D-6136
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RESEARCH ARTICLE

Agricultural Science Digest, Volume Issue : ()

Assessing Nutritional Quality of Sustainable forage Sequences Including Cereals, Legumes and Grasses in Irrigated Subtropics of Jammu and Kashmir - India

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10.18805/ag.D-6136

ABSTRACT

Background: The subtropical regions of Jammu and Kashmir face unique agricultural challenges due to their climatic conditions and irrigation needs. The integration of cereals, legumes and grasses into sustainable forage cropping sequences offer a promising solution to enhance both productivity and nutritional quality of livestock feed. This study aims to assess the nutritional quality of these diverse forage crops under irrigated conditions providing valuable insights for improving agricultural sustainability and livestock health in the region. By optimizing forage cropping systems, this research seeks to contribute to the development of resilient agricultural practices in the subtropics of Jammu and Kashmir.s

Methods: The study was conducted at Research Farm, Division of Agronomy, SKUAST – Jammu during 2020 and 2021 focused on assessing sustainable forage cropping sequences for continuous high-quality green fodder production in subtropical irrigated zones of India. The experimental field had sandy clay loam soil with slightly alkaline pH, low organic carbon and nitrogen levels and medium availability of potassium and phosphorus. It comprised 24 treatments arranged in RBD and replicated three times with nutrient application following recommended practices.

Result: The experimental results revealed that Multicut Sorghum + Maize with Root slips of Napier planted in July recorded significantly higher ADF, NDF, hemi cellulose and cellulose content at each cut which was statistically at par with Multicut Sorghum + Maize with Root slips of Setaria planted in July, Multicut Sorghum + Maize with Stem cuttings of Napier planted in January and Multicut Sorghum + Maize with Stem cuttings of Setaria planted in January during both the years of experimentation. However, significantly lowest ADF content was recorded with Multicut Bajra + Cowpea with stem cuttings of *Setaria* planted in January.

Key words: Acid detergent fibre, Cellulose, Cropping system, Hemi cellulose, Neutral detergent fibre, Sustainable.

INTRODUCTION

Forage and livestock are the integral part of the Indian agricultural system (Ghosh *et al.,* 2016). Agriculture and livestock sector provides employment to 52 per cent of the work force, whereas, the livestock sector alone creates large self-employment opportunities and nearly 70 per cent of Indian population is engaged in livestock production and management especially in rural areas (Pachauri *et al.,* 2020). It contributes about 6 per cent to the Gross Domestic Product and 25 per cent to the Agricultural Gross Domestic Product. The share of Indian livestock sector to the Gross Value Output has been increasing continuously at faster rate than the crop sector. This suggests that livestock is likely to emerge as an engine of agricultural growth in the coming decades. It is also considered as one of the potential sectors for export earnings.

India is world's largest livestock owner (535.78 million) with total bovine population of about 302.79 million and cattle population of about 192.49 million (DACFW, 2018). Despite the abundance of livestock in the region (20 per cent of world's livestock population on just 2.2 per cent of the world's geographical area) (Patil *et al.,* 2018), the productivity of the sector is very low *viz.* 20 to 60 per cent lower than the global average due to perennial problem of fodder scarcity (Halli *et al.,* 2018). This issue is exacerbated by factors such as shrinking traditional pasturelands due to urbanization and industrialization, seasonal and regional imbalances in fodder production and deficiencies in feed

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How to cite this article: Mehta, S., Sharma, N., Singh, B., Singh, A., Parida, D., Verma, A., Dahiya, P. and Rana, N. (2025). Assessing Nutritional Quality of Sustainable Forage Sequences Including Cereals, Legumes and Grasses in Irrigated Subtropics of Jammu and Kashmir - India. Agricultural Science Digest. 1-10. doi: 10.18805/ag.D-6136.

Submitted: 24-07-2024 **Accepted:** 10-12-2024 **Online:** 30-01-2025

and fodder management practices (Swati *et al.* 2024). Consequently, farmers are compelled to maintain large herds of animals, further straining land and fodder resources and impeding the economic viability of livestock rearing (Palsaniya *et al.,* 2008; Palsaniya *et al.,* 2009; Palsaniya *et al.,* 2010). Availability of good quality green forage to animals is the key to success of dairy enterprises and it is difficult to maintain the health and milk production of the livestock without supply of green fodder (Swati *et al.* 2023). This puts a pressure to increase fodder production for a healthy livestock population. Moreover, availability of milk per head per day in India is only 178 grams against the norm of 250 grams (Ahmad *et al.,* 2016). The human population in India is expected to reach over 1400 million by 2025 and the shift in lifestyle and feeding habits towards milk products, meat products and eggs led to increase the demand of livestock (Ahmad *et al.,* 2016). Only way to meet the fodder needs of livestock is to enhance productivity per unit land area and also through integration of fodder crops in the cropping system. But, cultivated fodder is limited to less than 4.5 per cent (8.6 million hectare) out of the 159.7 million hectare area under cultivation in country with annual total forage production of 846 million tonnes (IGFRI, 2018), whereas, the green forage requirement is 1061 million tonnes and dry fodder is 589 million tonnes which contributes 48.72 per cent of the demand only. At present, the country faces a net deficit of 63.5 per cent green fodder, 23.5 per cent dry crop residues and 64 per cent feeds (DES, 2022). Similarly, Jammu and Kashmir has livestock population of about 1.79 crores with cattle population and buffalo population of about 34.43 lakhs and 10.50 lakhs respectively (DES, 2022) and has milk production of about 1486.65 metric tonnes (DES, 2022). The total fodder production of Jammu and Kashmir is 86.5 lakh tonnes of which green fodder contributes 61.4 and dry fodder 25.1 lakh tonnes Union territory of JandK is 67 per cent deficit in green fodder and 27.31 per cent in dry fodder (Ahmad *et al.,* 2016).

To address these challenges and unlock the full potential of the livestock sector, there is an urgent need to explore and implement sustainable forage cropping systems tailored to the unique agro-ecological conditions of subtropical irrigated zones in Jammu and Kashmir. This situation can be handled through use of year-round alternative sources of fodder through agronomical interventions *viz.* stagger planting time of annual cereal fodders, blending legumes with cereals and using alternative sources of perennial fodders which could provide good quality fodder throughout the year so that the milk productivity as well as animal health may be maintained (Murali *et al.,* 2022). The combination of graminaceous and leguminous fodder crops improves the herbage quality substantially in terms of protein and mineral balances as the legumes component contains higher amount of protein, calcium and phosphorus (Kumar *et al.,* 2014a; Kumar *et al.,* 2014b; Palsaniya *et al.,* 2014).

MATERIALS AND METHODS

Location and climate

At the Research Farm of the Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, India, a research experiment was carried out in *kharif* season for two consecutive years 2020 and 2021. During the cropping seasons of both 2020 and 2021, the experimental site, situated at 32°40′N latitude and 74°58′E longitude, at an altitude of 293 meters above mean sea level, was located in the subtropical Shiwalik foothills of the North-Western Himalayas within Jammu and Kashmir (Fig 1). This region experiences distinct climatic patterns characterized by hot and dry early summers, followed by hot and humid monsoon seasons and cold winters. Meteorological data obtained from the nearby Research Farm at Chatha, SKUAST-Jammu, indicated an annual mean rainfall of 1115 mm with approximately 70 to 75 per cent occurring during

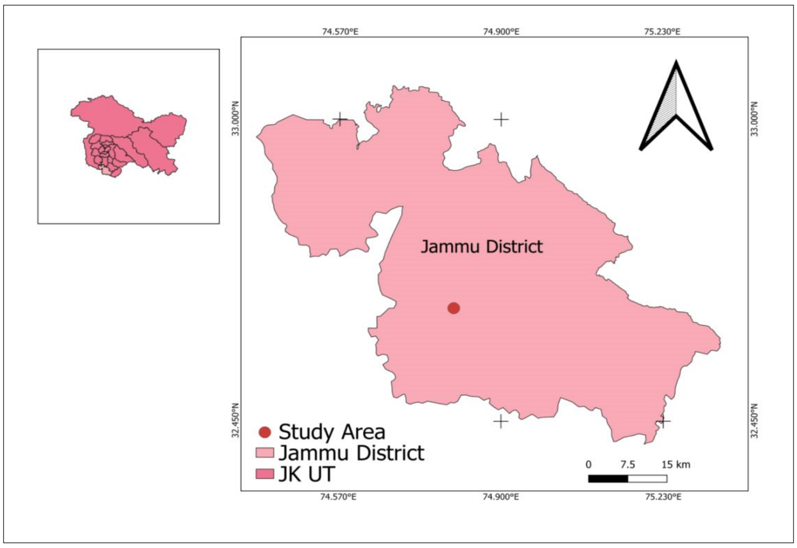

Fig 1: Description of study site.

the monsoon months of June to September and the remaining 25 to 30 per cent received sporadically during winter due to Western disturbances from January to March.

For the *kharif* annual fodder crops alongside perennial grasses, the growing period extended from the 15th to the 42nd Standard Meteorological Weeks (SMW) in both experimental years. Analysis of rainfall data revealed notable variations between normal and actual precipitation levels, with a total of 872.0 mm and 987.4 mm recorded during the respective cropping seasons. The highest weekly rainfall was observed in the 33rd and 28th SMW, with values of 185.6 mm and 167.4 mm, respectively. Mean weekly maximum temperatures ranged from 30.9°C to 41.8°C during the first year and 28.9°C to 39.8°C during the second year, while mean weekly minimum temperatures ranged from 17.2°C to 26.6°C and 14.3°C to 26.9°C, respectively. Relative humidity data showed fluctuations, with mean maximum (morning) values ranging from 48.9% to 93.4% and mean minimum (evening) values ranging from 18.2% to 73.4% during the first year and corresponding values of 48.0% to 89.0% and 20.0% to 72.0% during the second year.

Experimental design and Crop management

The experiment was laid out in randomized block design with three replications. The experiment comprised of eight treatments at three different staggers given below (Table 1 and 2).

Stem cuttings were utilized for sowing perennial grasses in January, while root slips were used in July, both with a plant-to-plant spacing of 50 cm. For annual cereal fodders, seed broadcasting method was employed with a seed rate ratio of 3:1 for areas where two mixed crops were sown and 1:2:2 for areas where three mixed crops were sown simultaneously. The nutrients were applied according to the recommended package of practice as basal dose during sowing of the crop and remaining nutrients were

Table 1: Detail of treatments.

T_{1a}	Multicut Bajra + Cowpea with Stem cuttings of Napier planted in January
T_{2a}	Multicut Bajra + Cowpea with Stem cuttings of Setaria planted in January
T_{3a}	Multicut Sorghum + Cowpea with Stem cuttings of Napier planted in January
T_{4a}	Multicut Sorghum + Cowpea with Stem cuttings of Setaria planted in January
T_{5a}	Multicut Bajra + Cowpea with Root slips of Napier planted in July
T_{6a}	Multicut Bajra + Cowpea with Root slips of Setaria planted in July
T_{7a}	Multicut Sorghum + Cowpea with Root slips of Napier planted in July
T_{8a}	Multicut Sorghum + Cowpea with Root slips of Setaria planted in July
T_{1b}	Multicut Bajra + Maize with Stem cuttings of Napier planted in January
T_{2b}	Multicut Bajra + Maize with Stem cuttings of Setaria planted in January
T_{3b}	Multicut Sorghum + Maize with Stem cuttings of Napier planted in January
T_{4b}	Multicut Sorghum + Maize with Stem cuttings of Setaria planted in January
T_{5b}	Multicut Bajra + Maize with Root slips of Napier planted in July
T_{6b}	Multicut Bajra + Maize with Root slips of Setaria planted in July
T_{7b}	Multicut Sorghum + Maize with Root slips of Napier planted in July
T_{8b}	Multicut Sorghum + Maize with Root slips of Setaria planted in July
T_{1c}	Multicut Bajra + Cowpea + Maize with Stem cuttings of Napier planted in January
T_{2c}	Multicut Bajra + Cowpea + Maize with Stem cuttings of Setaria planted in January
T_{3c}	Multicut Sorghum + Cowpea + Maize with Stem cuttings of Napier planted in January
T_{4c}	Multicut Sorghum + Cowpea + Maize with Stem cuttings of Napier planted in January
T_{5c}	Multicut Bajra + Cowpea + Maize with Root slips of Napier planted in July
T_{6c}	Multicut Bajra + Cowpea + Maize with Root slips of Setaria planted in July
T_{7c}	Multicut Sorghum + Cowpea + Maize with Root slips of Napier planted in July
T_{8c}	Multicut Sorghum + Cowpea + Maize with Root slips of Setaria planted in July

Table 2: Detail of crops and stagger.

Crop	*Kharif* annual cereals	Perennial grasses (Stem cuttings)	Perennials grasses (Root slips)
1st stagger Denoted by symbol (a)	15 April		
2nd stagger Denoted by symbol (b)	30April	15 January	15 July
3rd stagger Denoted by symbol (c)	15 May		

applied after each cut. The varieties that were used during the experimentation are given below (Table 3).

Estimation of forage quality of staggered planted annual forages

Plant sample from each net plot was sun-dried and then oven dried at 72°C for 36-48 hours to a constant weight and then grinded for analysis. The determination of different quality parameters *viz.*, neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analyzed as per the method suggested by Van Soest *et al.* (1991).

Acid detergent fibre (ADF) (per cent)

Acid detergent fibre was calculated as follows:

$$\text{ADF (per cent)} = \frac{(X\text{-}Y)}{S} \times 100$$

Where,

X = Weight of oven dried crucible including ADF.

Y = Weight of empty oven dried crucible.

S = Sample weight on dry matter basis.

Neutral detergent fibre (NDF) (per cent)

NDF was calculated as follows:

$$\text{NDF (\%)} = \frac{\text{(wt. of crucible + cell wall contents) - wt. of crucible}}{\text{wt. of the sample}} \times 100$$

Crude protein content (CP) (per cent)

Per cent crudeprotein =

$$\frac{\text{Vol.of N/ 10}H_2SO_4 \times 250 \times 0.0014 \times 6.25}{\text{Aliquot taken} \times \text{Weight of sample on DM basis}} \times 100$$

Hemi-cellulose content (per cent)

Hemi-cellulose (Per cent) = NDF (per cent) - ADF (per cent)

Statistical analysis

The results underwent testing for treatment means using the F-test of significance, based on the null hypothesis (Cochran and Cox, 1963). In cases where it was deemed necessary, standard errors were calculated along with critical differences at a significance level of 5% to discern treatment effects from chance effects.

RESULTS AND DISCUSSION

The quality parameters estimated in the present investigation include crude protein, ADF (acid detergent fibre), NDF (neutral detergent fibre), Hemi-cellulose and crude protein. Cell wall constituents are classified under neutral detergent fibre and acid detergent fibre. These are measure of fibrous part of a plant. Lower percentage of these components will improve the nutritive value of the fodder.

Acid detergent fibre of *Kharif* annual cereal fodder with perennial grasses (per cent)

The acid detergent fibre concentration refers to portions of forage which consist of cellulose and lignin. The acid detergent fibre values are important because they describe the ability of an animal to digest the forage. As the acid detergent fibre content increases, the digestibility of the forage usually decreases (Verma *et al.,* 2003). Among the different treatments (Table 4), significant variations with regard to acid detergent fiber was found at each harvesting interval where Multicut Sorghum + Maize with root slips of Napier planted in July recorded significantly higher ADF content to the tune of 42.19, 41.37 and 41.76 per cent which was statistically at par with the results obtained in Multicut Sorghum + Maize with root slips of *Setaria* planted in July, Multicut Sorghum + Maize with stem cuttings of Napier planted in January and Multicut Sorghum + Maize with stem cuttings of *Setaria* planted in January. However, significantly lowest ADF content was recorded with Multicut Bajra + Cowpea with stem cuttings of *Setaria* planted in January with the corresponding value of 25.38 per cent at first cut. At second and third cut, Multicut Bajra + Cowpea + Maize with stem cuttings of *Setaria* planted in January registered significantly lowest ADF to the tune of 24.18 and 24.53 per cent, respectively which might be due to the fact that more rapidly synthesized carbohydrates are converted into proteins and protoplasm, thus only smaller portion is available for cell wall formation. The results are in close conformity to the findings of Ayub *et al*. (2002). By and large, a similar trend with respect to ADF content was observed during second year of experimentation except for that a slight increase in ADF from previous year.This might be due to the variation in stage of fodder maturity and crop growth conditions (Tiwari *et al.,* 2019). It is observed that inclusions of Legumes in cereals are more digestible than only cereal fodder crops. Similar value of proximate principles and fibre fractions were reported by Palsaniya *et al.* (2012).

Neutral detergent fibre of *Kharif* annual cereal fodder with perennial grasses (per cent)

The neutral detergent fibre content refers to the total cell wall, composed of the acid detergent fibre fraction plus hemi-cellulose. Neutral detergent fibre content is important in ration formulation because it reflects the amount of forage that the animal can consume. As the neutral detergent fibre percentage increases, the dry matter intake will generally decrease (Patel *et al.,* 2022).

Amongst the different treatments (Table 4), Multicut Sorghum + Maize with root slips of Napier planted in July

Table 3: Detail of Crops and varieties.

Crop	Variety
Perennial grasses	
Napier grass	NB-21
Setaria	S-92
***Kharif* annual fodder crops**	
Multicut sorghum	Sprint Gold CSH-24 MF
Multicut Bajra	Wonder Leaf – HB-21
Cowpea	EC4216
Maize	African Tall

Table 4: Effect of *kharif* annual fodder with perennial grasses on quality (ADF and NDF per cent).

Treatments	ADF (per cent)						NDF (per cent)					
	I cut		II cut		III cut		I cut		II cut		III cut	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
T_{1a}	25.53	27.16	26.96	27.27	26.75	28.08	41.28	42.53	42.50	43.85	43.13	44.55
T_{2a}	25.38	26.58	26.80	26.69	26.17	27.5	41.02	42.27	42.24	43.59	42.87	44.29
T_{3a}	35.13	36.36	36.84	38.15	37.63	38.96	53.79	55.04	57.67	59.02	58.30	59.72
T_{4a}	35.10	36.33	36.64	37.95	37.49	38.82	53.72	54.97	57.60	58.95	58.23	59.65
T_{5a}	26.63	27.86	27.67	28.98	28.46	29.79	42.40	43.65	43.62	44.97	44.24	45.66
T_{6a}	26.29	27.52	27.32	28.63	28.11	29.44	42.19	43.44	43.40	44.75	44.03	45.45
T_{7a}	36.56	37.79	37.27	38.58	38.39	39.72	54.32	55.57	57.77	59.12	58.40	59.82
T_{8a}	36.50	37.73	37.19	38.5	38.32	39.65	54.15	55.4	57.70	59.05	58.32	59.74
T_{1b}	32.04	33.27	31.04	32.35	31.43	32.76	47.98	49.23	49.19	50.54	49.82	51.24
T_{2b}	32.01	33.24	30.79	32.1	31.19	32.52	47.88	49.13	49.09	50.44	49.72	51.14
T_{3b}	41.18	42.41	40.36	41.67	40.75	42.08	61.57	62.82	62.78	64.13	63.41	64.83
T_{4b}	41.04	42.27	40.22	41.53	40.61	41.94	61.45	62.7	62.67	64.02	63.29	64.71
T_{5b}	32.48	33.71	31.66	32.97	32.05	33.38	49.32	50.57	50.54	51.89	51.16	52.58
T_{6b}	32.22	33.45	31.38	32.69	31.79	33.12	49.26	50.51	50.48	51.83	51.11	52.53
T_{7b}	42.19	43.42	41.37	42.68	41.76	43.09	62.19	63.44	63.41	64.76	64.70	66.12
T_{8b}	42.07	43.3	41.23	42.54	41.63	42.96	62.06	63.31	63.27	64.62	63.90	65.32
T_{1c}	27.55	28.78	24.44	25.75	24.90	26.23	44.22	45.47	40.89	42.24	40.85	42.27
T_{2c}	27.28	28.51	24.18	25.49	24.53	25.86	44.00	45.25	40.66	42.01	40.62	42.04
T_{3c}	37.64	38.87	35.36	36.67	36.42	37.75	57.97	59.22	56.29	57.64	56.91	58.33
T_{4c}	37.60	38.81	35.30	36.61	36.32	37.65	57.58	58.83	55.90	57.25	56.52	57.94
T_{5c}	29.96	31.19	27.67	28.98	27.67	29	46.62	47.87	41.60	42.95	41.56	42.98
T_{6c}	29.67	30.9	27.38	28.69	27.38	28.71	46.00	47.25	40.98	42.33	40.94	42.36
T_{7c}	38.68	39.91	35.84	37.15	36.58	37.91	58.38	59.63	56.69	58.04	57.32	58.74
T_{8c}	38.40	39.63	35.57	36.88	36.50	37.83	58.41	59.66	56.73	58.08	57.35	58.77
SEm (±)	1.53	1.54	1.13	1.12	1.08	1.22	2.05	2.02	1.99	1.95	1.93	1.92
CD (5%)	4.59	4.63	3.39	3.35	3.24	3.67	6.14	6.05	5.97	5.84	5.80	5.76

Table 5: Effect of *kharif* annual fodder with perennial grasses on quality (Hemi cellulose and Cellulose per cent).

Treatments	Hemi cellulose (per cent)						Cellulose (per cent)					
	I cut		II cut		III cut		I cut		II cut		III cut	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
T_{1a}	16.36	15.37	16.54	16.58	16.38	16.47	18.55	19.58	19.92	20.94	21.34	22.4
T_{2a}	16.68	15.69	16.86	16.9	16.70	16.79	18.28	19.31	19.65	20.67	21.08	22.14
T_{3a}	18.66	18.68	20.26	20.87	20.67	20.76	24.27	25.3	28.60	29.62	30.38	31.44
T_{4a}	18.62	18.64	20.96	21.00	20.74	20.83	24.00	25.03	28.50	29.52	30.25	31.31
T_{5a}	15.77	15.79	15.95	15.99	15.79	15.87	19.71	20.74	21.08	22.1	22.50	23.56
T_{6a}	15.90	15.92	16.08	16.12	15.92	16.01	19.44	20.47	20.81	21.83	22.24	23.3
T_{7a}	17.75	17.78	20.50	20.54	20.01	20.10	25.67	26.7	29.63	30.65	31.05	32.11
T_{8a}	17.65	17.67	20.51	20.55	20.00	20.09	25.33	26.36	29.45	30.47	30.88	31.94
T_{1b}	15.94	15.96	18.16	18.19	18.39	18.48	23.75	24.78	25.12	26.14	26.54	27.6
T_{2b}	15.87	15.89	18.30	18.34	18.53	18.62	23.16	24.19	24.53	25.55	25.96	27.02
T_{3b}	20.38	20.41	22.42	22.46	22.66	22.75	30.53	31.56	31.89	32.91	33.32	34.38
T_{4b}	20.41	20.43	22.45	22.49	22.68	22.77	30.40	31.43	31.77	32.79	33.20	34.26
T_{5b}	16.84	16.86	18.88	18.92	19.11	19.20	24.63	25.66	25.09	26.11	27.62	28.68
T_{6b}	17.05	17.06	19.10	19.14	19.32	19.41	24.08	25.11	24.55	25.57	27.20	28.26
T_{7b}	20.00	20.02	22.04	22.08	22.94	23.03	31.57	32.6	32.94	33.96	34.36	35.42
T_{8b}	19.99	20.01	22.04	22.08	22.27	22.36	31.12	32.15	32.50	33.52	33.92	34.98
T_{1c}	16.67	16.69	16.45	16.49	15.95	16.04	21.63	22.66	20.32	21.34	21.76	22.82
T_{2c}	16.71	16.74	16.49	16.52	16.10	16.18	21.27	22.3	19.97	20.99	21.40	22.46
T_{3c}	20.33	20.35	20.93	20.97	20.49	20.58	28.26	29.29	25.70	26.72	27.13	28.19
T_{4c}	20.00	20.02	20.60	20.64	20.21	20.29	28.09	29.12	25.54	26.56	26.96	28.02
T_{5c}	16.67	16.68	13.93	13.97	13.89	13.98	22.19	23.22	20.87	21.89	22.31	23.37
T_{6c}	16.33	16.35	13.60	13.64	13.56	13.65	22.01	23.04	20.69	21.71	22.11	23.17
T_{7c}	19.70	19.72	20.85	20.89	20.74	20.83	29.83	30.86	26.53	27.55	27.96	29.02
T_{8c}	20.02	20.03	20.16	21.2	20.85	20.94	29.67	30.7	26.47	27.49	27.90	28.96
SEm (±)	0.58	0.61	0.41	0.43	0.66	0.52	1.36	1.37	1.56	1.50	1.48	1.38
CD (5%)	1.73	1.82	1.22	1.28	1.98	1.56	4.07	4.12	4.69	4.49	4.43	4.15

Table 6: Effect of *kharif* annual fodder with perennial grasses on crude protein (per cent).

Treatments		I cut		II cut		III cut	
		2020	2021	2020	2021	2020	2021
T_{1a}	Multicut Bajra + Cowpea with Stem cuttings of Napier planted in January	6.756	6.819	6.631	6.694	6.613	6.675
T_{2a}	Multicut Bajra + Cowpea with Stem cuttings of Setaria planted in January	6.744	6.806	6.619	6.681	6.600	6.663
T_{3a}	Multicut Sorghum + Cowpea with Stem cuttings of Napier planted in January	6.775	6.838	6.650	6.713	6.631	6.694
T_{4a}	Multicut Sorghum + Cowpea with Stem cuttings of Setaria planted in January	6.769	6.831	6.644	6.706	6.625	6.688
T_{5a}	Multicut Bajra + Cowpea with Root slips of Napier planted in July	6.750	6.813	6.625	6.688	6.606	6.669
T_{6a}	Multicut Bajra + Cowpea with Root slips of Setaria planted in July	6.756	6.819	6.631	6.694	6.613	6.675
T_{7a}	Multicut Sorghum + Cowpea with Root slips of Napier planted in July	6.775	6.838	6.650	6.713	6.631	6.694
T_{8a}	Multicut Sorghum + Cowpea with Root slips of Setaria planted in July	6.763	6.825	6.638	6.700	6.619	6.681
T_{1b}	Multicut Bajra + Maize with Stem cuttings of Napier planted in January	6.769	6.831	6.644	6.706	6.625	6.688
T_{2b}	Multicut Bajra + Maize with Stem cuttings of Setaria planted in January	6.775	6.838	6.650	6.713	6.631	6.694
T_{3b}	Multicut Sorghum + Maize with Stem cuttings of Napier planted in January	6.794	6.856	6.669	6.731	6.650	6.713
T_{4b}	Multicut Sorghum + Maize with Stem cuttings of Setaria planted in January	6.788	6.850	6.663	6.725	6.644	6.706
T_{5b}	Multicut Bajra + Maize with Root slips of Napier planted in July	6.775	6.838	6.650	6.713	6.631	6.694
T_{6b}	Multicut Bajra + Maize with Root slips of Setaria planted in July	6.763	6.825	6.638	6.700	6.619	6.681
T_{7b}	Multicut Sorghum + Maize with Root slips of Napier planted in July	6.794	6.856	6.669	6.731	6.650	6.713
T_{8b}	Multicut Sorghum + Maize with Root slips of Setaria planted in July	6.788	6.850	6.663	6.725	6.644	6.706
T_{1c}	Multicut Bajra + Cowpea + Maize with Stem cuttings of Napier planted in January	6.769	6.831	6.644	6.706	6.625	6.688
T_{2c}	Multicut Bajra + Cowpea + Maize with Stem cuttings of Setaria planted in January	6.775	6.838	6.650	6.713	6.631	6.694
T_{3c}	Multicut Sorghum + Cowpea + Maize with Stem cuttings of Napier planted in January	6.794	6.856	6.669	6.731	6.650	6.713
T_{4c}	Multicut Sorghum + Cowpea + Maize with Stem cuttings of Napier planted in January	6.781	6.844	6.656	6.719	6.638	6.700
T_{5c}	Multicut Bajra + Cowpea + Maize with Root slips of Napier planted in July	6.769	6.831	6.644	6.706	6.625	6.688
T_{6c}	Multicut Bajra + Cowpea + Maize with Root slips of Setaria planted in July	6.775	6.838	6.650	6.713	6.631	6.694
T_{7c}	Multicut Sorghum + Cowpea + Maize with Root slips of Napier planted in July	6.781	6.844	6.656	6.719	6.638	6.700
T_{8c}	Multicut Sorghum + Cowpea + Maize with Root slips of Setaria planted in July	6.788	6.850	6.663	6.725	6.644	6.706
SEm (±)		0.02	0.04	0.01	0.03	0.01	0.02
CD (5%)		NS	NS	NS	NS	NS	NS

recorded significantly higher NDF to the tune of 62.19, 63.41 and 64.70 per cent at all the harvesting intervals and was found to be statistically at par with multicut sorghum + maize with root slips of *Setaria* planted in July, multicut sorghum + maize with stem cuttings of Napier planted in January and Multicut Sorghum + Maize with stem cuttings of *Setaria* planted in January. According to Raju (2013), varying maturity stages of plants impact their fiber content significantly. This The reduced digestibility observed is attributed to processes such as thickening and hardening of plant fibers due to increased carbohydrate accumulation in cell walls including the presence of non-digestible lignin Ross *et al.* (2004). As plants mature, the proportion of easily digestible cell contents decreases while the weight proportion of stems increases and leaves decreases. This phenomenon likely contributes to the observed increase in NDF content as noted by Palsaniya *et al.* (2016). However, significantly lowest NDF was recorded with Multicut Bajra + Cowpea with stem cuttings of *Setaria* planted in January with the corresponding value of 41.02 per cent at first cut. At second and third cut, Multicut Bajra + Cowpea + Maize with stem cuttings of *Setaria* planted in January registered significantly lowest NDF to the tune of 40.66 and 40.62 per cent, respectively. Reza *et al.* (2012) also reported that low NDF content was attributed to succulent nature of these crops that led to reduction in the NDF content of crops.Almost a similar trend with respect to NDF was observed during second year of experimentation except for that a slight increase in NDF from previous year.

Hemi-cellulose of *Kharif* annual fodder with perennial grasses (per cent)

Hemi-cellulose content is derived from removing acid detergent fibre content from neutral detergent fibre. Data pertaining to Hemi-cellulose presented in Table 5 revealed that Multicut Sorghum + Maize with stem cuttings of *Setaria* planted in January recorded significantly higher Hemi-cellulose to the tune of 20.41 per cent at first cut and was found to be statistically at par with Multicut Sorghum + Maize with stem cuttings of Napier planted in January, Multicut Sorghum + Cowpea + Maize with stem cuttings of Napier planted in January, Multicut Sorghum + Maize with root slips of *Setaria* planted in July, Multicut Sorghum + Maize with root slips of Napier planted in July, Multicut Sorghum + Cowpea + Maize with stem cuttings of *Setaria* planted in January, Multicut Sorghum + Maize with root slips of *Setaria* planted in July and Multicut Sorghum + Cowpea + Maize with root slips of Napier planted in July. Further, it was also evident from the table that during second and third cut, Multicut Sorghum + Maize with stem cuttings of *Setaria* planted in January (22.45 and 22.68 per cent) was found to be significantly higher which was at par with Multicut Sorghum + Maize with stem cuttings of Napier planted in January, Multicut Sorghum + Maize with root slips of Napier planted in July and Multicut Sorghum + Maize with root slips of *Setaria* planted in July. Hemi-cellulose content of *kharif* annual fodder crops increased markedly with successive cuts. Hemi cellulose is calculated by subtracting acid detergent fibre from neutral detergent fibre. Neutral detergent fibre had positive association with acid detergent fibre and hemi cellulose (Tiwari *et al.,* 2019). Almost a similar trend was observed during both the years of experimentation.

Cellulose of *kharif* annual fodder with perennial grasses (per cent)

Among the different treatments (Table 5), significant variations with regard to cellulose content was found at each harvesting interval where Multicut Sorghum + Maize with root slips of Napier planted in July recorded significantly higher cellulose content to the tune of 31.57, 32.94 and 34.36 per cent which was statistically at par with the results obtained in Multicut Sorghum + Maize with root slips of *Setaria* planted in July, Multicut Sorghum + Maize with stem cuttings of Napier planted in January and Multicut Sorghum + Maize with stem cuttings of *Setaria* planted in January. However, significantly lowest cellulose content was recorded with Multicut Bajra + Cowpea with stem cuttings of *Setaria* planted in January at first cut with the corresponding value of 18.28, 19.65 and 21.08 per cent, respectively. By and large, a similar trend with respect to cellulose content was observed during second year of experimentation except for that a slight increase in cellulose from previous year.

Crude protein of *kharif* annual fodder with perennial grasses (per cent)

Protein content is one of the most important parameter affecting the nutritional values of fodder crops. To provide balanced diet to the animals, protein is very important constituents of animal feed. Among all quality components, crude protein is getting prime importance because it plays an important role to improve growth and productivity of animals as it is used for building new tissue as well as repairing damaged tissues.

The data pertaining to crude protein content of different fodder crops have been presented in Table 6. The data indicated that no significant difference was observed in crude protein content at different harvesting intervals of different fodder crops during both the years.Forage with higher value of crude protein is considered better in terms of quality. Protein content is one of the most important parameters affecting the nutritional value of fodder crops. However, no significant difference was observed in crude protein content of *kharif* fodder crops during both the years of experimentation. The results were in corroboration with Ahmad *et al.* (2007), Pachauri *et al.* (2020) and Konapura *et al.* (2021).

CONCLUSION

In the study of nutritional quality assessment of sustainable forage cropping sequences in the irrigated subtropics of Jammu and Kashmir, India, it was observed that the combination of Multicut Sorghum + Maize with root slips of

Napier planted in July recorded significantly higher levels of Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), hemi cellulose and cellulose content at each cut. These results were statistically comparable to those obtained with Multicut Sorghum + Maize with root slips of Setaria planted in July as well as with Multicut Sorghum + Maize with stem cuttings of Napier and Setaria planted in January, across both years of experimentation. However, no significant differences were found in crude protein content among all the treatments during the same period. This indicates that while certain forage combinations may enhance fiber content they do not necessarily influence the crude protein levels suggesting that other factors may need to be considered to optimize overall nutritional quality.

ACKNOWLEDGEMENT

All the authors acknowledge and thank Division of Agronomy, SKUAST-Jammu for their guidance and support.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All experimental procedures were approved by the Division of Agronomy, SKUAST-Jammu and handling techniques were approved by the Lovely Professional University, Punjab.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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