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IMPACT OF PLANTING METHODS ON BIOMASS PRODUCTION, CHEMICAL COMPOSITION AND METHANE YIELD OF SORGHUM CULTIVARS

Muhammad Umer Chattha[1], Muhammad Umair Hassan[1], Imran Khan[1,*], Muhammad Bilal Chattha[2], Muhammad Aamer[3], Muhammad Nawaz[4], Shakeel A. Anjum[1], Umair Ashraf[5] and Mina Kharal[6]

[1]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan; [2]Institute of Agricultural Sciences, University of the Punjab, Lahore, Pakistan; [3]Research Center on Ecological Sciences, Jiangxi Agricultural University, Nanchang, China; [4]College of Agriculture, Bahadur Campus Layyah, Bahauddin Zakariya University, Multan, Pakistan; [5]Department of Botany, University of Education (Lahore), Faisalabad Campus, Faisalabad, Pakistan; [6]Department of Management Sciences, National Textile University, Faisalabad, Pakistan
[*]Corresponding author's email: drimran@uaf.edu.pk

Bio-fuels are considered to be cheap, sustainable and more environmental friendly. Management considerations including sowing method and suitable cultivar have considerable effect on the dry matter yield of plants which in turns influenced the bio-fuel yield. Field experiment was conducted during 2016 and 2017 17 to assess the impact of sowing methods and cultivars on biomass production, biomass composition and methane production from sorghum bicolor. The ridge sowing performed better and resulted in taller plants with maximum diameter and leaves, dry matter and methane yield ha^{-1}. Moreover, the sowing methods had non-significant effect on protein, sugar, ash, acid detergent fiber (ADF), neutral detergent fiber (NDF), and lignin contents and specific methane yield. In case of cultivars Jawar-2011 performed significantly better with maximum plant height, leaves, dry matter production, protein and ash concentration and methane ha^{-1} as compared to other cultivars. In conclusion, ridge sowing and cultivar Jawar-2011 may be opted owing to high biomass production for increasing the methane yield ha^{-1}.
Keywords: Sorghum biomass, biofuel, renewable energy, anaerobic digestion, chemical composition, methane yield.

INTRODUCTION

The energy consumption and demands are increasing rapidly around the globe, owing to ever blooming population and development of economies (Zhou *et al.*, 2011). Nonetheless, fossil fuel reserves are continuously diminishing therefore, this has increased the research some alternative energy sources and development different other energy production, processes. Methane production through an-aerobic digestion is one of prime energy source that can be used for generation of heat and power. Different kind of biomass are used globally for the sustainable methane production including, solid waste of municipals, (Hartmann and Ahring, 2006), agriculture waste (Sakar *et al.*, 2009), carcasses of animals (Masse *et al.*, 2008) and variable bio-energy crops (Amon *et al.*, 2007). Amid bio-energy crops sorghum is being used around the globe for energy production (Han *et al.*, 2012; Yu *et al.*, 2012). Sorghum crop has short life cycle, great resistance against a-biotic stress (Habyarimana *et al.*, 2009), and lower fertilizer, pesticide and irrigation requirements (Sher *et al.*, 2012; Serna-Saldivar *et al.*, 2012) and it can also easy grown in different climatic conditions (Rao *et al.*, 2012). Consequently, is promising source of energy production to meet the blooming energy needs (Reddy *et al.*, 2005).

Management considerations including planting methods and cultivation of suitable cultivars have significant effect on the biomass production and quality. In-appropriate sowing method like broadcast and flat sowing results in poor germination and stand establishment which consequently affects the final grain and biomass yield of maize and sorghum. Therefore, the improved planting methods like ridge and bed sowing increased the seed germination and helps plant in utilizations of light, land and other inputs more effectively as compared to conventional sowing methods (Quanqi *et al.*, 2008). Moreover, ridge and raised bed improves the root growth owing to apposite soil conditions which resulting in a substantial increase in water and nutrient uptake take thereby, more biomass yield of maize (Bengough *et al.*, 2011). Ride and bed sowing remarkably increased the grain and dry matter production as compared to conventional broadcasting and line sowing (Abdullah *et al.*, 2008; Bakht *et al.*, 2011; Khan *et al.*, 2012; Kahriz and Kahriz, 2017).

Similarly, selection of suitable cultivar considerably influences the biomass yield, chemical composition which consequently influences the methane yield. Likewise, cultivars differed significantly in terms of biomass, which resultantly influenced the bio-fuel yield (Zhao *et al.*, 2009; Hassan *et al.*, 2018). Likewise, sorghum genotypes have remarkable variations for chemical composition (Miron *et al.*, 2005; Hassan *et al.*, 2018). The compositional attributes, including proteins, ADF, NDF lignin contents and, sugar and ash contents considerably affected the biomass digestibility and methane yield (Mahmood *et al.*, 2015). Moreover, the cultivars also differed significantly in terms of specific methane yield (SMY) and methane yield (ha^{-1}) (Tatah *et al.*, 2007). All these explanations suggested that sowing method and cultivar have substantial effect on dry biomass productivity and bio-energy production. Therefore, selection of suitable sowing method and cultivar is necessary to get good biomass yield for maximizing the methane yield. In Pakistan there is no information available about the influence of planting methods and cultivars on dry biomass production, compositional traits and methane productivity. Therefore, the proposed investigation was executed to determine the impact of diverse plant methods and variable cultivars on biomass production, composition of biomass and methane production of sorghum bicolor.

MATERIALS AND METHODS

***Experimental site*:** The current study was performed in 2016 and 2017 at Post-Graduate Agricultural Research, Station, University of Agriculture, Faisalabad. The soil at experimental site was sandy loam and averagely comprising of 0.89% organic matter, 0.03% nitrogen, 6.43 ppm phosphorus, and 186 ppm potassium, and had 7.95 pH. The soil characteristics were determined by the customary protocols of Homer and Pratt (1961). The mean monthly minimum, and maximum temperature, humidity and total rain fall from May to August over the two years are presented in Table 1.

***Experimental details and crop husbandry*:** The RCBD split plot design was employed with four sowing methods (Broadcasting, line, ridge and bed sowing) as the main plot and three sorghum cultivars (JS-263, Jawar-2011 and YS-2016) was allotted to sub plot with three replications. After harvesting of wheat crop, a presoaking irrigation was applied to field, after that when soil reached to workable moisture two cultivation followed by planking was done to prepare the seed bed. The sowing was done by broadcast method, line sowing, ridge sowing and bed sowing respectively and seed was used rate of 75 kg ha^{-1}. The rides and beds were prepared by ridge and bed maker. The fertilizer nitrogen (N) and phosphorus was used at 60 and 40 kg ha^{-1}. The 100% P and 50% N was applied to crop as basal dosage rest of 50% was applied with first irrigation. The urea (46%) and di-ammonium phosphate 46% P and 18%) was utilized as sources of N and P. Standard cultural practices, including irrigation application, weeding and pest control were done for better crop stand.

***Sampling and data collection*:** Leaf area meter was used to measure the leaf area and leaf-area index (LAI) was calculated as ratio of leaf and land area (Watson (1952). Furthermore, leaf-area duration and crop growth-rates were determined by protocols of (Hunt, 1978). Similarly, first LAI, LAD, and CGR was recorded after 40 days of sowing, and rest of the measurements were taken, with ten days' interval. Moreover, fifteen plants were harvested and plant height and stem dia-meter were measured and leaves were calculated and averaged. The experimental plots were harvested with sickle and sun dried and weighed to determine the dry matter production/plot and converted into t ha^{-1}.

***Biomass chemical analysis*:** The collected sorghum samples were dried and grinded to determine the various attributes. The contents of protein and ash in sorghum samples were measured by the methods of AOAC (1990). Moreover, sugar concentration was measured by the procedure of Dubois *et al.* (1956). The concentration of acid-detergent fibers (ADF) were determined by protocols of Georing and Vansoest, (1970), and neutral-detergent fibers (NDF) and lignin were determined with methods of Vansoest *et al.* (1991). The methane production from biomass samples were measured by Bioprocess Control's AMPTS. The slurry of cattle was used as bacterial source for an-aerobic digestion of bio-mass samples. The digester had the capacity of 400 ml, we used the 16 g substrate and then the made volume up to 400 ml. After that N gas was used to perch the digesters to create the an-aerobic conditions. The digesters were kept in water bath and temperature was kept constant at 37°C though out the digestion period. The samples of sorghum biomass were allowed to digest for twenty-eight days and methane production on every day was recorded by computerized system. The amount of volatile solids in each samples was determined to calculate the amount of SMY produced by each sample. In the end the SMY produced by each biomass samples were mathematically transformed into ha^{-1} basis.

Table 1. Prevailing weather conditions during 2016 and 2017.

Months	Monthly average maximum temperature (°C)		Monthly average minimum temperature (°C)		Monthly average temperature (°C)		Rainfall (mm)		Relative Humidity (%)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
May	39.8	41.1	25.6	26.0	32.7	33.5	25.0	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	32.0	33.7	193.5	161.4	59.6	70.0
August	35.7	38.1	26.5	28.6	31.1	33.4	48.1	66.0	62.2	68.9

***Statistical analysis*:** The date on all the collected traits were analyzed by analysis of variance technique and least significant different test (5% probability) was used to determine the differences amid the treatment means.

RESULTS

***Growth attributes and dry matter yield*:** The variable planting methods and genotypes had substantiated influence on the LAI, LAD and CGR. In all planting methods maximum LAI was observed 70 days after sowing (DAS), nevertheless, maximum LAI was documented in ridge sowing, whereas the lowest was recorded observed in broadcast sowing (Fig. 1). Likewise, maximum LAD and CGR was attained 60-70DAS, nonetheless, highest LAD and CGR was recorded in ridge sowing, whilst lowest LAD and CGR was found in broadcast method (Fig 1). In case of cultivars, maximum LAI was also observed after 70DAS, however, highest LAI (4.88, 4.68) was

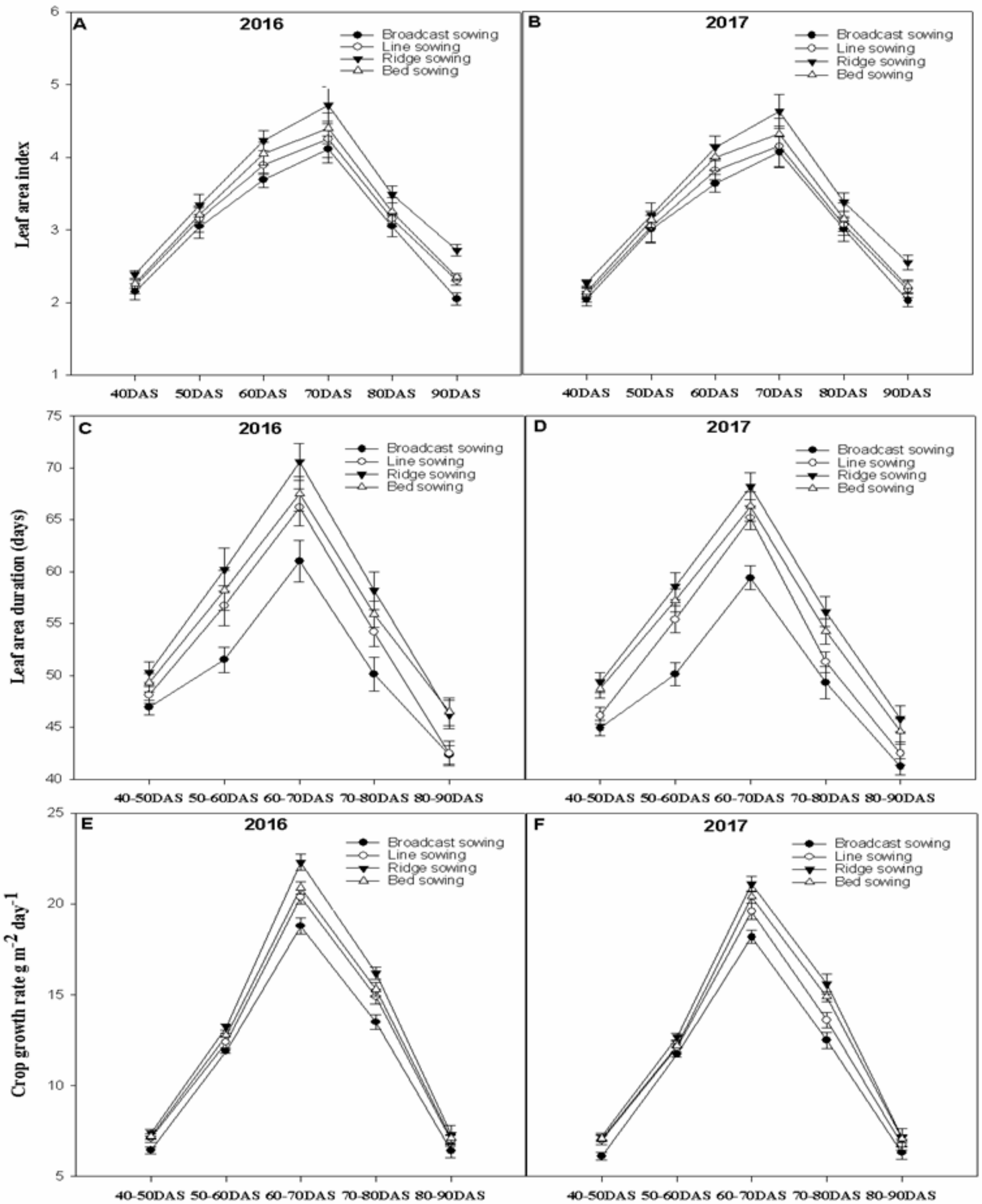

Figure 1. Influence of sowing methods on LAI (a, b), LAD (c, d) and CGR (e, f) of sorghum bicolor.

exhibited by the Jawar-2011 while lowest LAI (4.45, 4.31) was attained by JS-263 (Fig. 2). Likewise, maximum LAD and CGR was observed 60-70DAS; moreover, the highest LAD and CGR showed by Jawar-2011 followed by YS-2016, whilst lowest exhibited by JS-263 amongst the cultivars.

The variable sowing techniques and genotypes had remarkable impact on the growth characters including the plant height, leaves/plant and stem dia-meter (Table 2). The tallest plants with more leaves and stem dia-meter was recorded from the plant sown on ridges, followed by bed sown

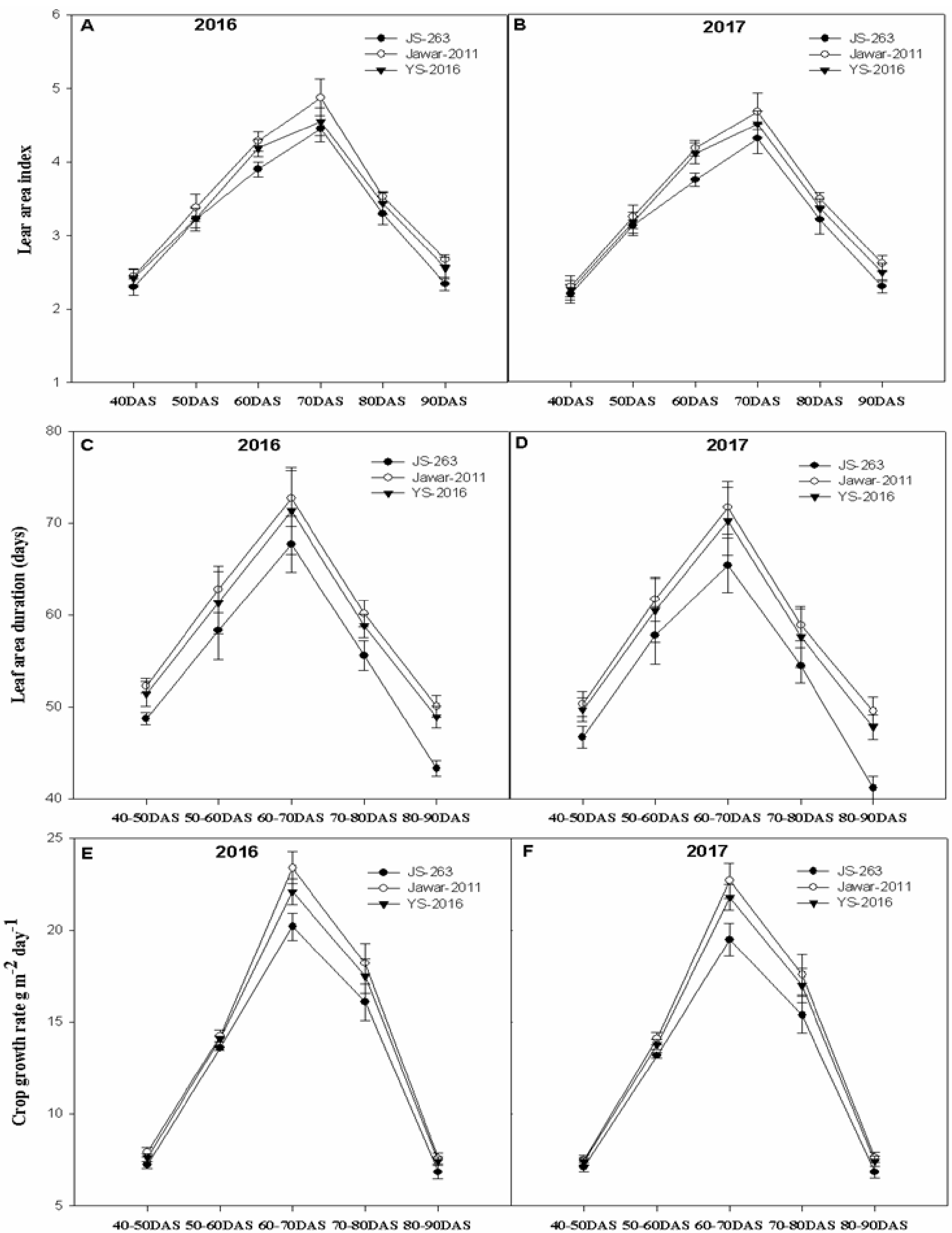

Figure 2. Influence of cultivars on LAI (a, b), LAD (c, d) and CGR (e, f) of sorghum bicolor.

sorghum, while shorter plants with lowest and stem diameter was observed in plots sown by broadcast method. Ridge sowing was remained at top with maximum dry matter yield (16.43 t ha^{-1}, 16.10 t ha^{-1}) while broadcasting remained at lower position with respect to dry matter yield (12.65 t ha^{-1}, 12.33 t ha^{-1}). As for the cultivars, taller plants with more leaves and thicker stems was observed in Jawar-2011, that was statistically comparable with the YS-2016, while shorter plants with lowest leaves and thinner stems were observed in JS-263 (Table 2). Jawar-2011 had maximum dried biomass yield (15.42 t ha^{-1}, 15.09 t ha^{-1}) that was remained same with was YS-2016, and cultivar JS-263 gave the lowest dried biomass yield (13.87 t ha^{-1}, 13.54 t ha^{-1}) (Table 2).

***Chemical composition of biomass*:** The variable sowing techniques had no significant impact the composition characters including, protein, sugar, ash, ADF, NDF and lignin concentration, whereas the cultivars had considerable effect on these attributes. The maximum protein concentration was exhibited by Jawar-2011 that was statistically at par with YS-2016, whereas the lowest was recorded in the biomass of JS-263 (Table 3). Conversely, highest sugar and ash concentration was recorded in JS-263, followed by YS-2016, while lowest was found in Jawar-2011. Moreover, highest ADF, NDF and lignin concentration was recorded for Jawar-2011 afterwards, YS-2016 and lowest ADF, NDF and lignin concentration was recorded in the biomass of JS-263 (Table 4).

***Specific methane yield and methane yield ha^{-1}*:** The planting techniques had non-significant influence on SMY while, cultivars had significant effect on SMY. In case of cultivars maximum SMY was exhibited by JS-263, followed by YS-2016, whereas lowest SMY was produced Jawar-2011. Moreover, planting methods and cultivars significantly affected the methane yield ha^{-1} basis. Ridge sowing produced the maximum methane yield (ha^{-1}), followed by bed sown sorghum whereas the lowest methane yield ha^{-1}was observed in broadcast sowing methods. As for cultivars highest methane yield ha^{-1} was recorded in Jawar-2011, after that in YS-2016, whilst lowest methane yield ha^{-1} was exhibited by the JS-263.

Table 2. Effect of sowing methods and cultivar on growth attributes and dry matter yield (t ha^{-1}) of sorghum bicolor.

	Plant height (cm)		Stem diameter (cm)		Leaves per plant		Dry matter yield t ha^{-1}	
	2016	2017	2016	2017	2016	2017	2016	2017
Sowing methods								
Broadcast	201c	196c	1.14d	1.12d	10.81c	10.52c	12.65c	12.33c
Line sowing	213b	207bc	1.25c	1.20c	12.42b	12.12b	14.57b	14.25b
Ridge sowing	229a	225a	1.48a	1.43a	13.88a	13.88a	16.43a	16.10a
Bed sowing	221ab	214ab	1.36b	1.32b	13.34a	13.02ab	15.26b	14.93b
LSD ($p \leq 0.05$)	11.66	14.06	0.036	0.06	0.75	0.93	1.09	1.10
Cultivars								
JS-263	210b	204c	1.25b	1.22b	12.12b	11.90b	13.87c	13.54b
Jawar-2011	223a	217a	1.35a	1.32a	13.09a	12.92a	15.42a	15.09a
YS-2016	215ab	210b	1.32a	1.27b	12.63ab	12.33b	14.89b	14.59a
LSD ($p \leq 0.05$)	8.51	5.68	0.04	0.04	0.61	0.53	0.52	0.53
SM×CV	NS	NS	NS	NS	NS	NS	NS	NS

Means in column have same letters do not differed significantly at 5% p level

Table 3. Effect of sowing methods and cultivar on protein, sugar and ash concentration of sorghum bicolor.

	Protein (%)		Sugar (%)		Ash (%)	
	2016	2017	2016	2017	2016	2017
Sowing methods						
Broadcast	9.65	9.54	10.05	10.55	7.56	7.73
Line sowing	9.97	9.73	10.62	10.52	7.74	7.56
Ridge sowing	10.4	10.3	11.21	11.10	7.80	8.11
Bed sowing	10.1	10.8	10.82	10.75	7.83	7.83
LSD ($p \leq 0.05$)	NS	NS	NS	NS	NS	NS
Cultivars						
JS-263	9.15b	9.02b	10.09b	9.99b	8.23a	8.17a
Jawar-2011	10.6a	10.5a	11.28a	11.17a	7.28c	7.23c
YS-2016	10.3a	10.2a	10.65ab	10.55b	7.69b	8.02b
LSD ($p \leq 0.05$)	0.52	0.48	0.71	0.61	0.1	0.13
SM×CV	NS	NS	NS	NS	NS	NS

Means in column have same letters do not differed significantly at 5% p level

Table 4. Effect of sowing methods and cultivar on acid detergent fiber, neutral detergent fiber and lignin contents of sorghum bicolor.

	ADF (%)		NDF (%)		Lignin (%)	
	2016	2017	2016	2017	2016	2017
Sowing methods						
Broadcast	37.71	38.81	56.02	56.10	5.10	5.16
Line sowing	38.13	39.18	56.51	56.51	5.12	5.25
Ridge sowing	39.08	40.07	55.97	56.05	5.23	5.32
Bed sowing	38.52	39.61	55.21	55.27	5.16	5.32
LSD *($p \leq 0.05$)*	NS	NS	NS	NS	NS	NS
Cultivars						
JS-263	36.05b	37.87b	50.40c	50.48b	4.81b	5.08b
Jawar-2011	40.35a	41.00a	59.38a	59.40a	5.37a	5.41a
YS-2016	38.67a	39.39ab	58.00b	58.07a	5.28a	5.29ab
LSD *($p \leq 0.05$)*	2.033	1.67	1.37	1.36	0.22	0.27
SM×CV	NS	NS	NS	NS	NS	NS

Means in column have same letters do not differed significantly at 5% p level

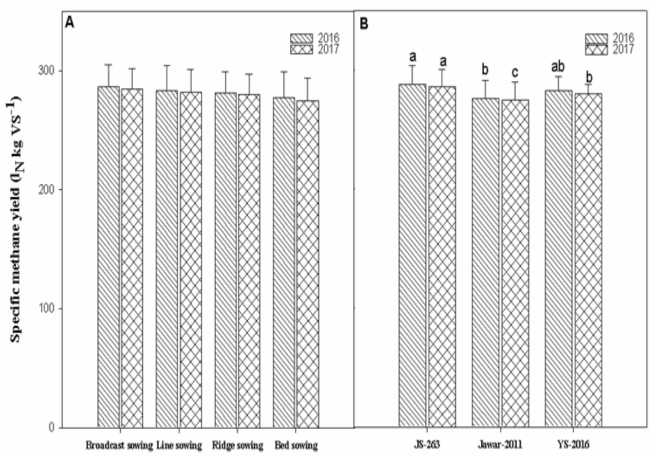

Figure 3. Influence of sowing methods (A) and cultivars (B) on specific methane yield of sorghum bicolor.

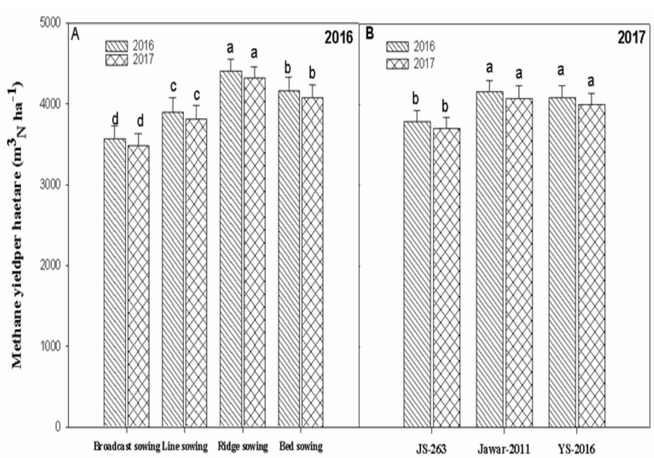

Figure 4. Influence of sowing methods (A) and cultivars on methane yield ha^{-1} (B) basis of sorghum bicolor.

DISCUSSION

The planting methods and cultivars had significant effect on growth attributes, including LAI, LAD, CGR, plant height, leaves and stem girth. In case of planting methods maximum LAI was exhibited by ridge sowing, while minimum was observed in broadcasting method. Ridge sowing provides apposite soil conditions including, proper moisture availability and aeration for emergence of seeds that leads to more plant population as compared to broadcasting (Abdullah *et al.*, 2008; Bakht *et al.*, 2011). Likewise, proper air circulation and water availability improved the root growth, which in turns improved the uptakes of water and nutrients resulting in higher LAI (Fig. 1, 2). LAI is the important assimilatory system of crop, which captures the light for carbon assimilations; therefore, the higher LAI provides more area for fixation for light which resultantly produced more CGR. Thus, higher CGR in ridge sowing can be attributed to more LAI as compared to other sowing methods. Likewise, higher LAD was also reported in ridge sowing that was also due to higher LAI. Likewise, Hussain *et al.* (2010) and Khan *et al.* (2012), also noticed the highest LAI, LAD and CGR in ridge sowing for maize crop as compared to flat sowing. Moreover, taller plant, with more stem diameter and leaves/plants was also recorded in ridge sowing, while sowing by broadcast method performed feebly. The bigger and better assimilatory system owing to higher LAI and CGR, resultantly, produced the taller and thicker plant with more leaves. These findings are same as reported by Ahmad *et al.* (2012) and Afzal *et al.* (2013), also noticed the cultivars behaved differently for the growth characters.

Cultivars also had considerable difference for LAI, LAD, and CGR. The highest LAI was experiential in Jawar-2011 that was due to maximum leaves and maximum lead width as compared to various other genotypes. Similarly, Khan *et al.* (2012), and Wiedenfeld and Matocha (2010), also noticed the remarkable difference among cultivars of maize as well as sorghum for the LAI. Similarly, Jawar-2011 also had the highest LAD and CGR amid the cultivars that can be ascribed to more LAI in Jawar-2011 compared to the other test genotypes. Likewise, Khan *et al.* (2012) also noticed the substantial variations among the maize and sorghum cultivars for LAI and CGR. Cultivar Jawar-2011 produced significantly taller plant, with maximum stem diameter and leaves. The taller plant with maximum leaves and stem diameter in Jawar-2011 can be attributed to higher LAI, which provided the more area for fixation of light, thus, produced more assimilates and resulting in better growth. Similarly, Kusaksiz (2010) and Ahmad *et al.* (2012) also noticed that cultivars behaved differently for plant heights, leaves and stem girth respectively. The sowing on ridges produced the maximum dry matter yield as compared to other methods, while, in case of cultivars maximum dry matter yield was exhibited by Jawar-2011 (Table 1). The higher dry matter in ridge sowing was the result of better soil conditions created by ridge sowing, which increased the water and nutrient uptake by the plant to produce maximum LAI which was responsible for the maximum CGR production and consequently higher dry matter yield. Similarly, Khan *et al.* (2012) and Bakht *et al.* (2011) also observed highest biomass yield in ridge sowing as paralleled to broadcasting and bed sowing. The higher dry biomass production in Jawar-2011 can be ascribed to more LAI, which in turns enhanced the CGR and consequently dry biomass yield. Previous researchers also reported the noticeable differences amid maize and sorghum genotypes for the dry matter yield (Ahmad *et al.,* 2012; Mahmood *et al.,* 2015).

The variable sowing techniques had no significant impact on the compositional characters of biomass. Similarly, Ahmad *et al.* (2012) and Afzal *et al.* (2013), noticed that the planting techniques had no impact on the compositional characters i.e., protein, fibers, lignin, and ash contents. Moreover, cultivars had significant effect on the chemical composition of biomass. The highest protein concentration was observed in Jawar-2011 amid cultivars. This higher protein concentration can be ascribed to more leaves per plant, because leaves are considered to be richer in protein as compared to other plant parts. Earlier researches reported that leaves are rich source of protein and found the remarkable variations amid different genotypes for protein contents (Miron *et al.,* 2006; Beck *et al.,* 2007). Conversely, JS-263 had higher sugar concentration amongst the cultivars. The higher sugar concentration in JS-263 can be ascribed to its genetic potential for accumulation of sugar. Likewise, Dolciotti *et al.* (1998) and Mahmood *et al.* (2015) also recorded the significant differences amid cultivars for sugar contents. The higher ADF, NDF and lignin concentration was exhibited by the Jawar-2011, while lowest was exhibited by the JS-263. The cultivar Jawar-2011 had maximum ADF, NDF and lignin can be due to more stem proportion which consequently increased the structural fiber and lignin concentration. Similarly, Beck *et al.* (2007) and Hassan *et al.* (2018) also noticed that cultivars had remarkable differences for the ADF, NDF and lignin concentration. Planting method had no effect on the specific methane yield (SMY) whilst tested cultivars had a significant impact on the SMY. Cultivar JS-263 exhibited highest SMY, among cultivars while, Jawar-2011 exhibited lowest SMY. The higher SMY in JS-263 can due to less lignin and structural fiber contents, which enhanced the digestibility of biomass and resultantly produced more SMY. The outcomes of our study are same with outcomes of Tatah *et al.* (2007) and Mahmood *et al.* (2015), they also found noticeable alterations among the cultivars for SMY. Ridge sowing performed superiorly with highest methane yield ha^{-1} owing to maximum dry matter yield ha^{-1}. In case of cultivars, Jawar-2011 produced highest methane yield ha^{-1}. The higher dry matter yield ha^{-1} basis was responsible for the higher methane yield ha^{-1} in Jawar-2011. Earlier researchers also reported the significant differences amongst cultivars for methane yield ha^{-1} (Mahmood and Honermeier, 2012; and Mahmood *et al.*, 2015).

***Conclusion*:** In conclusion, planting methods and cultivars had substantiated influence on growth, biomass production and methane yield. Ridge sowing was superiorly better in terms of growth, biomass production and methane yield. Cultivar Jawar-2011 performed significantly better and had better growth, with higher biomass production and methane yield. Consequently, ridge sowing and cultivar Jawar-2011 may be used to get the higher dry matter production in order to increase the methane yield.

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