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Production potential and economic viability of food- forage based cropping system under irrigated conditions

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ABSTRACT

A field experiment was conducted between 2001 and 2006 at Jhansi (Uttar Pradesh) to evaluate the production potential, system productivity and economics of six food-forage based cropping system under irrigated conditions of Bundelkhand region. Groundnut (*Arachis hypogea* L.) - berseem (*Trifolium alexandrinum* L. emend. Fiori & Paol.) - forage maize (*Zea mays* L.) + forage cowpea (*Vigna unguiculata* L. Wilczek.) recorded significantly superior forage equivalent yield (155.8 t/ha/year), system productivity (0.43 t/ha/day), net returns (Rs.56,670/ha/year) and benefit: cost ratio (1.62) than other sequences. The increase in forage equivalent yield and net returns with groundnut - berseem - maize (F) + cowpea (F) over groundnut - wheat (*Triticum aestivum* L.) - green gram (*Phaseolus radiatus* L. Walp.) was 35 and 44, respectively. Lowest net returns (Rs 29,575/ha/yr) was recorded with sorghum (single cut) - wheat - green gram. The crop sequence of sorghum (multi-cut) - berseem recorded higher B: C ratio (1.60) than groundnut - wheat - maize + cowpea (1.42) indicating higher returns from forage based systems. Integration of forage maize + cowpea during summer in food-forage system (groundnut - wheat - maize + cowpea) recorded 44 % increase in production efficiency over food-based system. Inclusion of forages [(berseem or maize (F)+ cowpea(F)] in groundnut-based cropping system, was found quite stable with sustainability index of 0.96 and 0.92, respectively. Land use efficiency (100.0) and employment generation efficiency (1.02 man-days/ha/day) were highest in round the year forage production system [Napier bajra hybrid + (cowpea-berseem)] due to intensive cropping schedule. Soil physico - chemical status of food-forage based system was improved with respect to organic carbon (17%) and available N (12.7%) and P (27%) in 0-15 cm soil over initial level. Infiltration rate was improved from 1.05 to 2.11 mm/hr. Soil pH, electrical conductivity and bulk density were marginally reduced. However, available K status was slightly increased indicating that food-forage based system not only maintains soil fertility but improves over period of time. Based on system productivity and net returns, groundnut - berseem - maize (F) + cowpea (F) was found most efficient food - forage based system for Bundelkhand region closely followed by groundnut - wheat - maize (F) + cowpea (F) and sorghum (multicut) - berseem.

Key words: Economics, Food-forage crops, Productivity, Sequential cropping, Soil fertility

Food-forage-based systems provide a support to small and marginal farmers by adjusting a substantial part of their land exclusively for forage production in grain crop based rotations. Efficient cropping system with respect to biological potential along with increased efficiencies of land and water are to be evaluated for specific regions (Yadav *et al.,* 1998). Bundelkhand zone under central plateau and hill region with semi-arid climate occupy maximum acreage under sorghum - wheat and groundnut - wheat under irrigated system. Fallow - lentil / pea, sesame / sorghum - chickpea/mustard are prominent cropping sequences followed under rainfed or partially irrigated systems which are less profitable (Tripathi and Agrawal, 2003). In Bundelkhand region, forages as *per-se* are deficit in supply and its intensity increases during lean period particularly in winter and summer. Some of the promising forage-based cropping systems for Bundelkhand have been identified by Singh *et al.,* (2002). Forage needs to be integrated in the existing food based cropping system as crop intensification either in space (intercropping) or in time (sequential cropping) or both. Food-fodder based crop rotations have been evaluated for their profitability and were found more remunerative than other in many agro-climatic and management situations (Suneethadevi *et al.,* 2004). The information on food-forage based system under irrigated condition for Bundelkhand region is meager. Therefore the present study was undertaken to find out most remunerative food-forage based system under irrigated conditions.

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MATERIALS AND METHODS

A field experiment was conducted for five years (2001 to 2006) at the Central Research Farm (25°27°N, 78°37°E, 275 m above mean sea level) of the Indian Grassland and Fodder Research Institute, Jhansi. The soil was sandy loam, low in organic carbon (0.41 and 0.45%), available nitrogen (173 and 193 kg/ha) and phosphorous (11.3 and 13.8 kg/ha) and medium in available potassium (265.0 and 268.5 kg/ha) at the start and end of the experiment, respectively. The site is characterized as semi-arid subtropical climate with cold winters and hot summers. The total rainfall of 1151 mm, 546 mm, 1194 mm, 456 mm and 439 mm were received in 41, 28, 36, 29 and 31 rainy days during 2001-02, 2002-03, 2003-04, 2004-05 and 2005-06, respectively. Average maximum (33.3, 25.1 and 40.2^{0}C) and minimum (8.4, 23.5 and 22.4^{0}C) temperature were recorded in experimental years during *kharif*, *rabi* and summer, respectively. The treatments consisted of six crop sequences viz., best food crop rotation of the region (groundnut - wheat - green gram), best forage crop rotation of the region [(sorghum (multi- cut) - berseem)], inclusion of best *kharif* forage crop in the rotation (sorghum (single cut) - wheat - green gram), inclusion of best *rabi* forage crop in the rotation [(groundnut - berseem - maize(F) + cowpea(F)], inclusion of best summer forage crop in the rotation [(groundnut-wheat-maize(F) + cowpea(F)], and round the year forage crop rotation [(NB hybrid + (cowpea-berseem)]. The experiment was laid out in RBD with 4 replications. The site of experimental field was same during all the experimental year. The varieties of different crops used were: groundnut 'Kaushal', single cut sorghum 'HC-136', multi-cut sorghum 'SSG-59-3' during *kharif*, wheat 'DL-78', berseem ' Wardan' during *rabi* and maize 'African Tall', cowpea 'Bundel lobia-1', green gram 'K-851'during summer. Sowing of *kharif*, *rabi* and summer crops was done in the first week of July, first week of November and second week of April, respectively. Sorghum (multi-cut) was sown in mid-April every year. The crops were raised under irrigated conditions with recommended package of practices of the region. Rooted slips of napier bajra hybrid 'IGFRI-3' were planted in July at a spacing of 1 m × 0.5 m and the crop was maintained as perennial stand. Cowpea in *kharif* and summer and berseem in *rabi* were planted as intercrop between 2 wider rows of napier bajra hybrid. After three years, the dead tussocks of napier bajra hybrid were thinned for accommodation of inter-crops during *kharif* and *rabi*. Grain crops were harvested at maturity. Among forage crops, single cut species were harvested at 50% flowering stage. In sorghum (multi-cut) and berseem, first cut 65 day stage and 55 day stage and subsequent cuts were taken at 25 and 30 days interval, respectively. After first cut, interval for subsequent cuts for napier bajra hybrid was 45 days. Data on growth and yield was taken at appropriate harvesting schedules of the crops. In multi-cut forage crops, cut-wise yield data was taken and the yield of all cuts was pooled to workout total biomass yield. The economics and berseem fodder equivalent yield were computed at prevailing market rates during 2005-06 of different input and output. Production efficiency was worked out by dividing the total production of a sequence by total duration of the crops in that sequence (Tomar and Tiwari, 1990). Sustainability indices were computed for the sequences on the basis of berseem forage equivalent yield (Singh *et al.*, 1990). Organic carbon, pH, bulk density, infiltration rate, available N, P and K in soil before start and after completion of the experiment were estimated by standard methods. The forage equivalent yield and economics data was statistically analyzed as per standard procedures.

RESULTS AND DISCUSSION

Crop productivity

Production potential of component crops of food-forage based-cropping sequences showed variation over 5 years (Table 1). Yearly variations were higher with food-based sequence (groundnut - wheat - green gram) than food- forage based system [(groundnut - wheat - maize (F) + cowpea (F)]. Between 2001-02 and 2003-04, yield level of groundnut (1.6 - 1.7 t/ha) and green gram (0.6 to 0.8 t/ha) was maintained which declined in following 2 years. The yield levels of grain legumes were highest in first year in all the cropping systems. There was improvement in wheat yields up to 3 years in groundnut-based system followed by reduction in yield in subsequent years. Inclusion of 2 legumes (groundnut and green gram / cowpea) may have contributed in build up of soil fertility to increase yield of wheat. Yield of grain legumes (groundnut and green gram) were relatively more stable than grain cereal (wheat) in different years. Crops were grown under assured condition; hence rainfall variability did not influence the yield levels. Average maximum temperature might have influenced the yield of summer crops as performance of green gram and maize (F) + cowpea (F) was poor. In sorghum (single cut) - wheat - green gram sequence, wheat yields were maintained up to 3 years. Yield of sorghum (multi-cut and single-cut) was gradually increased up to 4th year. This may be attributed to inclusion of legume in the system. Berseem yields declined after third year in all cropping system registering maximum reduction (10.3%) in sorghum (multi-cut) - berseem sequence followed by groundnut - berseem - maize (F) + cowpea (F) (6.8%). The increase in component crops yield was not maintained after third year possibly due to continuous

Table 1. Year wise and mean yield (t /ha) of food - forage based crop sequences

Cropping system	2001 - 02	2002 - 03	2003 - 04	2004 - 05	2005 - 06	Mean
Groundnut - wheat - green gram						
Groundnut	1.7 (4.4)	1.6 (3.5)	1.6 (4.1)	1.4 (3.8)	1.4 (2.7)	1.5 (3.7)
Wheat	4.6 (6.7)	4.6 (6.8)	4.9 (7.4)	4.4 (6.7)	4.2 (6.3)	4.5 (6.8)
Green gram	0.8 (0.9)	0.7 (0.8)	0.8 (0.8)	0.5 (0.8)	0.6 (0.7)	0.7 (0.8)
Sorghum(multi-cut) - berseem						
Sorghum (multi cut)	36.3	40.3	42.6	39.5	38.8	41.5
Berseem	83.4	80.0	76.5	74.6	75.6	78.0
Sorghum (multi cut)	36.5	38.9	40.9	39.7	38.1	38.8
Sorghum (single cut) - wheat - green gram						
Sorghum (single cut)	39.1	39.5	40.0	39.0	37.0	38.9
Wheat	4.4 (6.1)	4.3 (6.3)	4.4 (6.4)	4.3 (6.2)	3.9 (6.1)	4.2 (6.3)
Green gram	0.7 (0.7)	0.6 (0.7)	0.7 (0.8)	0.6 (0.6)	0.5 (0.6)	0.6 (0.7)
Groundnut - berseem - maize(F) + cowpea(F)						
Groundnut	1.9 (3.5)	1.7 (3.9)	1.7 (3.9)	1.6 (4.0)	1.7 (3.6)	1.7 (3.7)
Berseem	83.6	81.9	82.6	83.0	78.1	81.8
Maize(F) + cowpea(F)	20.5 (8.1)	23.0 (7.5)	23.5 (7.8)	21.1 (8.3)	21.9 (7.2)	22.1 (7.8)
Groundnut - wheat - maize(F) + cowpea(F)						
Groundnut	1.9 (4.9)	1.8 (4.7)	1.8 (4.3)	1.7 (4.3)	1.6 (3.9)	1.8 (3.6)
Wheat	4..8 (7.5)	4.7 (7.8)	5.0 (8.2)	4.7 (7.0)	4.4 (6.6)	4.7 (7.5)
Maize(F) + cowpea(F)	22.0 (12.5)	22.8 (12.0)	23.4 (12.0)	23.6 (11.6)	23.4 (11.9)	23.0 (12.0)
NB hybrid (Perennial) + (cowpea - berseem)						
NB hybrid + cowpea	46.3 (9.1)	59.3 (16.2)	62.3 (10.1)	50.5 (19.5)	49.5 (15.1)	50.2 (12.0)
NB hybrid + berseem	8.5 (37.8)	10.0 (36.7)	12.0 (36.9)	11.0 (25.6)	12.0 (25.8)	9.5 (34.5)
NB hybrid + cowpea	23.6 (6.8)	34.6 (13.6)	36.8 (14.2)	35.1 (10.9)	30.1 (12.0)	32.0 (11.5)

Figures in parenthesis indicate yield of haulm (groundnut), straw (wheat and green gram) and intercrop (cowpea and berseem)

cropping. The crops extract nutrients from the uniform zone of the root atmosphere. The successive crops after 3-4 years are not able to get sufficient nutrients for their growth and development resulting in reduction of yield. Among forages, yearly variations were more evident with perennial napier bajra hybrid registering 14.3 and 37.8 % reduction during 4th and 5th year over best performing year i.e., 3rd year. Napier bajra hybrid provides higher biomass up to 3 years and afterwards replacement of old tussocks by new slips was found beneficial (Tripathi and Agrawal, 2003). Yield of napier bajra hybrid during *rabi* was less due to poor growth owing to low temperature.

On mean basis, yield of groundnut (1.83 t/ha) and wheat (4.65 t/ha) were maximum in ground nut - wheat - maize (F) + cowpea (F) cropping sequence. Maximum berseem yield (81.8 t/ha) was recorded in groundnut - berseem - maize (F) + cowpea (F) sequence. Increase in yield in groundnut - berseem - maize (F) + cowpea (F) may be attributed to superior growth (plant height, LAI) and yield attributes of these crops (Table 2). Higher number of pods (17.2/m^2), number of grains/ pod (2.3) and 1,000 seed weight (455.5 g) of groundnut and effective tillers (425.0), number of grains/ ear head (37.4) and 1,000-grain weight (50.0 g) resulted in higher yield of wheat in groundnut - wheat - maize (F) + cowpea (F) sequence. This indicates that inclusion of forage crops in the sequence influenced the rhizosphere favourably. This supports the observation of Jain *et al.* (2007), who also found that wheat preceded by ground nut and followed by maize (F) + cowpea (F) produced 19 % higher yield than groundnut - wheat - green gram sequence.

System productivity

Pooled data indicated variation in system productivity interms of forage equivalent yield of food forage and forage-based cropping system. Among all the tested systems, groundnut - berseem - maize (F) + cowpea (F) produced highest forage equivalent yield (155.8 t/ha/year) registering an increase of 34.7 % over food grain based system (Table 3). The corresponding increase was 42.8 % with the round the year forage production system i.e., napier bajra hybrid (perennial) + (cowpea - berseem). Forage equivalent yield in groundnut - wheat - maize (F) + cowpea (F) was 23.3 % higher than groundnut - wheat - green gram due to replacement of summer crop with forage crops. Yield data (Table 1) showed that higher yield of forages (30 t/ha) as compared to summer legume (0.6 t/ha) in gross return terms contributed to increased forage equiva-

lent of the system. Lower forage equivalent yield (106.8 t/ha) was recorded with sorghum (single cut) - wheat - green gram. This indicates that sorghum (single cut) could not surpass the forage equivalent yield in groundnut - wheat - green gram (115.7 t/ha/yr). Contrast to this, sorghum (multi-cut) - berseem and groundnut - wheat - maize (F) + cowpea (F) were equal in performance with regard to forage equivalent yield. Multi-cut forage species in *kharif* and single-cut in summer were able to compete in terms of system productivity of groundnut in this zone. In groundnut-based cropping systems, total productivity was higher where forages were integrated in *rabi*, summer or in both the seasons. Wheat and green gram could not bring the yield advantages in forage equivalent yield when compared with berseem and maize + cowpea in *rabi* and summer, respectively. Groundnut - wheat - maize (F) + cowpea (F) was significantly superior in system productivity (0.43 t/ha/ day). The magnitude of increase was highest over sorghum (single cut) - wheat - green gram (48.3%) followed by groundnut - wheat - green gram (25.6%). This indicates groundnut based forage production systems has edge over groundnut-based food production and forage based cropping systems. Suneethadevi *et al.* (2004) also reported higher system productivity of maize (G) - lucerne (F) - Lucerne (S) when compared with sorghum (F) + redgram (G) - tomato. In another study, higher wheat equivalent yield was obtained in maize (F) + cowpea (F) - wheat based cropping system when compared with maize - wheat sequence (IGFRI,1990).

Sustainability and land use efficiency

Groundnut - berseem - maize (F) + cowpea (F) expressed the highest sustainable yield index (SYI) of 0.96 which might be due to above - average stability of *kharif* and summer crops and highest SYI of *rabi* crop (Table 3). The tested cropping systems have SYI of more than 0.8 due to inclusion of legumes in each system. Legumes are known to offer special advantage regarding stability of the systems because of their legume effect and wider adaptability to diverse conditions. Land use efficiency (LUE) of round the year forage production system i.e. napier bajra hybrid (perennial) + (cowpea - berseem) was highest (100%) closely followed by groundnut - berseem - maize + cowpea (96.3%) and groundnut - wheat - maize(F) + cowpea(F) (95.9%). NB hybrid occupied the field during the whole year having intercrop as cowpea in *kharif* and summer and berseem in *rabi*. Due to intensive cropping systems, LUE of the tested systems was more than 90%

Table 2. Important growth and yield attributes of individual crops in food-forage based cropping system (Mean of 5 years)

Cropping system	Plant height (cm)	Leaf area index (55 day stage)	L : S ratio	Pods* and effective tillers** (per m^2)	Grains/pod* and grains/ ear head**	1000 grain weight (g)
Groundnut - wheat - green gram						
Groundnut	46.5	2.78		16.5	1.9	450.8
Wheat	86.2	3.17		410.5	34.3	48.5
Green gram	59.0	2.55		11.5	6.8	37.9
Sorghum(multi-cut) - berseem						
Sorghum (multi-cut)	225.0	4.51	0.58			
Berseem	50.7	2.52	0.62			
Sorghum (multi-cut)	214.0	4.45	0.57			
Sorghum (single-cut) - wheat - green gram						
Sorghum (SC)	215.0	4.70	0.65			
Wheat	82.9	3.45		420.8	36.2	45.9
Green gram	54.1	2.47		12.2	7.4	36.7
Groundnut - berseem - maize(F) + cowpea(F)						
Groundnut	45.7	2.89		17.2	2.3	455.5
Berseem	58.5	2.69	0.64			
Maize(F) + cowpea(F)	182.0 (45.5)	4.57 (2.70)	0.62 (0.81)			
Groundnut - wheat - maize(F) + cowpea(F)						
Groundnut	46.5	2.81		16.8	2.2	460.3
Wheat	85.5	3.51		425.0	37.4	50.0
Maize(F) + cowpea(F)	189.2 (44.7)	4.59 (2.72)	0.56 (0.75)			
NB hybrid (Perennial) + (cowpea - berseem)						
NB hybrid + cowpea	114.5 (45.0)	2.40 (2.68)	0.87 (0.70)			
NB hybrid + berseem	60.4 (46.8)	2.20 (2.50)	0.65 (0.59)			
NB hybrid + cowpea	109.7 (42.3)	2.52 (2.71)	0.89 (0.76)			

Figures in parenthesis indicate values for intercrop (cowpea and berseem), * Groundnut and green gram, ** Wheat

except sorghum (single cut) - wheat - green gram. Duration of sorghum (single cut) was less than groundnut in *kharif* which might have reduced LUE of this system. Employment generation efficiency (1.02 man-days/ha/day) was found highest in round the year forage production system [napier bajra hybrid (perennial + (cowpea - berseem)] due to intensification through perennial component and seasonal intercropping of forage legumes. Sorghum (multi - cut) - berseem and groundnut - berseem - maize(F) + cowpea(F) recorded higher employment generation efficiency due to more involvement of manpower in harvesting (5-6 cuttings) of multi-cut forage species like sorghum (multi-cut) and berseem. Singh *et al.* (2002) also reported that perennial forage based system of napier bajra hybrid and guinea grass recorded highest employment generation efficiency (1.12 man-days/ha/day) and land use efficiency (100%).

Economics

Economics of food-forage based system showed maximum net returns (Rs 55,670 /ha/year) with groundnut - berseem - maize (F) + cowpea (F). The second best food-forage based system in of net returns was where wheat was grown in *rabi* preceding groundnut and following maize + cowpea (Table 3). The per cent increase in net returns with best treatment [(groundnut - berseem - maize (F) + cowpea (F)] was 44 % over food-grain based system (groundnut - wheat - green gram). Round the year forage production system showed superiority in net returns of 12.5 and 50 % over groundnut - wheat - green gram and sorghum (single cut) - wheat - green gram systems, respectively. Lowest net returns was obtained with sorghum (single cut) - wheat - green gram indicating unsuitability for Bundelkhand zone. Benefit cost ratio was highest (1.62) with groundnut - berseem - maize (F) + cowpea (F) closely followed by sorghum (multi-cut) - berseem (1.60). Lowest B: C ratio remained with the sequence producing lowest yield i.e. sorghum (single cut) - wheat - green gram. The sequence showing equal production were different in B:C ratio. Sorghum (multi-cut) - berseem recorded higher B:C ratio (1.60) than groundnut - wheat - maize+ cowpea (1.42) indicating higher returns from forage based sequences. This may be due to higher cost of production (Rs 3,112/ha/year) in groundnut - wheat - maize (F) + cowpea (F) than sorghum (multi-cut) - berseem. Production efficiency followed the similar trend to that of B:C ratio. Highest production efficiency was attained with groundnut - berseem - maize (F) + cowpea (F) closely followed by sorghum (multi-cut) -berseem. Lowest production efficient sequences were sorghum (single cut) - wheat - green gram and groundnut- wheat - green gram (Rs.81- 108/ ha/day). The monetary return use efficiency of sorghum (multi-cut) - berseem and groundnut - wheat - maize + cowpea was almost equal (Rs.136-140/ ha/day). Lal *et al.* (2003) also reported highest B: C ratio for sorghum (single cut) - wheat - fallow (1.57) due to lower cost of production closely followed by clusterbean - oats - maize (1.50).

Table 3. Forage equivalent yield, economics and system productivity of food-forage based cropping system (mean of 5 years)

Cropping system	Forage equivalent yield (t/ha/year)	System productivity (t/ha/day)	Cost of cultivation (x 10^3 Rs/ ha/year)	Net returns (x 10^3 Rs/ ha/year)	B : C ratio	Land use efficiency (%)	Employment generation efficiency (man days/ ha/ day)	Monetary return use efficiency (Rs/ha/day)	Sustainability index
Groundnut - wheat - green gram	115.7	0.32	34.5	39.4	1.14	89.0	0.54	107.9	0.82
Sorghum (multi-cut) - berseem	142.0	0.39	32.0	51.3	1.60	94.5	0.88	140.5	0.86
Sorghum (single cut) - wheat - green gram	106.8	0.29	30.5	29.6	0.97	79.5	0.65	81.0	0.90
Groundnut - berseem - maize(F) + cowpea (F)	155.8	0.43	35.0	56.7	1.62	96.3	0.78	155.3	0.96
Groundnut - wheat - maize(F) + cowpea (F)	142.7	0.39	35.2	49.9	1.42	95.9	0.60	136.8	0.92
Napier bajra hybrid (perennial) + (cowpea - berseem)	130.1	0.30	33.8	44.3	1.31	100.0	1.02	121.3	0.88
SEm±	3.9	0.02						4.5	
CD(P=0.05)	11.5	0.06						13.3	

Sale price (Rs/q) : Groundnut - 1,500, groundnut haulm - 60, wheat - 640, wheat straw -100, green gram - 1500, green gram straw- 100 , cereal green fodder (sorghum, maize, napier bajra hybrid) -45, legume green fodder (berseem, cowpea) - ?

Table 4. Physico-chemical changes in soil under food-forage based cropping system after five years

Cropping system	pH	Electrical conductivity (mmhos/cm)	Organic carbon (%)	Available nutrients (kg/ha)			Bulk density (g/cc)	Infiltration rate (mm/hr)
				N	P	K		
Groundnut - wheat - green gram	7.4	0.30	0.41	184.5	13.0	270.5	1.54	1.85
Sorghum (multi-cut) - berseem	7.3	0.30	0.43	193.7	13.6	272.7	1.55	1.98
Sorghum (single cut) - wheat - green gram	7.5	0.31	0.44	190.9	13.9	266.5	1.54	2.00
Groundnut - berseem - maize (F) + cowpea (F)	7.4	0.30	0.48	200.8	14.5	268.9	1.51	2.11
Groundnut - wheat - maize (F) + cowpea (F)	7.5	0.30	0.46	198.0	14.1	272.7	1.53	2.13
NB hybrid (perennial) + (cowpea - berseem)	7.3	0.29	0.45	195.5	14.0	261.6	1.59	1.99
Initial soil test values	7.4	0.31	0.41	173.0	11.3	265.8	1.68	1.05

Soil fertility

After five years of experimentation, it was observed that in general organic carbon; available N and infiltration rate was improved in food-forage based system (Table 4). The magnitude of increase was higher with the crop sequence [(groundnut - berseem - maize (F) + cowpea (F) and groundnut - wheat - maize (F) + cowpea (F)] where forage or food legumes were included. Available N (193.7 to 200.8 kg /ha) and organic carbon (0.43 to 0.48 %) were improved from initial test level (173.0 kg/ha and 0.41 %, respectively) in the systems where at least one forage crop was incorporated. The enhancement in fertility status of soils may be attributed to inclusion of legume and nourishment of forage crops as Bundelkhand soils are poor in organic carbon and available N status. P status was marginally improved over initial value (s) in all the sequences. Available K status was also slightly changed. In food grain-based sequences where berseem was included, the status was improved marginally over initial level. This signifies that K status was exhausted with continuous cropping and its balance could be maintained by essential application of potassium to crops and organic manures in forage/ food- forage based cropping systems. Bulk density was invariably reduced after 5 years of food - forage cropping. Lowest reduction was noted with napier bajra hybrid (perennial) + berseem. Infiltration rate was improved after completion of the experiment. Bulk density of napier bajra hybrid (perennial) + (cowpea - berseem) cropping system was increased due to intensive cultivation. Enhancement in fertility was higher with groundnut - berseem - maize (F) + cowpea (F) and groundnut - wheat - maize (F) + cowpea (F). Inclusion of 2 legumes in the system increased the organic carbon and available N, P and K in the soil. Yadav *et al.* (1998) also opined that inclusion of legumes in cropping systems resulted in better physico-chemical status of soil.

Thus it may be concluded that in mixed farming situation of Bundelkhand, groundnut - berseem - maize (F) + cowpea (F) was most efficient with respect to forage equivalent yield, land use efficiency and net returns followed by sorghum (multi-cut) - berseem. Integration of forages in food-based production systems may prove sustainable and economically viable cropping systems which not only provide food but also supports livestock by supplying green fodder.

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