



Enhancing Farm Productivity and Income through Farmers' Participatory Livestock Based Farming System in Arid Regions of Rajasthan

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Abstract: The study was conducted by ICAR-Central Arid Zone Research Institute, Jodhpur at Harsolav village in Nagaur district from 2016 to 2018 to increase farm productivity and income through improved crop technologies together with the integration of crops and livestock in participatory mode. The grass species *Cenchrus ciliaris* and *C. setigerus* were selected for pasture development under different land use systems. Intervention related to dual purpose crops viz., pearl millet (*Pennisetum glaucum*), clusterbean (*Cyamopsis tetragonoloba*), mung bean (*Vigna radiata*) and barley (*Hordeum vulgare*); and fodder crops viz., lucerne (*Medicago sativa*), oat (*Avena sativa*) and pearl millet (*Pennisetum glaucum*) were undertaken both under rainfed and irrigated condition. For livestock feed supplementation, low-cost concentrate mixtures containing non-conventional feed resources, multi-nutrient blocks (MNB), and multi-nutrient mixtures (MNM) were provided to the small and large ruminants owned by selected farmers. The results showed that improved cultivation practices for dual-purpose crops increased yield and economic returns by 12 to 18% compared with the farmers' traditional practices. Improved fodder crop cultivation enhanced green fodder availability, increased milk yield and farmers' income. The fodder crops like lucerne, oat and pearl millet provided net returns ranging from Rs. 26652 to Rs. 121924 ha⁻¹. Perennial pasture grasses increased fodder availability and provided benefit to the tune of Rs. 5000 to 6000 ha⁻¹ under rainfed condition. Supplementation of multi-nutrient blocks (MNB) at 250 g animal⁻¹ day⁻¹ increased daily milk yield by 9.14% in cattle, with a benefit-cost (B:C) ratio of 1.53, and by 8.32% in buffaloes, with a B:C ratio of 2.22. Similarly, supplementation of multi-nutrient mixture (MNM) at 100 g animal⁻¹ day⁻¹ in goats enhanced daily milk yield by 11.38%, with a B:C ratio of 1.12. Feeding a low-cost concentrate mixture fortified with *Prosopis juliflora* pod powder to cattle increased milk yield by 8.35% and reduced concentrate feed costs by Rs. 2.75 kg⁻¹, resulting in a B:C ratio of 2.20. Overall, the adoption of improved livestock management practices enhanced farm income by Rs. 13,998 (12.2%) over the existing farmers'

practices (Rs. 114,293), demonstrating the economic viability of integrated crop–livestock farming systems under arid-zone conditions.

Key words: Farm productivity, dual purpose crops, livestock, farming system, arid region

The arid region of Rajasthan is characterized by harsh climatic conditions, including low and erratic rainfall, high temperatures, strong winds, and high evapo-transpiration rates, which collectively result in a high crop water demand. The assured crop-growing period in western Rajasthan ranges from 25 to 90 days during July–September under shallow soils and from 35 to 105 days under deep soils (Rao *et al.*, 1994). Under such conditions, crop production alone cannot adequately address the challenges of sustainable dry land agriculture in arid ecosystems. Therefore, the integration of livestock with crop production has emerged as a viable strategy for enhancing sustainability, improving resource-use efficiency, and conserving natural resources in these fragile environments (Bhati *et al.*, 2009). Livestock-based farming systems also provide additional income and livelihood security while improving overall farm productivity in arid and semi-arid regions (Kumar *et al.*, 2021, Jat *et al.*, 2025). Despite the vast extent of grazing lands in the region, the availability of quality feed and fodder remains inadequate to meet the nutritional requirements of livestock. The fodder deficit in Rajasthan's arid regions has been estimated at nearly 60% of the total demand, ranging from 55% in western districts to 69% in central districts and 72% in eastern districts (Pratap Narain and Kar, 2005). The situation becomes particularly critical during drought years, which occur frequently in arid areas. During drought periods, deficiencies of dry and green fodder have been reported to reach 35.9% and 79.9%, respectively (Patidar *et al.*, 2014). It was also reported that fodder deficiency ranged from 47 to 51% under rainfed condition and 8 to 11% under irrigated condition in arid region (Patidar *et al.*, 2025).

Nevertheless, livestock constitute a major component of the regional economy and contribute substantially to the state's production of milk, wool, and meat (Patil *et al.*, 2009). Sustaining livestock productivity in arid regions requires a substantial increase in the availability of feed and fodder from both

grazing lands and cultivated fields, where productivity remains considerably lower than in well-irrigated regions. The persistent fodder shortage is primarily attributed to inadequate integration of fodder crops into existing cropping systems, shrinking pasture and grazing lands, fragmentation of landholdings, intensive cultivation practices, and increasing pressure on natural resources. Unless appropriate interventions are implemented, the gap between fodder demand and supply is likely to widen further.

Recognizing this challenge, increasing attention has been directed towards the adoption of improved technologies for the rehabilitation of degraded pastures, enhancement of biomass production, and integration of fodder resources within farming systems. Cultivation of dual-purpose crops that produce both grain and fodder offer a promising strategy for enhancing farm productivity under conditions of limited water availability. Crops such as pearl millet, sorghum, clusterbean, and other legumes grown under rainfed conditions provide both food and fodder; however, their productivity can be substantially enhanced through the adoption of improved varieties and recommended management practices. Likewise, cultivated fodder crops such as lucerne, oat, and multi-cut pearl millet or sorghum can be effectively integrated into existing cropping systems to augment the availability of green fodder throughout the year (Patidar and Rajora, 2016).

Under rainfed conditions, perennial pasture grasses such as *Cenchrus ciliaris* and *Cenchrus setigerus* can be established on field boundaries, wastelands, and community grazing lands, either alone or in association with fodder trees, to enhance forage production and improve rangeland productivity. In addition, strategic feed supplementation through complete fodder blocks (CFB), multi-nutrient blocks (MNB), and multi-nutrient mixtures (MNM) can significantly improve livestock productivity. Such interventions help overcome nutritional deficiencies commonly observed in arid-region livestock, which often do not receive balanced rations containing adequate nutrients and minerals required to realize their genetic production potential (Patel *et al.*, 2012).

Therefore, the integration of dual-purpose crops, cultivated fodder crops,

Table 1. Improved practices and farmer practices of different dual-purpose

Crops	Improved practices (IP)	Farmer practices (FP)
Pearl millet	Improved variety (RHB177), 20 kg P +40 kg N ha ⁻¹	Local variety, 20 kg N ha ⁻¹
Clusterbean	Improved variety (RGC-1017), 20 kg P +10 kg N ha ⁻¹	Local variety without fertilizer
Mung bean	Improved variety (IPM 2-3), 20 kg P +10 kg N ha ⁻¹	Local variety without fertilizer
Barley	Improved variety (RD2052), 40 kg P +80 kg N ha ⁻¹	Local variety, 20 kg P + 40 kg N ha ⁻¹

pasture development, and strategic feed supplementation represents a comprehensive and sustainable approach for enhancing feed and fodder availability, improving livestock productivity, and increasing farm income in the hot arid regions of Rajasthan.

Materials and Methods

The study was conducted by ICAR-Central Arid Zone Research Institute, Jodhpur at Harsolav village in Nagaur district of Rajasthan from 2016 to 2018. The village is situated at 26° 43' North Latitude and 73° 70' East Longitude. The total area of the village is 5919 ha comprising 2300 households with total population of the village 10607. The total number of livestock was 9879 including cattle, buffalo, sheep and goat. Approximately 20% of the total geographical area, comprising pastures, fallow lands, *oran* (sacred groves), *gochar* (community grazing lands), and wastelands, was available for livestock grazing. About 70% of the area constituted net cultivated land, of which nearly 24% was under irrigated crop cultivation.

The soil of study area was low in organic carbon content (0.02 to 0.39%), low to high available P (2.4-37.2 kg ha⁻¹) and medium to high in available K (90-753 kg ha⁻¹). The pH range of soil (7.5-8.39) and EC range of (0.37-2.25 dS m⁻¹) indicated that soils were moderately alkaline in nature. Water samples were collected from different tube well and analyzed for pH which ranged from 7.66 to 8.72 while electrical conductivity varied from 1.75 to 5.17 EC dS m⁻¹.

The on-farm trials consisted of four experiments i.e. performance of (i) pasture grasses, (ii) dual-purpose crops, (iii) irrigated fodder crops and (iv) supplementary feeding to livestock. For grass experiment, *Cenchrus ciliaris* and *C. setigerus* were selected for pasture development under different land use systems. These grasses were grown at field bunds, farmers' field boundary and grazing land of Goshala and their productivity was

compared with natural grasses. One hundred ten demonstrations were conducted on dual-purpose crops (pearl millet (43), Guar (35), mung bean (5) and barley (27) at 15 farmers' fields over a period of three years (under rainfed conditions). The area under each demonstration of dual-purpose crops was 0.4 ha. Intervention related to varieties and fertilizer management of dual-purpose crops is given in Table 1. The improved practices of different dual-purpose crops were compared with farmer practices. Under Irrigated fodder crops experiments, 61 demonstrations were conducted on Lucerne (33), oat (3) and rijka bajri (25) as per requirements of farmers on 0.1-0.2 ha area.

Livestock feeding trials involving multi-nutrient blocks (MNB), multi-nutrient mixtures (MNM), and low-cost concentrate supplementation containing non-conventional feed resources, including *Prosopis juliflora* pod powder, were conducted on selected farmers' fields. The trials included 19 goats and 28 large ruminants (cattle and buffaloes). Multi-nutrient blocks and mixtures were provided to the experimental animals in addition to the farmers' existing feeding practices during the lactation period. Each animal received 8 to 10 MNBs or the prescribed quantity of MNM over a period of approximately three months. The MNBs, developed at the Feed Technology Unit of ICAR-Central Arid Zone Research Institute (CAZRI), comprised of wheat bran, clusterbean *korma* (material left after extraction of endosperm of clusterbean seed), dolomite, mineral-vitamin mixture, common salt, molasses, and urea. The Composition (%) of Multi Nutrient Feed Block and Multi Nutrient mixture is given in Table 2.

Observations on crop growth and yield, livestock productivity, and milk production were recorded following standard experimental procedures. ANOVA was computed to see the level of significant difference among the grass treatments. Other statistical parameters such as mean, SD and SE were calculated using

Table 2. Composition (%) of multi nutrient feed block and multi nutrient mixture

Ingredients	Composition (%)	
	Multi Nutrient Feed Block	Multi Nutrient mixture
Molasses	45	45
Wheat bran	27	28
Clusterbean <i>korma</i>	7	8
Mustard seed cake	10	10
Urea	3.0	2
Mineral mixture	3	3
Salt	2	2
Dolomite	2	2
Guar gum	1	-
Total	100	100

standard method in order to analyze the impact of improved practices/interventions. The economics of individual farming-system components were evaluated and expressed in terms of net farm income per hectare. The cost of inputs and the price of produce at prevailing market rates were considered for working out the cost of cultivation, returns, and B:C ratio.

Results and Discussion

Performance of pasture grasses under different situations

To improve the availability of good quality forage, pasture grasses such as *Cenchrus ciliaris* and *Cenchrus setigerus* were grown at field bunds, farmer's field and grazing land of Gaushala. Maximum forage yields were recorded with *C. ciliaris* (1.19 kg m⁻² GFY and 0.3 kg m⁻² DFY) and *C. setigerus* (0.87 kg m⁻² GFY and 0.23 kg m⁻² DFY) grasses grown on farm bunds which were higher than that of grazing land and the strip of field during all three years of experiment (Table 3).

About 400 to 500 kg additional dry fodder yield of grasses can be harvested from bund of one ha area however, additional benefit reduces as field area increases. The relationship between increase in grass yield due to bunding and area of field is depicted in Fig. 1. The higher productivity of grasses on bund was due to more availability of soil resulted in better root development and ultimate plant growth. The roots of grasses binds soil particles, increases infiltration of rain water and reduces soil erosion (Singh and Ratan, 2008; Novara *et al.*, 2013). Cultivation of perennial grasses also improves soil health, C sequestration, and fodder supply (Halli *et al.*, 2022).

The variation in growth and yield of *C. ciliaris* and *C. setigerus* grasses was found significant. Average plant height and forages yield was more in *C. ciliaris* than *C. setigerus*. Though, both the grasses were found suitable for improving grazing lands but their productivity depends on the soil conditions. The plant growth and productivity of both *C. ciliaris* and *C. setigerus* were significantly higher than natural grasses

Table 3. Growth and forage yield of pasture grasses under different field situation at farmer's field village Harsolav (mean of three years)

Pasture Grasses	Site	Plant height (cm)	Fresh yield (kg m ⁻²)	Dry fodder yield (kg m ⁻²)
<i>Cenchrus ciliaris</i>	Gaushala	82.44	0.77	0.20
	Bund	113.73	1.19	0.30
	Farmers field	89.20	0.90	0.23
	CD (P=0.05)	10.40	0.18	0.05
<i>Cenchrus setigerus</i>	Gaushala	64.50	0.52	0.15
	Bund	80.87	0.87	0.23
	Farmers field	71.67	0.61	0.17
	CD (P=0.05)	10.40	0.18	0.05

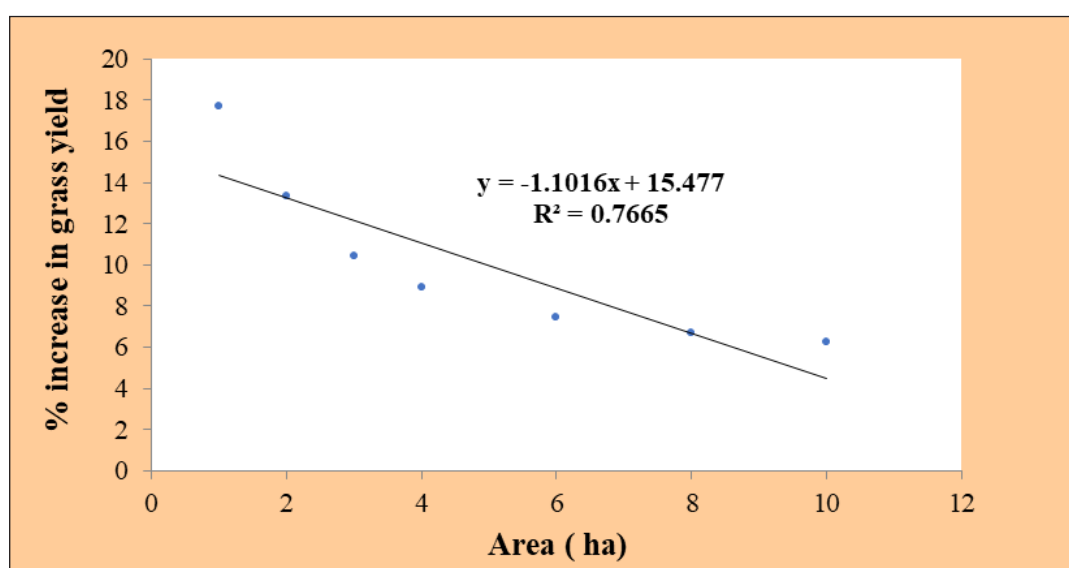


Fig 1. Projected relationship between increase in grass yield due to bunding and area of field.

viz., Lapra (*Aristida funiculata*), Bhurat (*Cenchrus biflorus*), Ganthia (*Dactyloctenium indicum*), Dob (*Cynodon dactylon*) etc.) Fig. 2. Pasture grasses i.e., *Cenchrus ciliaris* and *Cenchrus setigerus* grown as a sole pasture or in association with trees increased the forage production on degraded grazing lands as compared to natural pastures (Patidar *et al.*, 2015).

Performance of dual-purpose crops at farmers' field during Kharif and Rabi seasons

Improved practices of dual-purpose crops viz. pearl millet, clusterbean and mung bean were demonstrated at 15 farmers' field in Harsolav village of Nagaur District during kharif season of year 2015 to 2018. The results

showed that average grain yield of improved practices of pearl millet ranged from 1.19 to 1.32 t ha⁻¹ with mean of 1.25 t ha⁻¹. Stover yield under improved practices ranged from 2.07 to 2.13 t ha⁻¹. The increase in grain and straw yield of pearl millet due to improved practices was 17.5 and 9% respectively over farmers' practices. Grain yield of improved practices of clusterbean with an average of 0.66 t ha⁻¹ and straw yield of 1.06 t ha⁻¹ was recorded at farmers' field. The mean increase in grain and straw yield due to improved practices was 15.4 and 8.8 % respectively over farmer's practices. Similarly grain and stover yield of mung bean (IPM2-3) was increased by 13.9 and 6.2 percent over farmer's practices. Dual-purpose

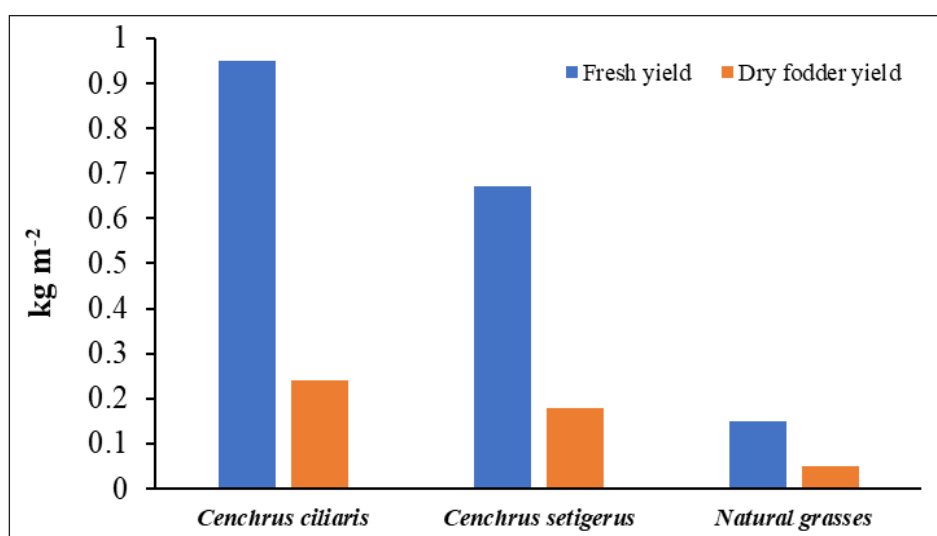


Fig 2. Productivity of different grasses.

Table 4. Effect of improved practices on yield of pearl millet, clusterbean, mung bean and barley

Crops	Grain yield (t ha ⁻¹)		Stover yield (t ha ⁻¹)		% increase	
	Improved practices ($\bar{x} \pm \text{SE}$)	Farmers practice ($\bar{x} \pm \text{SE}$)	Improved practices ($\bar{x} \pm \text{SE}$)	Farmers practice ($\bar{x} \pm \text{SE}$)	Grain	Stover
Pearl millet	1.25 $\pm$ 0.021	1.06 $\pm$ 0.025	2.125 $\pm$ 0.020	1.95 $\pm$ 0.027	17.5	9.0
Cluste bean	0.66 $\pm$ 0.021	0.57 $\pm$ 0.017	1.07 $\pm$ 0.048	0.98 $\pm$ 0.042	15.4	8.8
Mung bean	0.57 $\pm$ 0.029	0.50 $\pm$ 0.018	0.67 $\pm$ 0.031	0.63 $\pm$ 0.019	13.9	6.2
Barley	3.43 $\pm$ 0.140	2.99 $\pm$ 0.130	4.75 $\pm$ 0.200	4.24 $\pm$ 0.220	14.7	12

varieties of barley (RD2035 and RD 2052) were demonstrated at 11 farmers' field during rabi season in Harsolav village of Nagaur District. Result showed that grain yield of improved practices of barley varied from 3.25 to 3.59 t ha⁻¹ during three years of experiments with an average of 3.43 t ha⁻¹ and straw yield from 4.63 to 4.95 t ha⁻¹ with an average of 4.75 t ha⁻¹ (Table 4). The mean increase in grain and straw yield due to improved practices was 14.7 and 12% respectively over farmers' practices. Similar increase in grain and straw yield of barley with improved practices over farmers' practices (3.01 and 5.01 t ha⁻¹ grain and straw yield), respectively were also reported by Patidar and Patel (2011)

Performance of different varieties of pearl millet and clusterbean

Dual-purpose cultivars of pearl millet and clusterbean produced higher biomass as compared to local varieties. Among improved cultivar of pearl millet MPMH-17 produced maximum grain and straw yield followed by RHB-177 and CZP-9802. However, variety CZP 9802 produced higher stover yield than RHB-

177. The increase in grain and straw yield of pearl millet due to improved varieties was 18.75 and 8.86% respectively over local cultivars during Kharif 2015. Grain yield of improved variety of clusterbean (RGC 1017) varied from 0.52 to 0.74 t ha⁻¹ with straw yield from 0.82 to 1.2 t ha⁻¹ at different farmers' field. Increase in grain and straw yield due to improved variety was 14.55 and 5.61% respectively (Fig. 3)

Performance of irrigated fodder crops at farmers' field during rabi and Summer season

Fodder crops i.e. lucerne, oats and fodder beet were grown at farmers' fields to increase the availability of green fodder during Rabi season. Lucerne cv. Alamdar 51 oat cv. Kent and fodder beet cv. JK Kuber of were demonstrated at farmers' field during rabi season. Green fodder yield obtained from six cuts of lucerne varied from 50 to 85 t ha⁻¹ with an average of 48.9 t ha⁻¹. Oat was also grown at farmer's field to find the suitability with yield to the tune of 42.9 t ha⁻¹. Fodder beet was also demonstrated only at 4 farmer's field in small plots to find its suitability for obtaining high biomass production. The results showed that

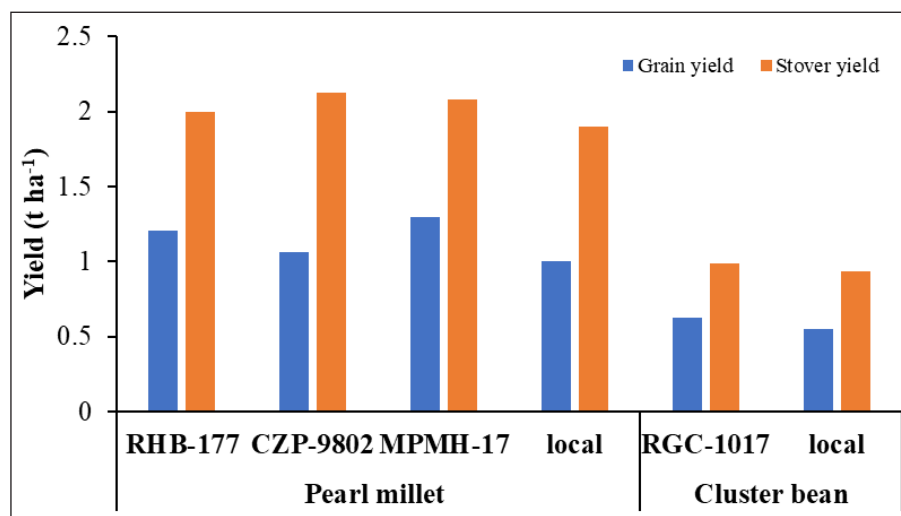


Fig. 3. Grain and stover yield of different varieties of pearl millet and clusterbean at village Harsolav.

Table 5. Fodder production under different crop sequences

Crop sequences	Fodder production (t ha ⁻¹)	Number of ACUs sustained
Perennial Lucerne	12.40	8.8
Annual Lucerne – fodder pearl millet	13.50	9.6
Fodder pearl millet - Barley	11.60	8.2

tuber yield was recorded to the tune of 52.31 along with 11.2 t ha⁻¹ fresh leaf. This helped in supplementing green fodder to the milch animals. For producing good quality of green fodder during summer season, cultivation practices of rijka bajri was demonstrated at farmers' field during summer season. Green fodder yield obtained from 2-3 cuts varied from 30 to 45 t ha⁻¹ with an average of 34.1 t ha⁻¹ at different farmers' field of Nagaur district

Year round fodder production potential at farmers' fields

For enhancing the green fodder availability round the year, different crop sequences were demonstrated at the farmers' field during Rabi and Summer season i.e., perennial lucerne, annual lucerne – fodder pearl millet and barley-Rijka bajri sequences. During *Kharif* season green fodder was made available through grasses and fodder crops. The fodder yield was maximum in annual lucerne - fodder pearl millet sequence followed by perennial lucerne (Table 5). However, all the systems were found at par for producing year round fodder. This system can be adopted on at least 10% of cultivated area and supplies 15 kg green fodder per day per animal that will increase milk yield by 10-12 %. This aligns with the similar results of experiment conducted at CAZRI Farm (Mathur *et al.*, 2019). Similar results on fodder production from different sequence such as barley-sorghum, lucerne- lucerne) and barley-pearl millet at farmers field were also reported by Patidar and Patel (2011).

Feeding of economical Concentrate Mixture containing Prosopis juliflora pods powder to cattle

A low cost and balanced concentrate animal feed mixture containing *Prosopis juliflora* pods powder developed by CAZRI for arid region technology was disseminated at Harsolav village. It was prepared by farmers utilizing the locally available feed resources. These includes *Prosopis juliflora* pods powder, clusterbean (*Cyamopsis tetragonoloba*) korma,

til (*Sesamum indicum*) seed cake, wheat bran, maize grain, common salt, mineral mixture as per requirement, simply mixing with a spade/hands, and filled in gunny bags for storage. No mechanization and electricity is essential for this process and this technology is rural friendly. The balanced concentrate mixture prepared had 20% crude protein and 73% total digestible nutrient (TDN) and costs Rs.2.75 kg⁻¹ cheaper. Five farmers family prepared it and fed to 11 cattle for four months in village Harsolav. Feeding of economical concentrate mixture increased milk yield 8.35% and also reduced cost of concentrate by Rs 2.75 per kg providing total benefit of 18290 with B:C ratio 2.2 (Table 6).

Feeding of multi nutrient blocks (MNB) in large ruminants

There are different means of supplementation of essential nutrients to the large ruminants, which mainly survive on grazing and partially with stall feeding of crop residues. The feeding of the blocks is a convenient and inexpensive method of providing a range of nutrients required by both rumen microbes and the animals, which may be deficient in the diet. The compact feed block is one of the most appropriate means to supplement the energy, non-protein nitrogen in combination of minerals and vitamins. The study evaluated feeding effect of multi-nutrient feed block on milk production of lactating buffaloes and cow. Twelve cows and 5 buffaloes belonging to 10 farmers were considered for the supplementary feeding trials at Harsolav, Nagaur districts. The 8 to 10 MNBs were provided to each animals for about 3 month period during lactation in addition to farmers practice. One block was fully consumed in a period of 7-10 days, depending on the basic diet being fed to the animals. The average daily milk yield of cows and buffaloes was increased by 9.14% and 8.32% respectively by feeding with MNB. An increase of total 701 liters of milk yield was obtained from 12 cows and 5 buffaloes after feeding of MNBs for three months period with B:C ratio of 1.53 in cow and 2.22 in buffaloes. The net benefit obtained from

Table 6. Balance feed and its effect on milk yield of cattle, buffalo and goat at farmer's field of village Harsolav

Livestock Species	Feed supplements	Number of livestock	Milk yield (L day ⁻¹)		% increase	Input Cost (Rs)	Output (Rs)	B:C
			Initial	Final				
Cattle	MNB	12	5.02	5.50	9.14	6987	17666	1.53
Buffalo	MNB	5	6.92	7.50	8.32	2690	8673	2.22
Goat	MNM	19	2.10	2.34	11.38	4140	8775	1.12
Cattle	Juliflora Pod	11	6.42	6.95	8.35	8316	26606	2.2

Table 7. Economics of dual-purpose crops intervention at farmer's field

Crops	Gross return (Rs ha ⁻¹)		Enhanced return (IP-FP)	B:C ratio
	IP	FP		
Pearl millet	28099	24377	3722	1.48
Clusterbean	34221	30136	4084	1.92
Mung bean	35945	31875	4070	1.71
Barley	81145	70903	10242	1.94

IP: Improved practices; FP: Farmers' practice.

extra milk yield was Rs.16662 (Table 6). MNB feeding improved milk yield, milk fat, general health status and reproductive performance of buffalos (Kachhawaha *et al.*, 2022), as it is a good source of protein, energy, and minerals. Similar results were also reported by Patel *et al.* (2014).

Feeding of multi nutrient mixture in goats (MNM)

The feeding trials of MNM were conducted on lactating goats at farmers' fields. Nineteen goats were selected for the supplementary feeding trials. Total 6 to 8 kg of MNM were provided to each animal for about 2.5 to 3.0-month period during lactation in addition to grazing. The MNM were offered to the animals @ 100 g day⁻¹ after goats returned from grazing. The daily milk yield increased by 11.4%. Similar results were also reported by Patel *et al.* (2015). A total of 391 liters increased milk yield was obtained from 19 goats belonging to 9 farmers after feeding of MNM for three months period. The net benefit obtained from extra milk yield was Rs.8775 with B: C of 1.12 (Table 6).

Economic analysis of Fodder crop Interventions

Critical appraisal of data (Table 7) indicates that higher gross returns were recorded with

adoption of improved practices in all dual-purpose crops i.e. pearl millet, clusterbean, mung bean and barley with benefit of Rs 3722, 4084, 4070 and 10242 per hectare, respectively. The incremental benefic cost ratio due to adoption of improved practices utilizing improved varieties and recommended dose of fertilizer varies from 1.48 to 1.94 in different crops. This shows that adoption of improved practices for cultivation of dual- purpose crop enhanced the economic returns of the farmers.

Similarly, cultivation of fodder crops and grasses for green fodder also enhance the income of farmers. During kharif season grasses gave a net return of Rs. 5072/ha with least cost of cultivation. Whereas in rabi season cultivation of lucerne and oat provided net returns of Rs.121924 and 55533/ha with B:C ratio of 1.56 and 1.83 respectively (Table 8). During summer season, green fodder crop (Rijka bajri) also provided net returns of Rs. 26652 per ha with B:C ratio 0.7 (Table 8).

The low B:C ratio of crops during Rabi and Summer season was due to high cost of cultivation incurred from use of irrigation water, however the gross benefits obtained was higher in this crops due to high green biomass

Table 8. Economics of improved intervention in fodder crops at farmers' field

Crops	Gross return (Rs ha ⁻¹)	Cost of cultivation	Net return	B:C ratio
Grasses	7905	2833	5072	1.79
Lucerne	199874	77951	121924	1.56
Oat	85867	30333	55533	1.83
Fodder pearl millet	65310	38658	26652	0.7

production. The net return was increased by 12-18% in dual-purpose crops due to improved practices. Cultivation of fodder crops under irrigated condition and improved pasture grasses under rainfed condition provided additional returns. Supplementary feeding in livestock also increased benefit by 8-12%. Thus, the improved practices of dual-purpose crop with irrigated fodder, pasture grasses on field bunds from one hectare of land with supplemental feeding to one animal increased farm income by Rs. 13998 (12.2%) over farmers practices (Rs. 114293).

Conclusions

The study has demonstrated with evidence the importance of improved farm practices in enhancing the income of existing livestock based farming system under both irrigated and rainfed situation in climatic constrained condition. The dual purpose (pearl millet, clusterbean, mung bean and barley) and fodder crops (lucerne, oat and rijka bajri) with improved practices have helped the farmers in increasing the availability of green as well as dry fodder. The feed supplementation to livestock with MNB and MNM has further enriched the farm income as result of increased milk yield and improvement in general health of livestock. Therefore, the study indicated that fodder production can be increased by growing improved practices of dual purpose and fodder crops along with improved pasture grasses on field bunds for sustaining livestock production in arid region. Thus, improved practices of dual-purpose crop with irrigated fodder, pasture grasses on field bunds from one hectare of land with supplemental feeding to one animal enhanced farm income by Rs. 13998 (12.2%) over farmers practices (Rs. 114293).

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Declarations

The authors have no competing interests.

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About the author

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Basant Kumar Mathur is a veterinarian by training and holds a Ph.D. in Animal Nutrition. He has specialized in livestock disease management, nutrition and the utilization of locally available and unconventional feed resources for improving livestock production in arid and drought-prone regions. His research has focused particularly on the nutritional evaluation and utilization of arid-zone feed resources, including *Citrullus colocynthis* seed cake, *Prosopis juliflora* pods, *Haloxylon salicornicum* seeds, and spineless cactus, for livestock feeding. He has also worked on assessment of feed requirements, formulation of balanced rations for small and large ruminants, mineral nutrition, and the development and dissemination of practical feeding technologies for arid livestock production systems. His research contributions include studies on unconventional feed resources, fodder production, silvipastoral systems, and livestock feeding and management under drought and scarcity conditions. He has contributed extensively to scientific literature and has been associated with national and international research and development programmes concerning livestock production and nutrition in arid environments.

