ISSN: 2957-9082
https://doi.org/10.56946/jspae.v1i1.12 Journal of Soil, Plant and Environment

ORIGINAL RESEARCH

Productivity and the Qualitative Response of Sorghum to Different Planting Patterns and Various Cultivars

Muhammad Asim [1*], Muhmmad Israr Khan[2], Abdul Rab[2]

[1]Department of Agronomy, University of Agriculture Faisalabad, Pakistan

[2]The University of Agriculture, Peshawar Pakistan

Corresponding author: masim@aup.edu.pk
Received: 25-Jan-2022
Revised: 18- Feb -2022
Accepted: 28-Feb-2022

ABSTRACT

Planting patterns and different cultivars play a significant role in forage crops quality and productivity. Therefore, we conducted a field experiment under different planting patterns and cultivars to evaluate sorghum crop yield, yield components, and quality at Agronomic Research Farm, Department of Agronomy, University of Agriculture Faisalabad, Pakistan, in 2015. The experiment consists of three sorghum cultivars (Jawar 2002, Sorghum-2011, and JS-2002) with a seed rate of 75 kg ha^{-1} at different planting patterns (P1=60 cm × 20 cm, P2=50cm × 24 cm, and P3=340 cm × 30 cm). Results showed that sorghum 2011 resulted in higher growth and qualitative attributes than other cultivars. For example, increase in plant height (237.11 cm), dry weight plant^{-1} (40.61 g), forage yield (57.66 ton ha^{-1}), crude protein contents (6.12 %), fiber contents (32.12 %) and ash contents (8.73%) was observed in sorghum 2011 as compared to other cultivars. Whereas, among planting pattern P_3 (40 x 30 cm) produced maximum plant height (236.33 cm), leaves plant^{-1}(13.66), stem diameter (1.09 cm), forage yield (55.52 ton ha^{-1}), dry matter yield (18.53 ton ha^{-1}) and crude protein contents (6.06 %) as compared to P1 and P2. This study suggested that the cultivar sorghum 2011 with a planting pattern of 40 x 30 cm is a promising option to improve yield, yield components and quality of sorghum crop.

Keywords: Sorghum, Planting pattern, Cultivars, Crude Protein, Fiber content

1. INTRODUCTION

Agriculture is the most important sector of Pakistan and greatly influences economic growth. It accounts for 21.4% of GDP and 45% of employment is engaged with agriculture (Gecho, 2017, Iqbal et al., 2015). Development in the agriculture sector stimulates growth in the agro-industry, especially the textile sector. Livestock is an important agriculture sector and has a central role in our country's rural economy. Its accounts for 54% of agricultural GDP and 11.9% of total GDP (Mehmood et al., 2020, Jahnke and Jahnke, 1982). Sorghum (*Sorghum bicolor* L.) is a member of the Poaceae family is locally called Jawar and is commonly used as fresh, silage or hay form. Sorghum is a dual-purpose (i.e., grown for grain and fodder yield) summer season crop

(Hedayetullah and Zaman, 2018; Sarfraz et al., 2012). It requires fewer resources and gives a high yield being the most drought-tolerant crop of the universe (Ringo et al., 2014) and can be grown in tropical and sub-tropical countries of the world. Sorghum has more potential to fulfill the future demands of livestock, grain food and beverages. Its syrup extracted from sweet sorghum is mainly used in ethanol production (Klasson et al., 2021, Rao et al., 2016; Kirouani et al., 2021). Sorghum is the fourth cereal crop of Kharif season and an important forage crop in many regions of the world, including Pakistan (Ghani et al., 2015; Rana et al., 2014). It exhibits rapid growth, is relatively resistant to dryness, high productivity and high percentage of protein. In short period sorghum produced a large amount of seed and fodder (Djanaguiraman et al., 2020). Its fodder comprises 11 % protein, 71 % carbohydrates, 2% crude fiber, mineral and nitrogen-free extract (Hussain et al., 2020). Sorghum accounts for half of the forage in the rainfed area. In Pakistan sorghum was cultivated on 198thousand hectares land with the production of 123 thousand tones and an average grain yield of 621 kg ha^{-1}(Hussain et al., 2015).

Fodder crops play a crucial role in the agricultural economy of developing countries by providing the cheapest source of feed for livestock (Herrero et al., 2013, Upton, 2004; Ramana, 2022). Livestock is a vital part of farming plays an important role in the economic development of the rural community of Pakistan. Livestock accounts for 55 % of agricultural GDP and 12 % of total GDP (Hussain et al., 2015). Lower fodder production and less accessibility to feed are the main factors of decreasing livestock in Pakistan. Furthermore, providing quality animal feed in a suitable amount can increase livestock production. Fodder production fulfills 30 to 50 % of the total fodder consumption in Pakistan. While, low quality of animal feed caused low meat and milk production (Nouman et al., 2014).

The available fodder contributes 1/3 less than that needed fodder and its deficiency is further increased due to a decline in area under fodder crops by 2% after each decade (Nadeem et al., 2017, Herrero et al., 2013). Amongst the Kharif forage crops, sorghum is an important one that possesses a wide range of ecological flexibility. The extension growers largely sow it for feed and fodder in rainfed and irrigated regions of the country. Almost sorghum is fed to every class of livestock (Kumar and Upadhyay, 2008). The performance of dairy animals depends on the regular availability of quality fodder insufficient amount. The vital limitation on profitable animal production in developing countries is the unavailability of quality forage (Kumar and Upadhyay, 2008, Quddus, 2012). Considerable, differences have been reported among the sorghum cultivars for yield, quality traits (Rao et al., 2013), and response to planting densities (Moosavi and Sciences, 2012).

Keeping in view the importance of fodder crop, the present study was conducted to find out the most suitable sorghum variety under suitable planting pattern for higher yield and fodder in terms of quality and quantity in the agro-ecological climate of Faisalabad.

2. MATERIAL AND METHODS

2.1 Experimental Site and Design

The experiment was performed at Agronomic Research Area, University of Agriculture Faisalabad, Pakistan in 2015. The experimental site lies between 30.35-41.47°N latitude and 72.08-73.40°E longitude at an elevation of 184.4 m above sea level. The experimental site's maximum and minimum temperature, rainfall, sunshine hours, relative humidity, wind speed, and evapo-transpiration were recorded at local meteorological station. The weekly maximum and minimum values of temperature, rainfall, sunshine hours, and wind speed are given below in figure 1.

The experiment was laid out in randomized complete block design with split plot arrangement using three replications and a net plot size of 6 m × 7.2 m. All the varieties were sown with a seed rate of 75 kg ha^{-1}. Fertilizers are applied at the rates of 58:58:0 (N: P: K). The experiment wasconsisted of three Sorghum cultivars (Jawar 2002, Sorghum-2011, and JS-2002) and three treatments of planting patterns (P1= 60 cm × 20 cm, P2 = 50 cm × 24 cm and P3= 40 cm × 30 cm). All other agronomic practices were kept the same for all the treatments.

2.2. Measurement and Analysis

2.2.1. Agronomic and Yield-related Parameters

Sorghum plants were counted in the one-meter length of three randomly selected rows in each plot and then averaged per square meter. For plant height (cm), ten sorghum plants were selected and their height was measured from the base to the tip of the longest leaf with measuring tape and then averaged. The total number of leaves from ten plants was counted and then average leaves per plant were calculated. Furthermore, to determine leaf area per plant (cm^2), at each harvest, leaves were removed from ten randomly selected plants and passed through the leaf area meter model LI-3000 and readings were noted. For the measurement of stem diameter (cm), the diameter of ten randomly selected plants from each plot was measured with the help of Vernier Caliper from the base, middle and top portions of the stem and then averaged.

Moreover, for the determination of the weight per plant (g), ten plants were randomly selected from each plot at each harvest with the help of sickle. Each plant was weighed and averages of these plants weights were calculated to get the fresh weight of each plant in grams. Fresh weight per plant (g) was observed by selecting five plants randomly and taken from each plot then weighted to determine the mean fresh weight per plant. While to evaluate dry weight per plant (g), fresh samples were dried at 60°C for 48 hours in a fan-assisted oven until a constant weight was reached and weighted to obtain the mean dry weight per plant. For the determination of forage yield (t ha^{-1}), all the crop plants in each net plot reserved for recording yield at final harvest and weighed separately with the help of a spring balance and converted into t ha^{-1}.

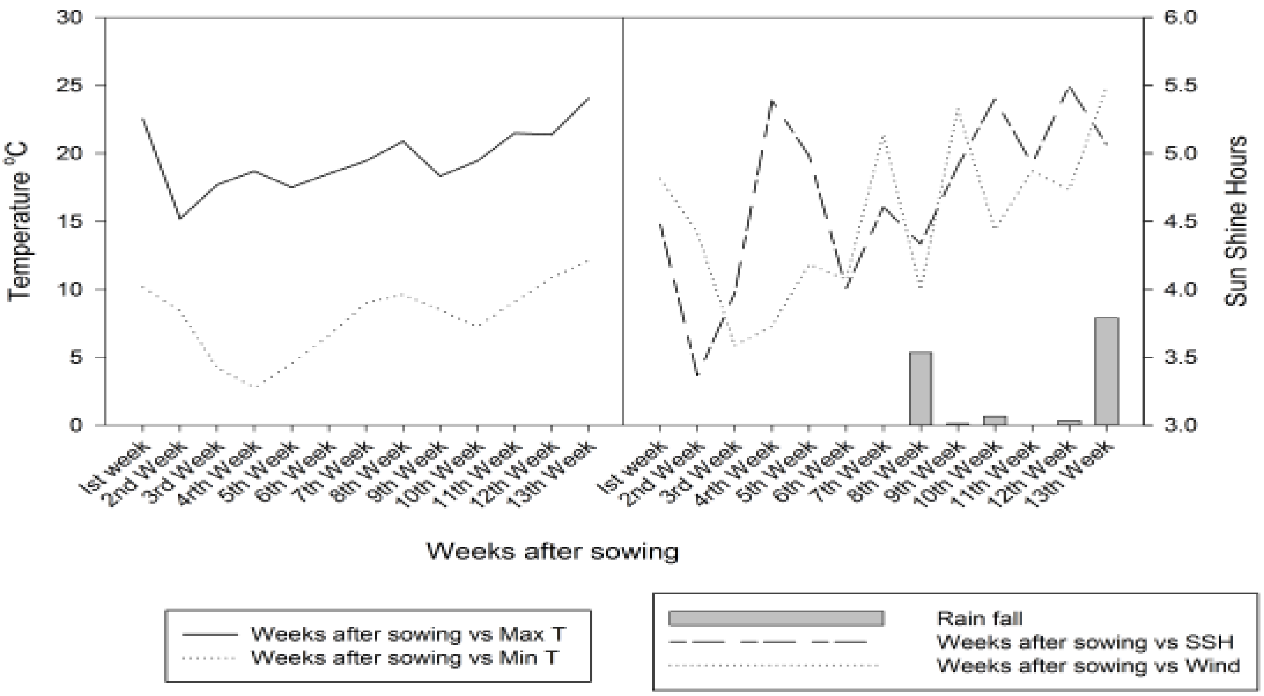

Figure 1. Weekly maximum and minimum values of temperature, rainfall, sunshine hours, and wind speed of the experimental site

The d**ry** matter yield (t ha^{-1}) were assessed by selecting randomly ten plants at harvest from each plot and chopped with the help of a forage cutter and then thoroughly mixed. The fresh weight of the sample was recorded and a sample of 500g was taken from each plot and dried in an oven at 70°C to a constant dry weight. These plants were selected from the plot area used for green forage yield and their weight was added in each respective plot. Dry matter percentage calculated was used to convert green forage yield to dry matter yield. Furthermore, to record dry matter (%), **a c**hopped known weight of forage from each plot was taken and then dried at 80 ^{0}C in an electric oven to a constant weight. The dry matter percentage for each plot was calculated following the formula below.

Dry matter (%) = Dry weight/fresh weight × 100

2.2.2. Quality Parameters

3.2.1. Crude Protein (%)

Initially, the samples were grinded with a locally made grinder until the sample was almost converted into a powdered form and no sieve was used. The powdered sample (1g) was added to KJeldahl digestion flask along with 30ml concentrated H_2SO_4 and 10g digestion mixture. The powdered sample (1g) was added to KJeldahl digestion flask along with 30ml concentrated H_2SO_4

and 10g digestion mixture. After keeping for half an hour it was heated slowly in the beginning and then on full heat until a transparent green liquid material resulted. On cooling transferred to a 250 ml volumetric flask and volume was made up to the mark. Aliquot of 10 ml from this material was taken in the micro kjeldahl apparatus using 15 ml 40% NaOH for each sample. It involves digestion of the plant material dried at 70°C with concentrated sulphuric acid and digestion mixture, comprising K_2SO_4, $CuSO_4$ and $FeSO_4$ in the ratio of 10: 0.5:1.

Nitrogen evolved as ammonia was collected in a receiver containing boric acid (4%) solution and mixed indicator of bromocresol green and methyl. The distillation was titrated against N/10 sulphuric acid till the original color of methyl red was restored. Blank was run to eliminate the percentage of nitrogen present in other chemicals used to digest the sample. From the quantity of acid used in titration, the percentage of element nitrogen was calculated by using the formulas. The reading obtained was multiplied by 6.25 to get crude protein percentage. The crude protein percentage was determined by using the standard procedure as recommended by (Salo-väänänen and Koivistoinen, 1996).

N (%)=A-B×100×100×0.0014/ Volume of digested sample used.

Where A= quantity of acid (N/10 H_2SO_4) used.

B= Blank reading (N/10 H_2SO_4 used in blank reading), 100= volume made after digestion, 100 for percentage (Which is equal to grams of N in 1ml of N),

0.0014= Factor (Which is equal to grams of N in 1ml of N/ 10H_2SO_4

2.2.3. Crude Fiber (%)

Two grams of oven-dried sample were digested in 200 mL of 1.25 % H2SO4 in 500 ml beaker for 30 minutes to determine crude fiber. Then contents were filtered by linen cloth and residues were washed and digested again with 200 ml 1.25% NaOH for 30 minutes and after that, it was again filtered and washed. The residues were put in a weighed china dish and dried in an oven for 24 hours at 105°C. After recording, the dry weight samples were placed in a muffle furnace at 600°C until grey or white ash was obtained. The weight of the ash was recorded. Crude fiber (%)= {(Wt. of dried residues – Wt. of ash)/Wt. of the dried sample)} ×100

The crude fiber percentage was determined by using the standard procedure as recommended by (Salo-väänänen and Koivistoinen, 1996).

2.2.4. Ash Contents (%)

A 5g of oven-dried sample was placed in a clean previously weighed china dish (W1) to determine ash content. The samples were placed in a muffle furnace at (550-650°C) until white or grey ash was obtained. After that, residues were cooled in a desiccator and recorded the weight (W2), and the percentage was calculated as follows:

Total ash % = [(W2 – W1) ÷ (Weight of the sample)] × 100

Total ash percentage was determined using the standard procedure proposed by AOAC (1990).

2.3. Statistical Analysis

Data collected on all parameters were analyzed statistically using MSTAT-C software (Crop and Soil Sciences Department of Michigan University of the United States). The least significance difference (LSD) test at the 5% probability level was applied to compare the treatment's means (Shrestha, 2019).

3. RESULTS

3.1 Growth and Yield Traits

Our results showed that growth and yield attributes were significantly affected by different planting patterns, different cultivars and their interactions (Table 1). Higher planting density (40.67 m^{-2}), plant height (237.11 cm), leaves per plant (13.67), leaf area per plant (2520.20 cm^2), stem diameter (1.11cm), weight per plant (280.94 g) were recorded in Sorghum 2011cultivar as compared to other cultivars. In the case of planting patterns, P_3 (40 × 30) resulted in higher planting density (40.77 m^{-2}), plant height (236.33 cm), number of leaves (13.66), stem diameter (1.09 cm), weight per plant (136.3 g) and dry weight per plant (40.34g) as compared to P_1 and P_2.The lowest growth and yield attributes were recorded in P_1(60 × 20 cm).

Data on forage yield showed significant difference among cultivars and planting patterns (Figure 2). The cultivar Sorghum-2011 produced maximum forage yield (57.6t ha^{-1}) followed by Jawar-2002 (52.5 t ha^{-1}) and cultivar JS-2002 produced a minimum forage yield (45.5 t ha^{-1}). In case of planting patterns, forage yield were found significant and it ranged from 47.39-55.5 t ha^{-1}. The maximum forage yield (55.52 t ha^{-1}) was found in plots where sorghum was sown using narrow row spacing P_3 (40 × 30). The minimum forage yield (47.39 t ha^{-1}) was recorded in P_1 followed by P_2.

Table 1. Response of Sorghum planting density (m^{-2}), plant height (cm), leaves plant^{-1}, leaf area plant^{-1}stem diameter (cm), weight plant (g), fresh weight per plant (g) and dry weight per plant (g) to different varieties and planting patterns.

Planting Pattern	Varieties	Planting density (m^{-2})	PH (cm)	Leaves plant^{-1}	LA plant^{-1}	Stem diameter (cm)	Weight plant (g)	Fresh weight per plant (g)	Dry weight per plant (g)
60 × 20 cm	Jawar 2002	39.33b	229.67cd	12.00b	2224.80e	1.04ab	241.45d	132.74c	38.00bc
60 × 20 cm	Sorghum 2011	39.00b	234.00c	12.33b	2406.50c	1.06ab	251.23c	135.03bc	38.89bc
60 × 20 cm	JS -2002	37.33c	223.67d	11.00c	2206.00c	1.08ab	235.36d	138.22b	35.51c
50 × 24 cm	Jawar 2002	38.33b	232.67c	13.00ab	2406.50c	1.09ab	261.23b	135.03bc	38.89bc
50 × 24 cm	Sorghum 2011	41.00a	236.33b	13.67ab	2513.40b	1.10a	265.14b	138.68	40.40ab
50 × 24 cm	JS -2002	38.33b	229.33cd	11.66c	2240.40e	1.13a	252.23c	141.59a	42.53a
40 × 30 cm	Jawar 2002	41.00a	235.00b	14.00a	2470.90c	1.02ab	283.45ab	138.22b	40.08ab
40 × 30 cm	Sorghum 2011	42.00a	241.00a	15.00a	2640.70a	1.02ab	294.14a	141.59a	42.53a
40 × 30 cm	JS -2002	39.33b	233.00c	12.00b	2340.30d	1.04a	265.24b	129.08c	38.40bc
ANOVA (F values)									
Varieties (V)		19.33**	8.23**	9.97**	27.24**	28.91**	42.83**	48.23**	13.62**
Planting Pattern (P)		18.45**	6.00*	7.65*	16.63**	6.74*	6.57*	9.52*	8.36*
V × P		2.95^{NS}	0.22^{NS}	0.51^{NS}	0.53^{NS}	0.27^{NS}	0.16^{NS}	0.08^{NS}	0.23^{NS}

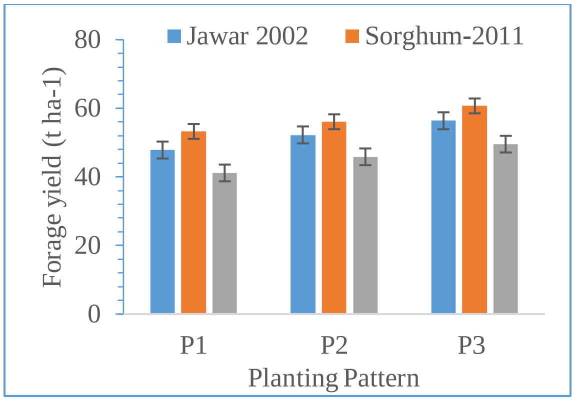

Figure 2. Changes in forage yield to different varieties and planting patterns. Note. P1, P2 and P3 represent different planting patterns.

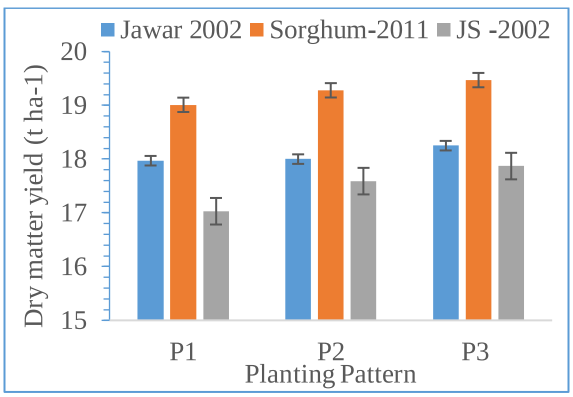

Figure 3. Changes in dry matter in response to different varieties and planting patterns. Note. P1, P2 and P3 represent different planting patterns.

Dry matter production of sorghum was significantly affected by cultivars and planting patterns (Figure. 3). Among cultivars, the cultivar Sorghum-2011 produced highest dry matter of 19.25t ha^{-1} followed by Jawar 2002, while cultivar JS-2002 (17.5t ha^{-1}) produced less dry matter. In case of planting pattern, the highest yield of dry matter (18.53 t ha^{-1}) was recorded in P_3 (40 × 30 cm). The minimum dry matter yield (18.0 t ha^{-1}) was observed in P_1 followed by P_2.

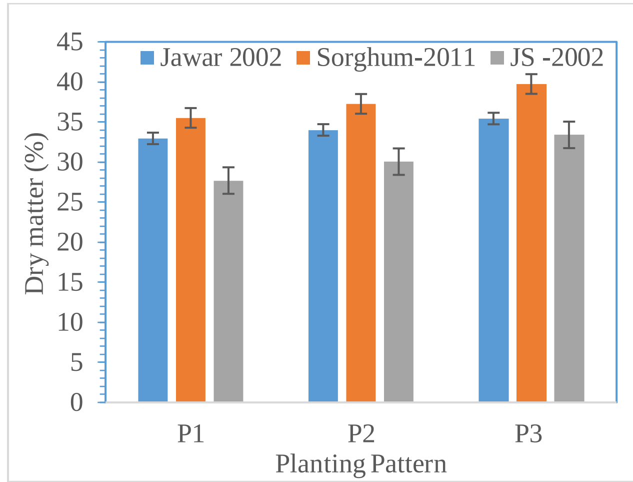

Figure 4. Changes in dry percent in response to different varieties and planting patterns. Note. P1, P2 and P3 represent different planting patterns.

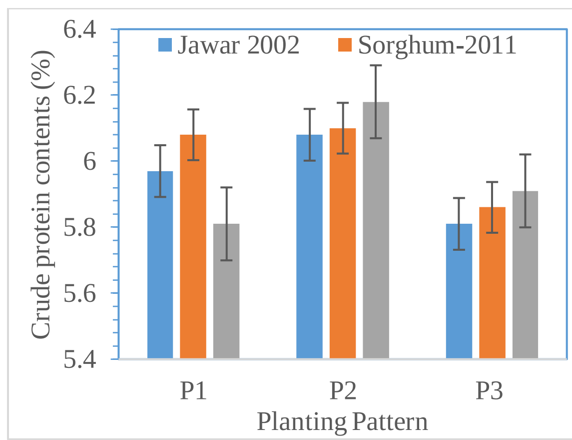

Figure 5. Changes in crude protein (%) in response to different varieties and planting patterns. Note. P1, P2 and P3 represent different planting patterns.

The data regarding dry matter (%) of three sorghum cultivars affected by planting patterns is presented in figure 4. The maximum dry matter (%) was recorded in cultivar Jawar-2002 (34.13%), followed by Sorghum-2011, while minimum dry matter percentage (30.38 %) was observed in JS-

2002. Among different planting patterns, dry matter percentage was found significant, and it ranged from 32.05-36.19 %. The maximum dry matter percentage (36.19%) was recorded in the treatment in which sorghum was sown by using a P_3 (40 × 30 cm) planting pattern. The minimum dry matter percentage (32.05 %) was recorded in the treatment P_1 followed by P_2.

3.2 Qualitative Attributes

The crude protein content of different cultivars as affected by various planting patterns is presented in figure 5. Maximum crude proteins (%) were observed in Sorghum-2011 (6.12%) followed by Jawar-2002 (6.03%), while minimum crude protein (%) was observed in JS-2002 (5.85%). In the case of planting patterns, crude protein percentages were found significant, and it ranged from 5.90-6.06% the highest crude protein (6.06%) was recorded in the treatment in P_3 (40 × 30 cm) planting pattern. The minimum crude protein percentage (5.90%) was recorded in the treatment P_1(60 × 20 cm) followed by P_2.

Analysis of variance indicates that the percentage of crude fiber was considerably diverse in all varieties of sorghum (Figure 6). Maximum crude fiber (32.12%) was observed in Sorghum-2011, and it was followed by Jawar-2002 (30.38 %), while minimum crude fiber (28.33 %) was observed in JS-2002. The effect of planting pattern on crude fiber percentage was found significant, ranging from 28.9-32.8%.

The maximum crude fiber percentage (32.88%) was recorded in treatment P_3. The minimum crude fiber percentage (28.91%) was recorded in the treatment P_1, followed by P_2.

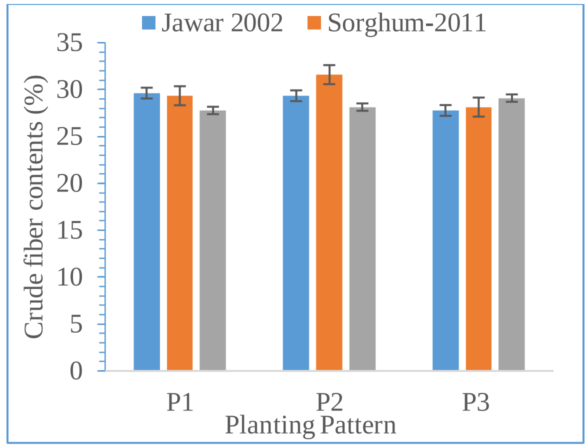

Figure 6. Changes in crude fiber content (%) in response to different varieties and planting patterns. Note. P1, P2 and P3 represent different planting patterns.

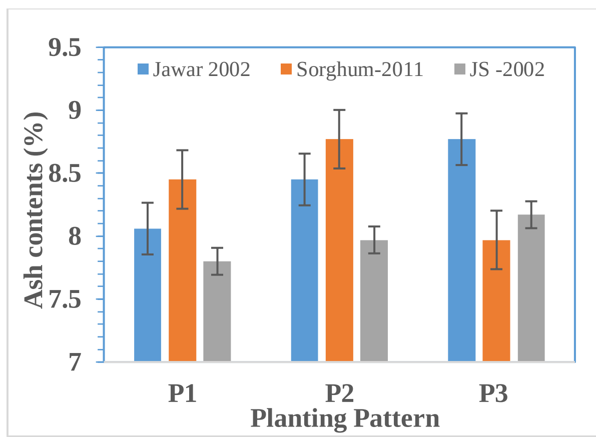

Figure 7. Changes in crude protein (%) in response to different varieties and planting patterns. Note. P1, P2 and P3 represent different planting patterns.

The data regarding ash percentage shows significant variation among sorghum cultivars (Figure 7). Ash percentage was maximum (8.73%) in cultivar Sorghum-2011 which was followed by Jawar-2002 (8.43%) and were minimum (7.98 %) in JS-2002. Among planting patterns, ash contents were found significant and ranged from 8.10-8.64 %. The maximum ash percentage (8.64 %) was recorded in P_3(40 × 30 cm) planting pattern. The minimum ash percentage (8.10 %) was recorded in the treatment P_1 (60 × 20 cm) planting patterns followed by P_2.

4. DISCUSSION

Selection of cultivar and planting pattern is one of the most important method to get higher yield and quality of sorghum crop. Therefore, we conducted a field experiment to evaluate the best responsive planting pattern and cultivar to improve sorghum yield and quality under sustainable agriculture.

Our results showed that growth and yield parameters including planting density (m^{-2}), plant height (cm), leaves plant^{-1}, leaf area plant^{-1}, stem diameter (cm), weight plant^{-1} (g) fresh weight plant^{-1} (g) and dry weight plant^{-1} (g) were significantly increased in the planting pattern of P3 (40 × 30 cm) under sorghum 2011 cultivar. These increments might be due to differentiation in the genetic makeup of cultivars and the adaptability of these varieties to different environmental conditions (Blum, 2004). Yousif et al. (2012) also found that different sorghum cultivars vary in plant height. Similarly Zulfiqar et al.(2009) documented that the number of leaves per plant were influenced by different planting pattern and cultivars. Present results contradict Miranda et al.(2013), who found non-significant dissimilarity in leaves number of various sorghum varieties. These contradictory results might have been due to differences in environmental conditions and the genetic potential of the varieties. An increase in weight per plant of Sorgum-2011 was due to greater plant height, leaf area, and stem diameter. Similarly, Gondal et al.(2017) showed significant differences among sorghum cultivars regarding weight per plant. Furthermore, Ayub et al.(2010) found non-significant differences in plant dry weight among six sorghum varieties, while Afzal et al. (2012) compared different sorghum cultivars. They found a significant difference in weight per plant of different forage sorghum cultivars.

Protein contents are a major parameter affecting forage crops' nutritional value and quality. It’s the mixture of true protein and non-protein nitrogen and the fodder with high protein contents is considered a good quality fodder. While crude fiber percentage is one of the most important parameters that influences forage crops' quality. Fodders with low crude fiber contents are considered good quality forage because low fiber contents increase digestibility and palatability and improve intake. In addition, ash contents are described as the mineral contents in dry matter feedstuff and are mostly measured on a % basis. In the present study, protein contents, crude fiber percentage and ash content were improved in the planting pattern of P_3 (40 × 30 cm) under sorghum 2011 cultivar. These significant differences may be due to the difference of growth stage at harvest. Another reason for these increments might be the more nutrient availability to plant in P_3 patterns. Panwar et al. (2000) also showed significant differentiation in crude fiber contents among varieties of sorghum. Ayub et al. (2010) studied two sorghum cultivars viz. JS -263 and Hegari for crude fiber percent and ash percentage revealed Hegari produced higher protein and ash contents than JS-263.

5. CONCLUSION

Based on our results, we observed that among different cultivars, sorghum 2011 resulted in higher yield, yield components and quality traits as compared to other cultivars. Similarly, Sorghum-2011 also performed better at the Planting pattern of P_3 (40 x 30 cm) compared to other planting patterns. Therefore, we concluded that the cultivar Sorghum-2011 performed better than the other two cultivars because it produced a higher yield with quality at Planting pattern P_3 (40 x 30 cm). It can be recommended for cultivation under Faisalabad conditions.

Authors Contributions:
M.A conceived the main idea of research, M.A wrote the manuscript. M.I.K and A.R revised the manuscript and provided suggestions. In addition M.A and AR assessed and analyzed the data, and performed data collection. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: We would like to thank the University of Agriculture Faisalabad, Pakistan for their financial support

Conflicts of Interest: The authors declare no conflict of interest.

Data Availability statements: The data presented in this study are available on request from the corresponding author.

REFERENCES

Afzal, M., Ahmad, A. & Ahmad, A. H. J. C. A. Î. M. 2012. Effect of nitrogen on growth and yield of sorghum forage (Sorghum bicolor (L.) Moenchcv.) under three cuttings system. 45, 57-64.

Ayub, M., Nadeem, M. A., Tahir, M., Ghafoor, A., Ahmed, Z. &Naeem, M. J. P. J. L. S. S. 2010. Comparative studies on the growth, forage yield and quality of sorghum (Sorghum bicolor L.) varieties under irrigated conditions of Faisalabad. 8, 94-97.

Blum, A. J. P. & Biotechnology Integration For Plant Breeding, C. P., Boca Raton, Fl, Usa 2004. Sorghum Physiology. 141-224.

Djanaguiraman, M., Prasad, P., Ciampitti, I. &Talwar, H. S. 2020. Impacts of Abiotic Stresses on Sorghum Physiology. Sorghum in the 21st Century: Food–Fodder–Feed–Fuel for a Rapidly Changing World. Springer.

Gecho, Y. J. S. S. 2017. Rural farm households' income diversification: The case of Wolaita Zone, Southern Ethiopia. 6, 45-56.

Ghani, A., Saeed, M., Hussain, D., Arshad, M., Shafique, M. & Shah, S. A. S. J. S. L. 2015. Evaluation of different sorghum (Sorghum bicolor L. moench) varieties for grain yield and related characteristics. 3, 72-74.

Gondal, M., Hussain, A., Yasin, S., Musa, M. &Rehman, H. J. S. J. O. A. 2017. Effect of seed rate and row spacing on grain yield of sorghum. 15, 81-91.

Hedayetullah, M. &Zaman, P. 2018. Forage Crops of the World, Volume I: Major Forage Crops, CRC Press.

Herrero, M., Grace, D., Njuki, J., Johnson, N., Enahoro, D., Silvestri, S. &Rufino, M. C. J. A. 2013. The roles of livestock in developing countries. 7, 3-18.

Hussain, J., Rabbani, I., Aslam, S. & Ahmad, H. J. W. S. P. S. J. 2015. An overview of poultry industry in Pakistan. 71, 689-700.

Hussain, M. I., Farooq, M., Muscolo, A., Rehman, A. J. E. S. & Research, P. 2020. Crop diversification and saline water irrigation as potential strategies to save freshwater resources and reclamation of marginal soils—A review. 27, 28695-28729.

Iqbal, M. A., Iqbal, A., Afzal, S., Akbar, N., Abbas, R. N., Khan, H. Z. J. A.-E. J. O. A. & Sciences, E. 2015. In Pakistan, agricultural mechanization status and future prospects. 15, 122-128.

Jahnke, H. E. &Jahnke, H. E. 1982. Livestock production systems and livestock development in tropical Africa, KielerWissenschaftsverlagVauk Kiel.

Kirouani, A., Laouar, M., Nadjemi, B. &Abdelguerfi, A. J. G. 2021. Genetic diversity of Algerian sorghum (Sorghum bicolor (L.) Moench) landraces by using agro-morphological markers. 5, 1-11.

Klasson, K. T., Boone, S. A. J. I. C. & Products 2021. Bioethanol fermentation of clarified sweet sorghum (Sorghum bicolor (L.) Moench) syrups sealed and stored under vegetable oil. 163, 113330.

Kumar, S. &Upadhyay, A. J. I. J. O. A. E. 2008. Goat Based Integrated Farming System: Farmers' Coping Strategy for Sustainable Livelihood Security in Arid Rajasthan. 63.

Mehmood, N., Arshad, M., Ahmed, H., Simsek, S. &Muqaddas, H. J. T. K. J. O. P. 2020. Comprehensive account on prevalence and characteristics of hydatid cysts in livestock from Pakistan. 58, 121.

Miranda, R. D. S., Alvarez-Pizarro, J. C., Araújo, C. M. S., Prisco, J. T. & Gomes-Filho, E. J. A. P. P. 2013. Influence of inorganic nitrogen sources on K+/Na+ homeostasis and salt tolerance in sorghum plants. 35, 841-852.

Moosavi, S. J. I. J. O. A. & Sciences, C. 2012. Effect of density plant and planting pattern on yield, yield components and morphological traits of forage sorghum in the second cultivation. 4, 28-32.

Nadeem, A., Nadeem, J., Sarwar, M. H., Sarwar, M. J. A. J. O. F. S. & Health 2017. Making the decision to breastfeed the baby and its advantages for the women's health'. 3, 88-94.

Nouman, W., Basra, S. M. A., Siddiqui, M. T., Yasmeen, A., Gull, T., Alcayde, M. A. C. J. T. J. O. A. & Forestry 2014. Potential of Moringaoleifera L. as livestock fodder crop: a review. 38, 1-14.

Panwar, V., Tewatia, B. &Lodhi, G. J. I. J. O. A. N. 2000. Performance and value of different sorghum fodder varieties. 17, 67-69.

Quddus, M. J. B. J. O. A. S. 2012. Adoption of dairy farming technologies by small farm holders: practices and constraints. 41, 124-135.

Ramana, D. 2022. Livestock Based Production Systems for Climate Adaptation in Dryland Areas. Climate Change Adaptations in Dryland Agriculture in Semi-Arid Areas. Springer.

Rana, A., Ahmad, A., Saleem, N., Nawaz, A., Hussian, T. &Saad, M. J. J. G. I. A. S. S. 2014. Differential response of sorghum cultivars for fodder yield and quality. 2, 6-10.

Rao, P. S., Vinutha, K., Kumar, G. A., Chiranjeevi, T., Uma, A., Lal, P., Prakasham, R., Singh, H., Rao, R. S., Chopra, S. J. S. S. O. T. A. & Perspectives, F. 2016. Sorghum: A multipurpose bioenergy crop.

Rao, S., Patil, J., Umakanth, A., Mishra, J., Ratnavathi, C., Prasad, G. S. & Rao, B. D. J. S. T. 2013. Comparative performance of sweet sorghum hybrids and open pollinated varieties for millable stalk yield, biomass, sugar quality traits, grain yield and bioethanol production in tropical Indian condition. 15, 250-257.

Ringo, J., Onkware, A., Were, B. A. I., Too, E. &Gudu, S. 2014. Diversity of Sorghum (Sorghum bicolor L. Moench) Germplasm from Tanzania.

Salo-Väänänen, P. P. &Koivistoinen, P. E. J. F. C. 1996. Determination of protein in foods: comparison of net protein and crude protein (N× 6.25) values. 57, 27-31.

Sarfraz, M., Ahmed, N., Farooq, U., Ali, A. &Hussain, K. J. J. O. A. R. 2012. Evaluation of sorghum varieties/lines for hydrocyanic acid and crude protein contents. 50, 39-47.

Shrestha, J. P-Value: A true test of significance in agricultural research.2019.

Upton, M. 2004. The role of livestock in economic development and poverty reduction.

Yousif, A., Nhepera, D. & Johnson, S. J. F. C. 2012. Influence of sorghum flour addition on flat bread in vitro starch digestibility, antioxidant capacity and consumer acceptability. 134, 880-887.

Zulfiqar, B., Abbasi, N. A., Ahmad, T. & Hafiz, I. A. J. P. J. B. 2009. Effect of explant sources and different concentrations of plant growth regulators on in vitro shoot proliferation and rooting of avocado (Perseaamericana Mill.) cv.“Fuerte”. 41, 2333-2346.

How to cite this article:

Asim, M., Khan, K.M., Rab, A. Productivity and the Qualitative Response of Sorghum to Different Planting Patterns and Various Cultivars. Journal of Soil, Plant and Environment. (2022); 1(1)-pp; 89-101.