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Research article

Sustainable forage cropping systems for round the year green fodder supply in irrigated subtropics of Jammu

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Abstract

Field experiments were conducted during 2020-21 and 2021-22 to evaluate various forage-based cropping systems for irrigated conditions of Jammu. The experiment was laid out in a randomized block design and replicated thrice. Results showed that multicut sorghum + maize with root slips of napier planted on field boundaries in July recorded significantly highest green forage yield which was though statistically at par with multicut sorghum + maize with root slips of *Setaria* planted on field boundaries in July followed by multicut sorghum + maize with stem cuttings of napier planted on field boundaries in January and multicut sorghum + maize with stem cuttings of *Setaria* planted on the field boundaries in January during *kharif* season. In *rabi* season, berseem + oat with root slips of napier planted on field boundaries in July was found to be significantly superior than other treatments. Multicut bajra + maize - berseem + barley with stem cuttings of napier planted on field boundaries in January recorded higher system productivity which was at par with the treatment multicut bajra + cowpea - berseem + oat with stem cuttings of napier planted on field boundaries in January.

Keywords: Annual fodder, Cropping system, Legumes, Perennial grasses, System productivity

Introduction

Forage and livestock are the integral part of Indian agricultural system (Ghosh *et al.*, 2016). The agriculture and livestock sector provides employment to 52% of the work force. Whereas, the livestock sector alone creates large self-employment opportunities and nearly 70% of Indian population is engaged in livestock production and management especially in rural areas (Raju, 2013). It contributes around 6% to the Gross Domestic Product and 25% to Agricultural Gross Domestic Product. The share of Indian livestock sector to the Gross Value Output of the national agriculture has been increasing continuously at a faster rate than the crop sector (Anonymous, 2023a). This suggests that livestock is likely to emerge as an engine of agricultural growth in coming decades. It is also considered as one of the potential sectors for export earnings.

Despite being the fact that India has highest livestock population, the productivity of livestock is very low *viz.* 20 to 60% lower than the global average due to lack of quality fodder (Halli *et al.*, 2018). If we trace out the possible reasons, deficiency of feed and fodder accounts for half of the total loss followed by the problems of health, breeding and reproduction and management (Anonymous, 2023b). To compensate for low productivity of the livestock, farmers maintain a large herd of animals, which adds to pressure on land and fodder resources (Palsaniya *et al.*, 2010). On the other hand, traditional green grasses in pasture lands are reducing gradually due to urbanization and industrialization but demand of cultivated fodders are increasing due to increasing growth of livestock sector (Singh *et al.*, 2018; Shinde and Mahanta, 2020). Availability of 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 (Mahanta *et al.*, 2020). This puts a pressure to increase fodder production for a healthy livestock population. Total fodder production of Jammu and Kashmir is 91.5 lakh tonnes of which green fodder contributes 61.4 and dry fodder 25.1 lakh tonnes (Anonymous, 2023c). The state is 67% deficit in green fodder and 27.31% in dry fodder. As of 2023,

Jammu and Kashmir's livestock population includes 14.58 lakh cattle, 16.26 lakh sheep, 0.214 lakh buffaloes, and 3.17 lakh goats, which require fodders for healthy production (Anonymous, 2023d). Moreover, the need of hour is not only to enhance fodder production but also to make fodder accessible round the year for all types of animals adequately. This situation can be handled through use of year round alternative sources of fodder which include perennial grasses, annual cereal fodders and legume fodders which could provide good quality fodder throughout the year. Keeping these in view, the present investigation was conducted to evaluate various forage-based cropping systems for round the year fodder supply under irrigated conditions of Jammu.

Materials and Methods

Study site and experimental design: The field experiment was conducted at Research Farm, Agronomy Division, Sher-e-Kashmir University of Agricultural Sciences and Technology –Jammu during 2020-21 and 2021-22. Geographically, the experimental site was located at 32° 40' N latitude and 74° 58' E longitude with an altitude of 332 meters above mean sea level in sub-tropical shivalik foothills of north-western Himalayas of Jammu and Kashmir. The site is endowed with hot and dry early summers followed by hot and humid summers and cold winters. During crop growth period in first year, the maximum temperature of 41.8 °C was recorded during May, whereas minimum temperature of 4.8 ^{0}C was recorded in February. During second year, the maximum temperature was recorded in June (39.8 °C) and the minimum temperature was 2.8°C in December. As per the rainfall, the contribution of south-west monsoon rains which were received from June to September about 75%, whereas remaining 25% of rains were received in few showers of cyclonic winter rains. During the first-year cropping period, there was 5.66% decrease in actual rainfall than normal rainfall, whereas during the second year there was 10.23% increase in actual rainfall.

The experiment was laid down in an area of approximately 1387.5 m^2 with plot size of 13.125 m^2 each. Different sources of fodder were put in mixed cropping, *viz*. seasonal fodders and perennial fodders were tried (Table 1). Indeed, the experiment comprised of eight treatments with three staggered sowings (Table 2). The experiment was laid out in randomized block design with three replications. In *Kharif* season, fodders like maize (*Zea mays),* cowpea (*Vigna unguiculata L.* Walp.*),* bajra (*Pennisetum glaucum),* sorghum (*Sorghum bicolor* L. Morlch.) were sown and in *Rabi* season, berseem (*Trifolium alexandrinum),* oats (*Avena sativa*), lucerne *(Medicago sativa),* barley *(Hordeum vulgare)* were sown. Hybrid napier and *Setaria (Setaria sphacelata)* were perennial grasses, which were taken as boundary plantations planted 50 cm apart from each other along with cereal fodders and legumes. Seasonal fodders were sown by the method of broadcasting in plots where land was prepared twice by rotavator. In case of berseem fodder, land was puddled and then sowing was done. The root slips @ 20,000/ ha was used for establishment of perennial grasses namely hybrid napier and *Setaria* with spacing of 50 cm, respectively. Crops were fertilized with recommended dose of N:P_2O_5:K_2O. Full dose of P and K and half dose of N was given as basal before sowing/planting of crops; the remaining half dose of recommended N was applied in split doses after each cut. The irrigation was given to crops as and when required.

Observations and analysis: Green forage yield (t/ ha) and system productivity (t/ha) was calculated by converting each season yield into berseem + oats equivalent yield and then adding produce of different seasons in a year. The data recorded for fodder crop characters were subjected to statistical analysis according to procedure outlined by Cochran and Cox (1963).

Results and Discussion

Green forage yield of kharif fodder crops: Results of green forage yield for the individual cuts and total green forage yield of the investigated forage cropping systems during the year 2020-21 and 2021-22 were recorded (Table 3). Among different forage cropping systems, total fresh forage yield of *Kharif* forage cropping sequence multicut sorghum + maize with root slips of napier planted on field boundaries in July was found to be significantly highest (70.58 t/ha) which was though statistically at par with multicut sorghum + maize with root slips of *setaria* planted on field boundaries in July (70.34 t/ha) followed by multicut sorghum + maize with stem cuttings of napier planted on field boundaries in January (70.26 t/ha)

Table 1. Crops and varieties used in the study

Crop	Variety
Multicut sorghum	Sprint Gold CSH- 24 MF
Multicut bajra	Wonder Leaf-HB-21
Maize	African tall
Cowpea	EC4216
Berseem	BL-1
Oats	JHO-851
Barley	VL-118
Lucerne	Sirsa no. 9
Napier grass	Hybrid napier NB-21
Setaria	S-92

Table 2. Treatment details of study

S. No.	Treatments	Symbol
1	Multicut bajra + cowpea - berseem + oat with stem cuttings of napier planted in January	T_{1a}
2	Multicut bajra + cowpea - berseem + oat with stem cuttings of *Setaria* planted in January	T_{2a}
3	Multicut sorghum + cowpea - lucerne + oat with stem cuttings of napier planted in January	T_{3a}
4	Multicut sorghum + cowpea - lucerne + oat with stem cuttings of *Setaria* planted in January	T_{4a}
5	Multicut bajra + cowpea - berseem + oat with root slips of napier planted in July	T_{5a}
6	Multicut bajra + cowpea - berseem + oat with root slips of *Setaria* planted in July	T_{6a}
7	Multicut sorghum + cowpea - lucerne + oat with root slips of napier planted in July	T_{7a}
8	Multicut sorghum + cowpea - lucerne + oat with root slips of *Setaria* planted in July	T_{8a}
9	Multicut bajra + maize - berseem + barley with stem cuttings of napier planted in January	T_{1b}
10	Multicut bajra + maize - berseem + barley with stem cuttings of *Setaria* planted in January	T_{2b}
11	Multicut sorghum + maize - lucerne + barley with stem cuttings of napier planted in January	T_{3b}
12	Multicut sorghum + maize - lucerne + barley with stem cuttings of *Setaria* planted in January	T_{4b}
13	Multicut bajra + maize - berseem + barley with root slips of napier planted in July	T_{5b}
14	Multicut bajra + maize - berseem + barley with root slips of *Setaria* planted in July	T_{6b}
15	Multicut sorghum + maize - lucerne + barley with root slips of napier planted in July	T_{7b}
16	Multicut sorghum + maize - lucerne + barley with root slips of *Setaria* planted in July	T_{8b}
17	Multicut bajra + cowpea + maize - berseem + oat + barley with stem cuttings of napier planted in January	T_{1c}
18	Multicut bajra + cowpea + maize - berseem + oat + barley with stem cuttings of *Setaria* planted in January	T_{2c}
19	Multicut sorghum + cowpea + maize - lucerne + oat + barley with stem cuttings of napier planted in January	T_{3c}
20	Multicut sorghum +cowpea + maize - lucerne + oat + barley with stem cuttings of *Setaria* planted in January	T_{4c}
21	Multicut bajra + cowpea + maize - berseem + oat + barley with root slips of napier planted in July	T_{5c}
22	Multicut bajra + cowpea + maize - berseem + oat + barley with root slips of *Setaria* planted in July	T_{6c}
23	Multicut sorghum + cowpea + maize - lucerne + oat + barley with root slips of napier planted in July	T_{7c}
24	Multicut sorghum + cowpea + maize - lucerne + oat + barley with root slips of *Setaria* planted in July	T_{8c}

Three staggers denoted by a, b and c (different dates of sowing in both *Kharif* and *Rabi* seasons)

and multicut sorghum + maize with stem cuttings of *Setaria* planted on field boundaries in January (70.10 t/ha). Similar findings were recorded by Rehman and Raja (2020) which showed that sorghum when sown with legumes competes for nutrients and mutual shading effect resulted in low yield of sorghum + cowpea and sorghum + cowpea + maize. The combination of multicut sorghum and maize allowed for efficient use of available resources, as both sorghum and maize are known for their high biomass production. Moreover, legume crops had suppressive effect. Additionally planting root slips of napier and *Setaria* on field boundaries enhanced forage availability, as these species are robust perennials known for their high yield potential and drought resistance. The timings of planting, whether in July or January, it ensured continuous forage supply with minimal gaps, thus maximizing yields. These practices optimized land use and water efficiency, contributing to the overall high forage yields.

Green forage yield of rabi fodder crops: Green fodder yield of forage cropping sequence berseem + oat with root slips of napier planted on field boundaries in July (76.21 t/ha) was found to be significantly superior (Table 4) which was at par with berseem + oat with stem cuttings of napier planted in January (75.83 t/ha) followed by berseem + oat with root slips of *Setaria* planted in July (75.80 t/ha) and berseem + oat with stem cuttings of *Setaria* planted in January (75.10 t/ha). The results were in corroboration with Helmy *et al*. (2011) and Kumar and Sarlach (2020) who observed that the superiority could be attributed to the genetic potential yield of berseem and oats plus the fact that inclusion of legumes in cereals made more efficient use of available resources, improvement of soil fertility through addition of nitrogen by fixation (Kumar *et al*., 2014a).

Green forage yield of perennial grasses: Two years data pertaining to green forage yield of perennial

Table 3. Green forage yields (t/ha) in *Kharif* season during 2020 and 2021

Treatments	Sowing/ Harvesting time	I cut		II cut		III cut		Total yield	
		2020	2021	2020	2021	2020	2021	2020	2021
T1a	15 April I cut-15 June II cut- 30 July III cut- 15 September	20.69	21.07	15.10	15.46	12.43	12.84	48.22	49.37
T2a		20.51	20.89	14.92	15.28	12.25	12.66	47.68	48.83
T3a		22.14	22.52	16.55	16.91	13.88	14.29	52.57	53.72
T4a		21.87	22.25	16.29	16.66	13.62	14.03	51.78	52.94
T5a		20.92	21.28	15.31	15.67	12.64	13.05	48.87	50.00
T6a		20.89	21.06	15.25	15.60	12.60	12.80	48.74	49.46
T7a		22.36	22.74	16.77	17.13	14.10	14.52	53.23	54.39
T8a		22.34	22.72	16.75	17.11	14.08	14.49	53.17	54.32
T1b	30 April I cut - 30 June II cut- 15 August III cut- 30 September	23.68	24.06	19.84	20.15	17.17	17.58	60.69	61.79
T2b		23.65	24.04	19.79	20.15	17.12	17.53	60.56	61.72
T3b		25.84	26.22	23.01	23.37	20.34	20.75	69.19	70.34
T4b		25.76	26.14	22.93	23.29	20.26	20.67	68.95	70.10
T5b		23.91	24.31	19.81	20.17	17.14	17.55	60.86	62.03
T6b		23.84	24.22	19.78	20.01	17.10	17.39	60.72	61.62
T7b		26.00	26.38	23.05	23.41	20.38	20.79	69.43	70.58
T8b		25.99	26.34	22.98	23.32	20.29	20.60	69.26	70.26
T1c	15 May I cut-15 July II cut- 30 August III cut-15 October	19.62	19.99	12.04	12.40	9.36	9.77	41.02	42.16
T2c		19.45	19.83	11.87	12.23	9.20	9.63	40.52	41.69
T3c		21.14	21.68	13.23	13.59	10.56	10.96	44.93	46.23
T4c		20.65	21.52	13.15	13.43	10.51	10.81	44.31	45.76
T5c		19.81	20.12	12.19	12.52	9.48	9.95	41.48	42.59
T6c		19.70	20.08	12.12	12.48	9.46	9.87	41.28	42.43
T7c		21.15	21.35	13.56	13.82	10.75	11.29	45.46	46.46
T8c		21.08	21.25	13.49	13.79	10.70	11.21	45.27	46.25
SEM		0.44	0.35	0.40	0.43	0.41	0.39	1.13	1.21
CD ($p < 0.05$)		1.14	1.05	1.15	1.23	1.17	1.12	3.20	3.45

grasses napier and *Setaria* sown in January and July were recorded (Table 5). Among all the different treatments, multicut sorghum + cowpea + maize - lucerne + oat + barley + stem cuttings of napier planted in January (269.11) had significantly highest yields (269.11 t/ha), which was although at par with all the treatments involving napier sown with stem cuttings in January. It was probably due to the fact that napier when sown with stem cuttings in January gave more number of cuts during first year than napier sown with root slips in July. Whereas green forage yield of *Setaria* was lesser, which could be due to its low yield potential than napier grass (Kumar *et al*., 2014b).

Berseem + oat equivalent yield: The economic yield of crop component in all the eight forage cropping sequence was converted into berseem + oat forage equivalent yields (Table 6). For this, the value of yields obtained from different crops was converted into berseem + oat forage equivalent yield with the help of existing market sale price of produce in the locality. Afterwards, berseem forage equivalent yield of all crops in a particular crop sequence was summed up as berseem + oat forage equivalent yield of that particular sequence. In *Kharif*, highest berseem equivalent yield was recorded in multicut sorghum + maize with root slips of napier planted on field boundaries in July (51.63 t/ha) whereas, the highest berseem equivalent yield in perennial grasses were recorded with napier planted with stem cuttings in January. The combination of multicut sorghum and maize maximized resource utilization through complementary growth patterns and multiple harvests, while the integration of napier grass on field boundaries

Table 4. Green forage yields (t/ha) in *Rabi* season during 2020-21 and 2021- 22

Treatments	Sowing/ Harvesting time	I cut		II cut		III cut		IV cut		V cut		Total yield	
		2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
T1a		12.09	12.24	16.99	17.34	21.73	22.32	20.88	21.90	19.03	20.11	90.74	93.93
T2a		12.01	12.16	16.91	17.26	21.54	22.13	20.69	21.71	18.84	19.92	90.01	93.20
T3a	20 September	8.64	8.79	13.54	13.89	14.95	15.54	14.10	15.12	12.25	13.33	63.47	66.66
T4a	I cut- 9 Nov. II cut-19 Dec.	8.29	8.44	13.32	13.67	14.73	15.32	13.88	14.90	12.03	13.11	62.26	65.45
T5a	III cut- 28 Jan IV cut- 9 March	12.22	12.37	17.12	17.47	21.77	22.36	20.92	21.94	19.07	20.15	91.10	94.29
T6a	V cut-18 April	12.15	12.30	17.05	17.40	21.68	22.27	20.83	21.85	18.98	20.06	90.71	93.90
T7a		8.69	8.84	13.59	13.94	15.00	15.59	14.15	15.17	12.30	13.38	63.75	66.94
T8a		8.68	8.83	13.58	13.93	14.99	15.58	14.14	15.16	12.29	13.37	63.68	66.87
T1b		16.22	16.37	18.22	18.57	18.10	18.69	17.25	18.27	15.40	16.48	85.17	88.36
T2b		16.11	16.26	18.11	18.46	18.07	18.66	17.22	18.24	15.37	16.45	84.87	88.06
T3b	05 October	10.58	10.73	12.58	12.93	11.26	11.85	10.42	11.44	8.57	9.63	53.41	56.58
T4b	I cut- 9 Nov II cut- 03 Jan	10.33	10.48	12.35	12.70	11.03	11.62	10.18	11.20	8.33	9.41	52.22	55.41
T5b	III cut- 12 Feb IV cut-24 March	16.63	16.78	18.65	19.00	18.38	18.97	17.53	18.55	15.68	16.76	86.87	90.06
T6b	V cut- 28 April	16.56	16.71	18.56	18.91	18.29	18.88	17.44	18.46	15.59	16.67	86.42	89.61
T7b		10.91	11.06	12.91	13.26	11.59	12.18	10.74	11.76	8.89	9.97	55.06	58.25
T8b		10.98	11.14	12.65	13.02	11.33	11.92	10.48	11.50	8.63	9.71	54.08	57.30
T1c		14.25	14.40	18.35	18.72	19.11	19.70	18.28	19.30	16.43	17.51	86.44	89.65
T2c		14.18	14.33	18.24	18.61	19.04	19.97	18.19	19.21	16.34	17.42	86.00	89.54
T3c	20 October	9.24	9.39	12.87	13.24	14.55	14.14	12.91	13.72	10.95	11.93	60.52	62.42
T4c	I cut- 9 Dec II cut- 18 Jan	9.20	9.30	12.98	13.29	13.52	14.01	13.11	13.59	11.92	11.80	60.73	62.00
T5c	III cut- 27 Feb IV cut- 08 April	14.59	14.74	18.57	18.94	19.21	19.80	18.36	19.38	16.51	17.59	87.25	90.46
T6c	V cut- 12 May	14.50	14.65	18.53	18.90	19.12	19.70	18.27	19.29	16.41	17.49	86.83	90.03
T7c		9.40	9.55	13.04	13.41	14.30	14.89	13.45	14.48	11.60	12.68	61.78	65.00
T8c		9.35	9.50	12.92	13.29	13.87	14.46	13.02	14.04	11.17	12.25	60.34	63.55
SEM		1.13	1.28	0.94	0.91	0.99	0.93	0.97	1.00	0.95	0.96	1.34	1.33
CD ($p < 0.05$)		3.21	3.63	2.69	2.59	2.81	2.66	2.77	2.83	2.72	2.73	3.83	3.79

Table 5. Green forage yields (t/ha) of perennial fodders during 2020-21and 2021-22

Treatments	I cut		II cut		III cut		IV cut		V cut		VI cut		VII cut		Total yield	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
T1a	33.21	36.01	34.45	37.26	34.88	38.03	35.04	37.07	35.40	37.80	34.75	38.72	34.98	38.97	242.71	263.86
T2a	12.41	15.21	13.65	16.46	14.08	17.23	14.24	16.27	14.60	17.02	13.95	17.94	14.18	18.19	97.11	118.32
T3a	33.24	36.04	34.48	37.29	34.91	38.06	35.07	37.10	35.43	37.83	34.78	38.75	35.01	39.00	242.92	264.07
T4a	12.30	15.10	13.54	16.35	13.97	17.12	14.13	16.16	14.49	16.89	13.84	17.81	14.07	18.06	96.34	117.49
T5a		34.68		35.24		36.06	33.66	35.85	33.45	35.67	33.28	36.61	34.03	36.86	134.42	250.97
T6a		16.38		16.94		17.76	15.36	17.55	15.15	17.37	14.98	18.31	15.73	18.56	61.22	122.87
T7a		34.71		35.27		36.09	33.69	35.88	33.48	35.70	33.31	36.64	34.06	36.89	134.54	251.18
T8a		16.27		16.83		17.65	15.25	17.44	15.04	17.26	14.87	18.20	15.62	18.45	60.78	122.1
T1b	33.89	36.69	35.13	37.94	35.56	38.71	35.72	37.75	36.08	38.48	35.43	39.40	35.66	39.65	247.47	268.62
T2b	12.61	15.41	13.85	16.66	14.28	17.43	14.44	16.47	14.80	17.20	14.15	18.12	14.38	18.37	98.51	119.66
T3b	33.26	36.06	34.50	37.31	34.93	38.08	35.09	37.12	35.45	37.85	34.80	38.77	35.03	39.02	243.06	264.21
T4b	12.74	15.54	13.98	16.79	14.41	17.56	14.57	16.60	14.93	17.33	14.28	18.25	14.51	18.50	99.42	120.57
T5b		35.36		35.92		36.74	34.34	36.53	34.13	36.35	33.96	37.29	34.71	37.54	137.14	255.73
T6b		16.58		17.14		17.96	15.56	17.75	15.35	17.57	15.18	18.51	15.93	18.76	62.02	124.27
T7b		34.73		35.29		36.11	33.71	35.90	33.50	35.72	33.33	36.66	34.08	36.91	134.62	251.32
T8b		16.71		17.27		18.09	15.69	17.88	15.48	17.70	15.31	18.64	16.06	18.89	62.54	125.18
T1c	33.53	36.33	34.77	37.58	35.20	38.68	35.36	37.72	35.72	38.45	35.07	39.37	35.30	39.62	244.95	267.75
T2c	12.37	15.17	13.61	16.42	14.04	17.19	14.20	16.23	14.56	16.96	13.91	17.88	14.14	18.13	96.83	117.98
T3c	33.96	36.76	35.20	38.01	35.63	38.78	35.79	37.82	36.15	38.55	35.50	39.47	35.73	39.72	247.96	269.11
T4c	12.88	15.68	14.12	16.93	14.55	17.70	14.71	16.74	15.07	17.47	14.42	18.39	14.65	18.64	100.4	121.55
T5c		35.00		35.56		36.38	33.98	36.17	33.77	35.99	33.60	36.93	34.35	37.18	135.7	253.21
T6c		16.34		16.90		17.72	15.32	17.51	15.11	17.33	14.94	18.27	15.69	18.52	61.06	122.59
T7c		35.43		35.99		36.81	34.41	36.60	34.20	36.42	34.03	37.36	34.78	37.61	137.42	256.22
T8c		16.85		17.41		18.23	15.83	18.02	15.62	17.84	15.45	18.78	16.20	19.03	63.1	126.16
SEM	0.94	1.02	1.03	1.01	0.84	0.96	0.88	0.95	0.89	0.	0.99	0.86	0.94	0.90	3.25	3.04
CD ($p< 0.05$)	2.77	2.99	3.03	2.96	2.47	2.82	2.57	2.78	2.62	2.69	2.92	2.52	2.77	2.63	9.25	8.64

Table 6. Berseem + oat equivalent yields (t/ha) of *Kharif, Rabi* and perennial fodders during 2020-21 and 2021-22

Treatments	Berseem + oat equivalent yield (t/ha)					
	Kharif		*Rabi*		Perennial	
	2020	2021	2020-21	2021-22	2020-21	2021-22
T1a	35.86	36.71	74.72	75.83	199.15	216.50
T2a	35.45	36.31	73.99	75.10	79.68	97.08
T3a	39.09	39.95	47.48	48.59	199.32	216.67
T4a	38.50	39.37	46.25	47.36	79.05	96.40
T5a	36.34	37.18	75.10	76.21	110.29	205.92
T6a	36.24	36.78	74.69	75.80	50.23	100.82
T7a	39.58	40.44	47.73	48.84	110.39	206.10
T8a	39.54	40.39	47.68	48.79	49.87	100.18
T1b	45.13	45.95	69.19	70.30	203.05	220.41
T2b	45.03	45.89	68.88	69.99	80.83	98.18
T3b	51.45	52.30	37.41	38.52	199.43	216.79
T4b	51.27	52.13	36.22	37.33	81.58	98.93
T5b	45.25	46.12	70.87	71.98	112.53	209.83
T6b	45.15	45.82	70.44	71.55	50.89	101.97
T7b	51.63	52.48	39.04	40.15	110.46	206.21
T8b	51.50	52.24	38.07	39.18	51.31	102.71
T1c	30.50	31.35	70.42	71.53	200.98	219.69
T2c	30.13	31.00	69.99	71.10	79.45	96.80
T3c	33.41	34.38	44.52	45.63	203.45	220.81
T4c	32.95	34.03	44.73	45.84	82.38	99.73
T5c	30.84	31.67	71.24	72.35	111.34	207.76
T6c	30.70	31.55	70.83	71.94	50.10	100.59
T7c	33.80	34.55	45.79	46.90	112.75	210.23
T8c	33.66	34.39	44.33	45.44	51.77	103.52
SEM	0.44	0.41	1.16	1.21	1.76	1.58
CD ($p < 0.05$)	1.25	1.16	3.31	3.45	5.06	4.52

further enhanced land use efficiency (Palsaniya *et al*., 2010). Napier grass, whether planted on boundaries or as a perennial system, contributed significantly to overall yield due to its rapid growth, regeneration capacity, and ability to utilize resources year-round. The success of these systems likely stemmed from their efficient use of water, nutrients, and light, as well as their enhanced resilience to environmental stresses (Meena *et al*., 2023).

System productivity: System productivity was significantly highest in multicut bajra + maize - berseem + barley with stem cuttings of napier planted on field boundaries in January than the other cropping systems in comparison (Table 7). The highest system productivity might be attributed to higher green forage yield of napier, berseem and bajra. The next promising cropping system for feasible sustainable forage supply round the year was multicut bajra + cowpea - berseem + oat with stem cuttings of napier planted on field boundaries in January. Multicut bajra and maize provided high biomass during the warm season, while berseem and barley offered quality forage in the cool season. The integration of napier grass on field boundaries further maximized land use efficiency and contributed to year-round forage production (Palsaniya *et al*., 2010). This combination allowed for efficient exploitation of water, nutrients and sunlight throughout the year. The inclusion of a legume (cowpea) in this system might offer additional benefits through nitrogen fixation (Joshi *et al*., 2012). These results highlighted the potential of well-designed, diverse cropping systems to

Table 7. Berseem + oat equivalent yields and system productivity to supply green fodder round the year (mean of 2 years)

Treatments	*Kharif* berseem + oat equivalent yield (t/ha)	*Rabi* berseem + oat equivalent yield (t/ha)	Perennial fodders berseem + oat equivalent yield (t/ha)	System productivity (t/ha)
T1a	36.28	75.28	207.82	319.38
T2a	35.88	74.55	88.38	198.81
T3a	39.52	48.04	208.00	295.56
T4a	38.93	46.81	87.73	173.47
T5a	36.76	75.66	158.11	270.53
T6a	36.51	75.25	75.52	187.28
T7a	40.01	48.29	158.24	246.54
T8a	39.96	48.24	75.03	163.23
T1b	45.54	69.75	211.73	327.02
T2b	45.46	69.44	89.51	204.41
T3b	51.88	37.97	208.11	297.96
T4b	51.70	36.78	90.25	178.73
T5b	45.69	71.43	161.18	278.30
T6b	45.49	71.00	76.43	192.92
T7b	52.06	39.60	158.33	249.99
T8b	51.87	38.63	77.01	167.51
T1c	30.93	70.98	210.34	312.25
T2c	30.57	70.55	88.13	189.25
T3c	33.89	45.08	212.13	291.10
T4c	33.49	45.29	91.06	169.84
T5c	31.26	71.80	159.55	262.61
T6c	31.12	71.39	75.34	177.85
T7c	34.18	46.35	161.49	242.02
T8c	34.03	44.89	77.65	156.57
SEM	0.80	1.21	1.81	3.60
CD ($p < 0.05$)	2.30	3.45	5.15	10.25

achieve sustainable year-round forage production by leveraging the strengths of different crop species and maximizing resource use efficiency (Singh *et al*., 2018).

Conclusion

Based on the findings of two years study, it was concluded that the cropping system comprised multicut bajra + maize - berseem + barley with stem cuttings of napier planted on field boundaries in January, was found to be the best feasible sustainable forage cropping system for round the year availability of quality fodder with maximum yields.

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