Fig 2: Effect of different cultivars on LAI (A, B), LAD (C, D) and CGR (E, F) of sorghum bicolor

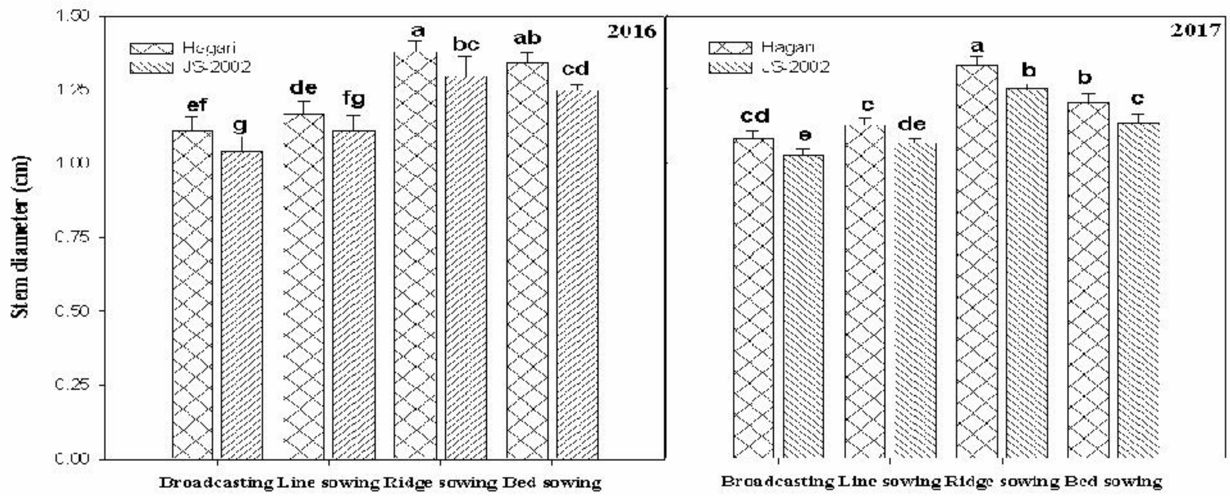

Fig 1: Interactive effect of sowing methods and cultivars on the stem diameter of sorghum bicolor.

Table 3. Effect of planting method and cultivar on the growth attributes and dry matter yield of sorghum bicolor.

Sowing methods	Plant height (cm)		Stem diameter (cm)		Leaves per plant		Dry matter yield t ha^{-1}	
	2016	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Broadcast	188c	185c	1.07b	1.05c	10.16b	9.90b	10.86c	10.73d
Line sowing	200bc	195bc	1.14b	1.09c	11.95a	11.63a	12.48b	12.35c
Ridge sowing	222a	219a	1.37a	1.29a	12.28a	11.86a	14.28a	14.15a
Bed sowing	214ab	208ab	1.33a	1.17b	12.18a	11.73a	13.30b	13.18b
LSD *(p ≤ 0.05)*	**19.12**	**13.55**	**0.09**	**0.05**	**0.46**	**0.82**	**0.83**	**0.67**
Cultivars								
Hagari	209a	205a	1.25a	1.19a	11.95a	11.59a	13.16a	13.08a
JS-2002	203b	198b	1.21b	1.12b	11.33b	10.97b	12.29b	12.12b
LSD *(p ≤ 0.05)*	**5.99**	**6.70**	**0.02**	**0.01**	**0.37**	**0.42**	**0.63**	**0.78**

Means sharing same letter not differed significantly at p ≤ 0.05, SM: Sowing method, CV: Cultivar, NS: Non-significant.

Table 4. Effect of planting method and cultivar on qualitative attributes of sorghum bicolor.

Sowing methods	Protein (%)		Sugar (%)		ADF (%)		NDF (%)	
	2016	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Broadcast	7.83	7.80	9.86	9.73	34.82	35.49	47.16	47.60
Line sowing	8.18	8.13	9.05	8.93	35.36	36.00	47.51	47.85
Ridge sowing	8.54	8.49	9.46	9.38	35.71	36.31	46.86	47.28
Bed sowing	8.34	8.29	9.06	8.93	35.16	35.75	46.20	46.48
LSD *(p ≤ 0.05)*	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Cultivars								
Hagari	8.40a	8.37a	8.94b	8.82b	36.80a	37.34a	48.57a	48.90a
JS-2002	8.04b	7.98b	9.77a	9.67a	33.73b	34.43b	45.30b	45.70b
LSD *(p ≤ 0.05)*	**0.24**	**0.18**	**0.61**	**0.51**	**2.66**	**2.57**	**1.84**	**1.81**

Means sharing same letter not differed significantly at p ≤ 0.05, Non-significant

Table 5. Effect of planting method and cultivar on qualitative attributes of sorghum bicolor.

Sowing methods	Lignin (%)		Ash (%)	
	2016	2017	2016	2017
Broadcast	4.26	4.52	8.20	8.19
Line sowing	4.53	4.59	8.30	8.30
Ridge sowing	4.60	4.70	8.42	8.43
Bed sowing	4.57	4.69	8.44	8.45
LSD ($p \leq 0.05$)	**NS**	**NS**	**NS**	**NS**
Cultivars				
Hagari	4.66a	4.88a	8.69a	8.63a
JS-2002	4.32b	4.36b	7.99b	8.06b
LSD ($p \leq 0.05$)	**0.24**	**0.30**	**0.24**	**0.15**

Means sharing same letter not differed significantly at $p \leq 0.05$, NS: Non-significant.

Table 6. Effect of planting method and cultivar on methane yield and methane yield ha^{-1} of sorghum bicolor

Sowing methods	Specific methane yield (l_N kg VS^{-1})		Methane yield (m^3_N ha^{-1})	
	2016	2017	2016	2017
Broadcast	318.33	315.50	3313.2d	3266.5d
Line sowing	309.30	312.00	3608.2c	3549.8c
Ridge sowing	312.50	309.50	4048.0a	3994.7a
Bed sowing	314.80	311.17	3772.2b	3722.2b
LSD ($p \leq 0.05$)	**NS**	**NS**	**153.00**	**109.25**
Cultivars				
Hagari	306.92b	303.50b	3754.0a	3695.7a
JS-2002	320.58a	318.00a	3616.8b	3570.9b
LSD ($p \leq 0.05$)	**10.27**	**11.09**	**129.34**	**82.08**

Means sharing same letter not differed significantly at $p \leq 0.05$, l_N = norm litter, m^3_N=norm cubic meter, VS = volatile solid.

DISCUSSION

Planting methods had considerable influence on the LAI, LAD and CGR. Amongst sowing methods maximum LAI, LAD and CGR was observed in ridge sowing because sowing on ridges and beds provides the loose fertile soil, which provides more moisture, aeration, and less compaction, that improves the root growth thus resulting in more water and nutrient uptake and thereby produced more LAI. Hence, the highest LAD in ridges can also be ascribed to more LAI. Similarly, LAI is the important assimilatory system of crop, which captured the light for carbon assimilations, therefore, the larger LAI provides more area for fixation of light which resultantly produced more CGR. Therefore, the higher CGR in ridge sowing can be ascribed to more LAI as compared to other sowing methods. Hussain *et al.* (2010) also reported the maximum LAI, LAD and CGR in ridge sowing as compared to flat sowing. Likewise, the maximum plant height, stem diameter and leaves per plant were observed in ridges as compared to other sowing methods. The better assimilatory system owing to higher LAI and CGR resulted in taller plants, better stem diameter and leaves per plant. Earlier researchers also found the noticeable differences among the sowing methods for growth attributes (Afzal *et al.,* 2013). In this study we also reported the considerable difference among the cultivars for LAI, LAD and CGR. The higher LAI in Hagari, can be ascribed to more leaves per plant, leaf width and differences in leaf architecture. These results are in assist with earlier findings of Khan *et al.* (2012), and Wiedenfeld and Matocha (2010), they also observed the considerable variations among the cultivars for LAI. Similarly, the higher LAD in Hagari was due to more LAI, in addition more CGR in this cultivar can be ascribed to more LAI, which captured the more light and produced more dry matter yield as compared to JS-2002. Previous researchers also reported the considerable variations amongst cultivars for LAD and CGR (Khan *et al.,* 2012). We also observed that Hagari produced significantly taller plant, with maximum stem diameter and leaves. The taller and thicker plants in Hagari can be results of more LAI, which consequently captured more light and thus produced the more assimilates for better plant growth. Earlier, Ahmad *et al.* (2012) also observed considerable variations among the genotypes for plant height and leaves count per plant.

In this study we observed that planting methods had non-considerable effects on the qualitative attributes including the, protein, sugar, ADF, NDF, lignin and ash concentrations. Our observation confirmed by previous studies of Afzal *et al.* (2013) who reported non-significant effect of methods on the protein, ash and structural fiber contents. We found the clear impact of cultivars on the qualitative attributes (Table 5, 6) with maximum protein content was showed by the Hagari as compared to the JS-2002. The higher protein concentration in Hagari can be ascribed to more leaves, because leaves are considered to be rich in protein and lower in structural fiber and lignin contents. The noticeable difference in protein concentration due to cultivar has also been documented by other researchers (Mahmood *et al.,* 2015). The maximum sugar concentration was observed in JS-2002 whilst lowest sugar concentration was exhibited by the Hagari. These results are in assist with earlier finding of Mahmood *et al.* (2015) who reported the significant differences among the cultivars for sugar concentration. Cultivar Hagari had higher ADF, NDF and lignin concentration, while JS-2002 was characterized by lower concentrations. The higher ADF, NDF and lignin concentration in Hagari can be ascribed higher stem proportion and less sugar concentration in stem which in turns increased the structural fiber and lignin contents. Conversely, the lower ADF, NDF and lignin in JS-2002 ascribed to more sugar concentration which resultantly reduced the accumulation of structural fiber and lignin contents. Earlier researchers also reported the clear impact of sorghum cultivars on the ADF, NDF and lignin concentration (Beck *et al.,* 2007; Mahmood *et al.,* 2015).

The higher methane yield ha^{-1} in ridge sowing can be ascribed to more dry matter ha^{-1} as compared to other planting methods. Cultivars also had significant effect on the SMY and methane yield ha^{-1}. Cultivar JS-2002 exhibited the maximum SMY as compared to JS-2002. A possible reason for the higher SMY in JS-2002 can be due to reduced structural fiber and lignin contents that enhanced the digestibility of biomass and consequently the SMY. These findings are in agreement with results of Hassan *et al.* (2018a) they also observed considerable differences among the cultivars for SMY. Conversely, the higher methane yield ha^{-1} was observed in Hagari as compared to the JS-2002. The maximum dry matter ha^{-1} in Hagari was responsible for the higher methane yield ha^{-1} as compared to JS-2002. These results agree with those reported by Mahmood *et al.* (2015) and Hassan *et al.* (2018b) they concluded considerable variations amid the cultivars for methane yield ha^{-1} basis.

Conclusions: It may be concluded that sowing methods and cultivar had significant effects on the biomass production and methane yield. Ridge sowing resulted in better growth, which produced the higher dry matter yield and consequently led to higher methane yield ha^{-1} as compared to other sowing methods. Likewise, cultivar Hagari, was superior in terms of growth, dry matter production and methane yield. Therefore, ridge sowing and cultivar Hagari may be promoted owing to higher dry matter for maximizing methane yield ha^{-1}.

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