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Effect of tillage practices and intercropping ratios on quantity and quality of cereals-sesbania forage

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Tillage practices and intercropping plays an imperative role in the final production and quality of forages. Therefore, field studies were performed to compare forage quantity and quality of cereals and sesbania grown alone and in combination with different row ratios under different tillage practices during 2013 and 2014. The experiment consisted of tillage practices; i. e., minimum tillage (MT), and deep tillage (DT) and variable row ratios, i.e., sole sorghum, sole millet, sole sesbania, sorghum + sesbania (1:1), sorghum + sesbania (1:2), sorghum + sesbania (2:1), millet + sesbania (1:1), millet + sesbania (1:2), millet + sesbania (2:1). The experiment was performed in RCBD with a split plot arrangement having three replications. The results indicated that forage yield was significantly affected by tillage practices; however, forage quality remained non-significant. The deep tillage produced maximum fresh forage yield (FFY) and dry matter yield (DMY) compared to MT. Cereals-sesbania row intercropping significantly affected fodder yield and quality. The maximum fresh forage and dry matter yields were observed in cereals alone and the lowest was recorded in millet + sesbania (1:2) ratios. Growing of cereals + sesbania at different row ratios improved forage quality (ash % and crude protein %); however, an increase in rows of sesbania in the mixture decreased the crude fiber contents. In conclusion, growing sesbania alone or in row intercropping with cereals has the potential to improve the forage as compared to cereals grown alone.
Keywords: Cereals, sesbania, tillage practices, row ratios, forage quality

INTRODUCTION

Pakistan is predominantly an agricultural country, and agriculture employs to more than 42% labor force. In addition, it has a share of 19.3% in Pakistan's GDP (Govt. of Pakistan, 2020). Livestock is a significant sub-sector contributing 60.56% to value addition in agriculture and 11.69% to overall GDP (Govt. of Pakistan, 2020). In the Pakistani rural dairy production system, major portion of feed, up to 50-60%, comes from grazing of pastures and wheat straw has a share of 25% and green crops and concentrates have a share of 10-15%, and 5%, respectively (Younas, 2013). The production and availability of good quality forage is imperious for livestock production (Rojas-Downing *et al.,* 2017),and a good quality forage demand is common in the dairy industry (Darapuneni *et al.,* 2018).

The rapid increase in population has substantially decreased the land area across the globe, which is leading to reduction in production and availability of forage (Zhang *et al.,* 2011). Crop residues are also an essential source of feed for animals (Cho *et al.,* 2012); however, they are deficient in nutrients and proteins to meet the livestock needs (Niderkorn *et al.,* 2012). This deficiency of nutrients and proteins can be solved by purchasing or stocking higher quality roughages, including silage and hay (Russelle *et al.,* 2007; Sulc and Tracy, 2007). Although this practice is essential to meet the feed needs, however, the production cost is substantially increased, and profit reduced; therefore, appropriate methods must be used to fulfill the needs of livestock for the sustainable development of this industry (Ross *et al.,* 2004; Strydhorst *et al.,* 2008).

Intercropping has tremendous potential for forage production than sole cropping, and it is also considered a feasible

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approach for forage production (Zhang *et al.,* 2011; El-Shamy *et al.,* 2017). This system helps the farming community to use the principle of diversity (Ghosh, 2004), which decreases the dependence on a single crop, and farmers can grow different crops to meet their ultimate objective (Iqbal *et al.,* 2018; Seleiman and Hafez, 2021). Moreover, intercropping also improved the land production per unit area, which helps in the efficient use of farm resources (Ahmad *et al.,* 2006; Mucheru-Muna *et al.*, 2010). The intercropping of cereals with legumes improves the microbial activities and nutrients availability, which triggers higher biomass production (Alvey *et al.,* 2003). Legume intercropping systems with cereals is the better option for efficient utilization of nutrient, compensatory growth of individual plant species and may prove more productive and profitable cropping system (Ananthi *et al.,* 2017) and even beneficial in the low-input farming system (Knudsen *et al.,*2004). Generally, cereals produce more biomass yield; however, they are low in protein contents than leguminous crops (Staniak *et al.,* 2014). Similarly, it is the pre-requisite, that the food for the cattle should contain a higher amount of protein contents. The inter-cropping of cereals with fodder crops improves the quality of the produced and affects the two crops concurrently grown on the same field. Cereal-legume intercropping improves soil fertility by nitrogen fixation and increasing soil organic carbon due to which greater yield is obtained (Doré *et al.,* 2011).

Sorghum (*Sorghum bicolor*) is an important crop cultivated globally for food and feed purposes (Hassan *et al.,* 2018). Sorghum is an essential source of protein and energy; therefore, it is an important fodder crop for animals (Nirmal *et al.,* 2016). Moreover, it is an a essential critical crop being used throughout the world for bio-energy and bio-ethanol production (Hassan *et al.,* 2019; Hassan *et al.,* 2020; Seleiman *et al.*, 2021). Sesbania (*Sesbania grandiflora*) is an important leguminous crop that belongs to the family Leguminosae. It is a good fodder crop, and intercropping of sesbania with pearl millet has shown better nutritional value for animal feed (Rasool *et al.,* 2017). Millet is a essential crucial fodder crop, and it is considered a quick-growing and short-duration crop. It can also be grown for grain purposes, and it has an appreciable drought and heat tolerance ability a higher dry matter production (Ayub *et al.,* 2007).

Further, agricultural practices strongly impact plant and animal diversity due to environmental ecosystem functioning (Alarcón *et al.,* 2018; Seleiman *et al.,* 2020). Tillage practices are most important to maintain proper soil physical structure, optimum crop growth for maximum profit (Yadav *et al.,* 2017; Ding *et al.,* 2020) and good tillage practices are considered to have a share of >20% in crop production (Alam *et al.,* 2014). The appropriate tillage practices improve production and soil health, whilst inappropriate practices lead to destruction of soil structure, increase soil erosion, and reduce soil organic matter and nutrient availability (Lal, 1993; Seleiman *et al.,* 2019).

The shallow tillage practices do not break the hard pan produced due to contentious tillage and other factors thus leads to poor root growth and availability of nutrients and resulting in poor growth and biomass production. Conversely, deep tillage practices break the soil hardpan and lead to better root growth and biomass production (Kheir *et al.,* 2018). To obtain a good fodder yield with better nutritional value, an appropriate tillage operation is necessary in legume and non-legume intercropping systems. Thus, we hypothesized that tillage practices and different inter-cropping ratios might affect the forage yield and quality. Therefore, the present study was conducted with different tillage practices, *i.e.,* minimum tillage and deep tillage, and with different intercropping ratios of millet and sesbania crops to find appropriate sowing techniques for better forage yield with maximum nutritional value.

MATERIALS AND METHODS

***Experimental site*:** The current study was performed for two years (2013, 2014) at the Agronomic Research Area, University of Agriculture Faisalabad. The soil samples were collected from various field points and homogenized to make the composite samples and subjected to determine the different physical and chemical properties (Homer and Pratt, 1961). The soil was sandy loam, had a pH of 7.91, organic matter 0.78%, and available N 0.3 g kg^{-1} soil, P 6.4 mg kg^{-1}, and K 185 mg kg^{-1}. The study site has semi-arid conditions, and other climatic conditions during both years are given in Figure 1.

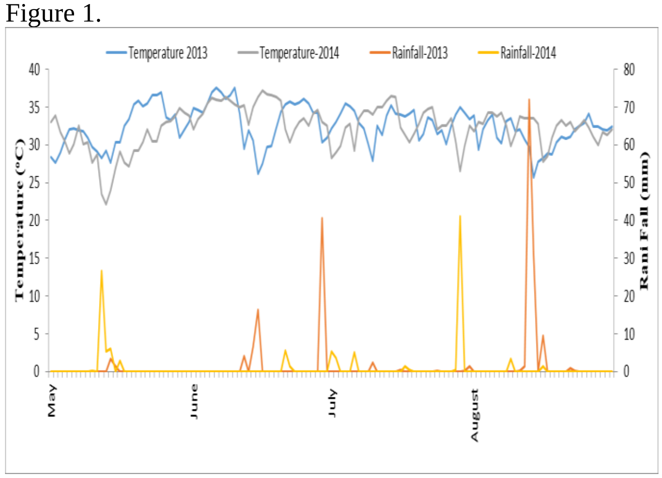

Figure 1. Prevailing weather conditions during both growing seasons.

***Experimental details*:** The study consisted of different tillage practices i.e., minimum tillage (MT) and deep tillage (DT) and variable row ratios, i.e., sole sorghum, sole millet, sole sesbania, sorghum + sesbania (1:1), sorghum + sesbania (1:2), sorghum + sesbania (2:1), millet + sesbania (1:1), millet + sesbania (1:2), millet + sesbania (2:1). In minimum tillage, the soil was plowed once with cultivator followed with planking, while in deep tillage, the field was plowed once with a chisel plow and once with a cultivator and subsequent planking. The study was executed in the RCBD with split plot arrangements having three replications. The tillage practices were placed in the main plot, whereas the variable row ratios of different crops were placed in sub-plots.

***Crop husbandry*:** The crop was sown in both years with a hand drill in 30 cm apart rows, with ten rows per plot. The seed was used at 75 kg ha^{-1}, 20 kg ha^{-1}, and 20 kg ha^{-1} for sorghum, miller, and sesbania, respectively. NPK fertilizers in the form of Urea (46% N), SSP (21% P), and SOP (50% K) were applied at the rate of 110 kg ha^{-1}, 60 kg ha^{-1} and 100 kg ha^{-1} respectively each year to cereals. Moreover, in the case of sesbania N was applied at the rate of 50 kg ha-1 whereas other nutrients were applied at the same rate. Three irrigations each of 7.5 cm (first; 21 days, second; 35 days and third; 50 days, after sowing) were applied during the entire growth period. The atrazine at the 2.5 L ha^{-1} was applied to control the *Horse purslane* weed, and Furadon was applied at 10 kg ha^{-1} to control borer attack.

***Field measurements*:** All plots, including (cereals and sesbania) were harvested manually at about 50% flower initiation on 30th August during both years. The complete plots were hand-harvested and weighed to determine fresh forage yield and later on dried to determine the dry matter yield and converted into t ha^{-1}.

***Biomass analysis*:** A subsample of the harvested material was retained for forage quality analysis. The retained material was dried and ground to determine different compositional traits. The crude protein was determined using the micro kjeldahl method (Jackson, 1962). The crude fiber was analyzed by following the procedure defined by Van Soest *et al.* (1991). Moreover, total ash was analyzed according to AOAC (1990).

***Statistical analysis*:** The computer--operated statistical software (STATISTIX 8.1) was used to analyze the collected data statistically. The recorded data on the biomass yield and quality traits were analyzed using variance (ANOVA) technique, and differences amongst treatment means were compared using the HSD at 0.05 P (Steel *et al.*, 1997).

RESULTS

***Effect of tillage practices and variable row ratios on forage yield and composition of cereal forage*:** The different tillage practices significantly affected the cereals forage quantity, but the effect on cereals' forage quality was non-significant (Table 1). The maximum fresh forage yield (FFY) (33.24 and 36.12 t ha^{-1}) during 2013 and 14, respectively, and dry matter yield (DMY) (7.65 and 8.36 t ha^{-1}) was obtained with deep tillage (DT), and the lowest FFY (27.89 and 30.78 t ha^{-1}) and DMY (6.28 and 6.85 t ha^{-1}) were recorded in minimum tillage (MT) (Table 1). Likewise, variable row ratios significantly affected the forage and dry matter yield and forage quality. Sole sorghum remained at the top, and it produced the maximum FFY (54.15and 50.50 t ha^{-1}) and DMY (11.70 and 12.77 t ha^{-1}), followed by sole Millet, and lowest FFY and DMY was obtained with Millet + sesbania (1:2) (Table 1). Row ratios of different cereals-sesbania intercropping significantly improved the quality characters like crude fiber, crude protein, and total ash contents (Table 2). The highest protein (10.31% and 10.97%) and ash contents (9.39% and

Table 1. Effect of variable tillage practices and row ratios on the yield and quality of cereals forage in cereals-sesbania intercropping.

Treatments	Fresh forage yield (t ha^{-1})		Dry matter yield (t ha^{-1})		Crude protein (%)		Crude fiber (%)		Ash contents (%)	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Tillage Practices (TP)										
Minimum tillage	27.89b	30.78b	6.28b	6.85b	8.74	9.24	33.54	35.64	8.80	9.14
Deep tillage	33.24a	36.12a	7.65a	8.36a	8.66	9.26	35.15	37.45	8.48	8.91
HSD (0.05P)	**0.46**	**0.32**	**0.15**	**0.27**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Row ratios (RR)										
Sole sorghum	50.50a	54.15a	11.70a	12.77a	9.18d	9.71c	34.68b	36.18a-c	8.28e	8.69c
Sole millet	42.10b	45.18b	9.61b	10.41b	7.07h	7.52f	36.89a	39.87a	7.94f	8.19d
Sole sesbania	------	--------	--------	--------	----	------	----	------	-----	-----
Sorghum+ Sesbania (1:1)	26.53e	29.08d	6.02e	6.55e	10.14b	10.79ab	32.85c	34.93bc	8.91b	9.30b
Sorghum+ Sesbania (1:2)	18.10g	20.53e	4.06g	4.50g	10.31a	10.97a	31.72d	33.77c	9.39a	9.80a
Sorghum+ Sesbania (2:1)	36.91c	41.23b	8.47c	9.29c	9.87c	10.50b	33.93b	35.84a-c	8.56cd	8.70c
Millet + Sesbania (1:1)	23.19f	25.70d	5.14f	5.66f	7.60f	8.02e	34.75b	36.91a-c	8.70c	9.09bc
Millet + Sesbania (1:2)	16.02h	19.79e	3.71h	3.99g	8.15e	8.74d	33.97b	35.95a-c	8.92b	9.40ab
Millet + Sesbania (2:1)	31.18d	33.92c	7.04d	7.72d	7.32g	7.77ef	36.00a	38.89ab	8.46de	9.04bc
HSD (0.05P)	1.32	4.01	0.25	0.63	0.10	0.32	1.02	4.92	0.18	0.41
TP × RR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means with different letters indicating significant differences at *HSD at* $P \leq 0.05$.

9.80%) were recorded with sorghum+ sesbania (1:2) (Table 1).

Total ash content and crude protein were reduced with the decreased rate of sesbania rows in intercropping. The maximum crude fiber was observed in sole Millet, which decreased by increasing the concentration of sesbania in intercropping ratios; a similar trend was observed during the second year (Table 1).

***Effect of tillage practices and variable row ratios on forage yield and composition of legume forage*:** Sesbania forage quantity was significantly affected by tillage practices, but tillage practices had no impact on the sesbania forage quality (Table 2). Deep tillage produced the maximum FFY and DMY as compared to minimum tillage (Table 2). Different row ratios significantly affected both the quantity and quality of sesbania forage. Maximum FFY (23.15 and 25.75 t ha^{-1}) during 2013 and 14, respectively, and DMY (6.58 and7.53 t ha^{-1}) was recorded with sole sesbania, followed by the sorghum+ sesbania (1:2) and lowest FFY and DMY recorded in millet + sesbania (2:1) (Table 2) during both years. Row ratios of different cereals-sesbania intercropping significantly improved the quality of sesbania forage. The maximum protein and ash contents was noticed with Sole sesbania and minimum protein and ash contents obtained from millet +

Table 2. Effect of variable tillage practices and row ratios on yield and quality of sesbania in cereals-sesbania intercropping.

Treatments	Fresh forage yield (t ha^{-1})		Dry matter yield (t ha^{-1})		Crude protein (%)		Crude fiber (%)		Ash contents (%)	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Tillage Practices (TP)										
Minimum tillage	12.60b	13.72b	3.45b	3.87b	20.58	21.39	24.55	25.45	9.09	9.63
Deep tillage	14.42a	15.65a	3.99a	4.43a	19.73	20.48	25.33	27.12	9.05	9.52
HSD (0.05P)	0.28	0.54	0.14	0.66	NS	NS	NS	NS	NS	NS
Row ratios (RR)										
Sole sorghum	-----	----	-----	-----	----	----	-----	-----	-----	----
Sole millet	-----	----	-----	-----	----	----	-----	-----	-----	----
Sole sesbania	23.15a	25.75a	6.58a	7.53a	21.22a	21.20ab	24.00c	25.66	9.24a	10.01a
Sorghum+ Sesbania (1:1)	13.71c	14.64bc	3.72c	4.11b	19.63bc	20.27ab	24.78bc	26.29	9.10ab	9.65ab
Sorghum+ Sesbania (1:2)	15.29b	16.62b	4.23b	4.67b	20.56ab	21.73a	24.50c	25.90	9.13ab	9.71ab
Sorghum+ Sesbania (2:1)	7.58e	8.37d	1.99d	2.21c	18.77c	19.42b	25.64ab	26.74	8.95ab	9.32bc
Millet + Sesbania (1:1)	13.04d	13.77c	3.54c	4.00b	20.24a-c	21.26a	25.01bc	26.37	9.07ab	9.52bc
Millet + Sesbania (1:2)	14.81b	15.86bc	4.11b	4.54b	20.67ab	21.82a	24.47c	26.10	9.11ab	9.64ab
Millet + Sesbania (2:1)	7.00e	7.78d	1.84d	2.02c	19.99a-c	20.83ab	26.19a	26.93	8.87b	9.20c
HSD (0.05P)	0.60	2.49	0.38	0.75	1.57	1.77	1.13	Ns	0.33	0.39
TP × RR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means with different letters indicating significant differences at *HSD at P ≤ 0.05*.

Table 3. Effect of tillage practices and row ratios on yield and quality of mixed forage in cereals-sesbania intercropping.

Treatments	Fresh forage yield (t ha^{-1})		Dry matter yield (t ha^{-1})		Crude protein (%)		Crude fiber (%)		Ash contents (%)	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Tillage Practices (TP)										
Minimum tillage	34.59b	38.03b	8.27b	9.11b	12.97	13.46	32.84	33.32	8.83	9.11
Deep tillage	40.76a	44.28a	9.90a	10.89a	12.94	13.44	33.13	34.24	8.71	8.99
HSD (0.05P)	0.43	0.70	0.21	0.59	NS	NS	NS	NS	NS	NS
Row ratios (RR)										
Sole sorghum	50.50a	54.15a	11.70a	12.77a	9.18ef	9.71e	34.68ab	36.18b	8.28ab	8.69bc
Sole millet	42.10c	45.18bc	9.61c	10.41cd	7.07f	7.52f	36.89a	39.87a	7.94b	8.19c
Sole sesbania	23.15i	25.75g	6.58g	7.53g	21.22a	21.20a	24.00c	25.66d	9.24a	10.01a
Sorghum+ Sesbania (1:1)	40.24d	43.72cd	9.74c	10.66bc	14.21bc	15.45bc	32.85ab	33.18bc	8.99a	9.12b
Sorghum+ Sesbania (1:2)	33.39g	37.16ef	8.30ef	9.17ef	15.61b	15.86b	31.47b	32.22c	9.15a	9.36ab
Sorghum+ Sesbania (2:1)	44.49b	49.61ab	10.46b	11.51b	12.21cd	12.91d	34.19ab	33.53bc	8.73ab	8.86bc
Millet + Sesbania (1:1)	36.23f	39.48de	8.68de	9.66de	12.67cd	13.21d	34.91ab	34.83bc	8.88ab	9.22b
Millet + Sesbania (1:2)	30.83h	33.66f	7.83f	8.53f	13.84bc	14.29cd	33.37ab	33.55bc	9.10a	9.34ab
Millet + Sesbania (2:1)	38.18e	41.71c-e	8.88d	9.74c-e	10.58de	10.92e	34.54ab	34.99bc	8.60ab	8.68bc
HSD (0.05P)	1.52	4.72	0.57	0.94	2.37	1.41	4.39	3.31	0.96	0.68
TP × RR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means with different letters indicating significant differences at *HSD at P ≤ 0.05*.

sesbania (2:1) (Table 2). Moreover, maximum crude fiber (26.19% and 26.93%) was observed in Millet + Sesbania (2:1), followed by sorghum+ sesbania (2:1) and lowest fiber contents (24.0% and 25.66%) recorded from sole sesbania (Table 2).

***Effect of tillage practices and variable row ratios on forage yield and composition of mixed forage*:** The tillage practices and varying row ratios significantly impacted the FFY and DMY of mixed forage. Deep tillage produced more FFY by 17% and 16% and DMY by 19% and 19% during both years compared to minimum tillage (Table 3). However, the tillage practices had a non-significant impact on the qualitative characteristics of forage (Table 3). Amongst row ratios, maximum FFY (50.50 and 54.15 t ha^{-1}) during 2013 and 14, respectively and DMY (11.70 and 12.77 t ha^{-1}) were noticed with sole sorghum, followed after sorghum+ sesbania (2:1) and lowest FFY and DMY was recorded in millet + sesbania (2:1) (Table 3). Crude protein and total ash contents were

Table 4. Effect of variable tillage practices and row ratios on land equivalent ratio.

Treatments	Cereals	Sesbania	Mixed	Cereals	Sesbania	Mixed
		2013			2014	
Minimum tillage × Sole sorghum	1.00	-	1.00	1.00	0	1.00
Minimum tillage × Sole millet	1.00	-	1.00	1.00	-	1.00
Minimum tillage × Sole sesbania	-	1.00	1.00	-	1.00	1.00
Minimum tillage × Sorghum+ Sesbania (1:1)	0.52	0.58	1.10	0.53	0.56	1.09
Minimum tillage × Sorghum+ Sesbania (1:2)	0.35	0.66	1.01	0.38	0.65	1.03
Minimum tillage × Sorghum+ Sesbania (2:1)	0.72	0.32	1.04	0.75	0.34	1.09
Minimum tillage × Millet + Sesbania (1:1)	0.54	0.56	1.10	0.56	0.54	1.10
Minimum tillage × Millet + Sesbania (2:1).	0.37	0.63	1.00	0.40	0.61	1.01
Minimum tillage × Millet + Sesbania (2:1)	0.73	0.29	1.02	0.77	0.29	1.06
Deep tillage × Sole sorghum	1.00	-	1.00	1.00	-	1.00
Deep tillage × Sole millet	1.00	-	1.00	1.00	-	1.00
Deep tillage × Sole sesbania	-	1.00	1.00	-	1.00	1.00
Deep tillage × Sorghum+ Sesbania (1:1)	0.53	0.60	1.13	0.54	0.58	1.12
Deep tillage × Sorghum+ Sesbania (1:2)	0.37	0.67	1.04	0.38	0.64	1.02
Deep tillage × Sorghum+ Sesbania (2:1)	0.74	0.33	1.07	0.77	0.30	1.07
Deep tillage × Millet + Sesbania (1:1)	0.56	0.57	1.13	0.57	0.53	1.09
Deep tillage × Millet + Sesbania (2:1)	0.33	0.64	0.97	0.39	0.61	1.00
Deep tillage × Millet + Sesbania (2:1)	0.75	0.31	1.06	0.73	0.31	1.04

Table 5. Effect of variable tillage practices and row ratios on benefit cost ration (BCR).

Treatments	Cereals	Sesbania	Mixed	Cereals	Sesbania	Mixed
		2013			2014	
Minimum tillage × Sole sorghum	1.28	-	1.50	1.34	-	1.56
Minimum tillage × Sole millet	1.12	-	1.35	1.12	-	1.39
Minimum tillage × Sole sesbania	-	1.15	0.85	-	1.20	0.90
Minimum tillage × Sorghum+ Sesbania (1:1)	0.92	0.75	1.27	0.95	0.78	1.32
Minimum tillage × Sorghum+ Sesbania (1:2)	0.84	0.82	1.05	0.85	0.88	1.11
Minimum tillage × Sorghum+ Sesbania (2:1)	1.05	0.69	1.42	1.10	0.75	1.47
Minimum tillage × Millet + Sesbania (1:1)	0.91	0.71	1.14	0.96	0.74	1.20
Minimum tillage × Millet + Sesbania (2:1).	0.79	0.79	0.92	0.82	0.82	0.99
Minimum tillage × Millet + Sesbania (2:1)	0.99	0.65	1.21	1.04	0.69	1.27
Deep tillage × Sole sorghum	1.35	-	1.62	1.42	-	1.72
Deep tillage × Sole millet	1.29	-	1.41	1.34	-	1.53
Deep tillage × Sole sesbania	-	1.29	0.99	-	1.34	1.08
Deep tillage × Sorghum+ Sesbania (1:1)	1.10	0.80	1.34	1.15	0.10	1.40
Deep tillage × Sorghum+ Sesbania (1:2)	0.95	0.91	1.16	1.05	0.11	1.19
Deep tillage × Sorghum+ Sesbania (2:1)	1.22	0.76	1.51	1.27	0.93	1.61
Deep tillage × Millet + Sesbania (1:1)	0.99	0.77	1.21	1.04	0.92	1.30
Deep tillage × Millet + Sesbania (2:1)	0.90	0.82	1.11	0.96	0.14	1.17
Deep tillage × Millet + Sesbania (2:1)	1.16	0.70	1.30	1.24	0.82	1.35

enhanced when concentration of sesbabia increased in intercropping ratio. Maximum crude protein and total ash contents were observed in ole sesbania, followed by sorghum+ sesbania (1:1) during both years (Table 3). Crude fiber percentage increased by decreasing the concentration of sesbania in mixture. Maximum crude fiber was observed in Sole Millet and however, minimum crude fiber observed from sole sesbania (Table 3).

***Land equitant ratio (LER) and benefit-cost ratio* (*BCR*):** The results indicated that different tillage practices and crop ratios significantly impacted the LER and BCR. In the case of cereals forage, maximum LER was recorded in sole sorghum with deep tillage, and minimum LER was noted in sorghum+ sesbania with MT (Table 5). In the case of sesbania forage, maximum LER was observed for Sole sorghum in DT and lowest LER was noted for millet + sesbania (2:1) with MT (Table 4). In case of mix forage maximum LER was recorded in sorghum+ sesbania with DT and lowest LER was observed for millet + sesbania (1:2) with MT (Table 4). The results regarding BCR are given in Table 5. The results showed that maximum BCR was observed for cereals forage in sole sorghum with DT and minimum BCR was noted in millet + sesbania (2:1) with MT (Table 5). In the case of sesbania forage maximum BCR was recorded for sole sesbania with DT, and lowest BCR was recorded in millet + sesbania (2:1) with MT. Lastly, for mixed forage maximum BCR was noted in sole sorghum with DT and lowest BCR was recorded in sole sesbania with MT (Table 5).

DISCUSSION

The cereals forage has substantial importance in ruminant's feed owing to higher biomass productivity (Iqbal *et al.,* 2018). However, cereals are considered poor in nutrients to meet the animal dietary requirements. The one way to increase forage production and quality is to intercropping of cereals with legumes (Ghanbari-Bonjar and Lee, 2003). The cereal intercropping with leguminous crops improves both forage yield and quality. The cereal intercropping with leguminous crops improve the both forage yield and quality. Intercropping of different crops combination for forage production showed different results because of their varied root density, nutrient sequestration capacity and their survival in changing environments (Reddy and Palled, 2016). Cereal-legume intercropping may prove productive, cost effective and better forage for animals than solitary cropping. The cereal-legume intercropping produced good quality forage by efficient utilization of soil resources and increasing soil fertility via increasing soil organic carbon (Ananthi *et al.,* 2017).

Other tillage practices also influenced seed germination and plants survival under variable climatic conditions (Alarcón *et al.,* 2018). Thus, there is a need to find out proper tillage practices and appropriate plant species combinations to obtain optimum forage yield with maximum nutritional quality (Rasool *et al.,* 2017). Cereals forage different tillage practices significantly influenced quantity, while the effect on cereals forage quality was non-significant in present study. The DT significantly increased the FFY and DMY during both years. The DT favors the better root growth and proliferation owing to loosened soil conditions (Zhao *et al.,* 2014). Deep tillage practices break down the soil hard pan which allows better root growth and ensures better nutrient and water uptake, resulting in a substantial increase in FFY and DMY (Liu *et al.,* 2010). Moreover, DT also allows incorporating of crop residues in soil and makes soil loose, which enhances chemical reaction in soil and therefore improves soil physio-chemical conditions and results in better growth and biomass production (Alam *et al.,* 2014).

Different row ratios significantly affected the quantity and quality of cereals forage in the present study, which is inconsistent with the outcomes of Yadav *et al.* (2017) they also found a positive effect of legume-cereals intercropping on the forage yield and quality. Sesbania forage yield increased significantly with tillage practices, but forage quality was not affected by tillage practices. The different intercropping improves the quality of forage compared to alone cultivation of forage crops (Mass *et al.* 2007). The intercropping with legumes improve the soil nutrient status, soil enzymatic activities and nitrogen uptake by plants which in turn improves overall quality of biomass (Mass *et al.,* 2007). In our experiment, mixed forage (sesbenia-pearl millet), yield and nutritional value were enhanced with different tillage practices and intercropping ratios. Previously, it was concluded that grasses and sesbania intercropping increased forage yield and nutritional quality owing to improvement in nutrient uptake by plants and better soil microbial activities (Contreras-Govea *et al.,* 2009 a, b; Rasool *et al.,* 2017). The leguminous crops fix the nitrogen which help to fulfill the plants' needs (Pal and Sheshu, 2001) Thus, in this way nitrogen availability substantially increased to cereals grown in intercropping with legumes which triggered the higher biomass production and better protein contents in this study.

The leguminous crops improved the nutritional values and protein contents owing to their ability to fix nitrogen and higher protein contents (Strydhorst *et al.,* 2008). The protein content of forages is significantly affected by the nitrogen availability; as legumes considerably fix the nitrogen and increase its availability to plants (Ahmad et al 2007). Therefore, in this study, intercropping of legumes also increased protein contents of cereals. Legumes also significantly improved fertilizer use efficiency (FUE) and increased the absorption and utilization of applied fertilizers, which improved biomass production and quality (Iqbal *et al.,* 2019).

The sesbania crop considerably fix the soil nitrogen, as nitrogen is an essential component of plant protein and other molecules (Dahmardeh *et al.,* 2009); therefore, more fixing of nitrogen by sesbania in this study led to a significant increase in biomass quality of all the crops. The tillage practices had a non-significant effect on ash contents, but the ash percentage of forage was significantly affected by row ratios. It was observed that by decreasing the ratio of cereals in intercropping, the total ash percentage of forage was increased. Similarly, Thippeswamy and Alagundagi (2001) also reported that intercropping of sorghum + beans resulted in more ash contents than alone sorghum. In the present study, fibers contents were decreased, whilst protein and ash contents were increased in mixed forage. Cereals are considered to be higher in lignin, and legumes crops are considered to be lower in fiber contents compared to the cereals; therefore, intercropping of legumes in cereals reduced the fiber contents and increased the protein contents (Sleugh *et al.,* 2000; Eskandari *et al.,* 2009). The results indicated that different tillage practices and intercrop ratios significantly affected the LER and BCR (Table 4, 5). DT gave maximum LER and BCR which could be due to higher biomass production in tillage systems than MT. Similarly, mix forage production gave maximum BCR and LER due to production of maximum biomass in this system compared to sole cereals and sesbania production system.

***Conclusion*:** In conclusion different tillage practices significantly affected the fresh and dry biomass however, tillage practices had a non-significant impact on quality traits. Deep tillage produced maximum fresh and dry biomass as compared to minimum tillage. Similarly, different intercropping systems also clearly affected the forage production and quality. The maximum fresh and dry biomass yield was obtained with cereals alone however, the intercropping of Millet + sesbania (1:2) resulted in maximum protein and ash contents. Thus, it is suggested that intercropping of cereals with sesbania could be an essential practice to get good biomass yield and better quality.

***Conflict of Interest*:** The authors declare that there is no conflict of interest.

***Authors' Contribution*:** MSIZ and MKK executed the field research. MSIZ, MUC and MKK wrote the original draft of manuscript. IM, MUH SA and MK review the edited the work.

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