Journal of Animal Research: v.9 n.3, p. 451-458. June 2019
DOI: 10.30954/2277-940X.03.2019.10

Effect of Forage Crop Rotation on Soil Nutrients Status and Productivity of Land and Water

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Received: 16 March, 2019 **Revised:** 24 April, 2019 **Accepted:** 25 April, 2019

ABSTRACT

Two experiments were conducted for one year duration each initiating from summer (experiment 1) and winter season (experiment II), respectively to understand whether preceding crop has any impact on biomass yield, water productivity and soil nutrients status. Multicut sorghum-berseem crop rotation yielded 21.53, 31.44 and 21.68% higher dry biomass (DM), protein (CP) and gross energy (GE) in experiment II than experiment I. Highest water productivity of 3.12±0.01 kg DM/m^3 was recorded in Berseem-sorghum crop rotation in experiment II followed by annual rye-sorghum rotation (2.83±0.02 kg DM/m^3). Nutritional (kg CP/m^3 or Mcal/m^3) water productivity were also highest in berseem-sorghum crop rotation. Depletion of soil nitrogen (N) was highest in sorghum-berseem crop rotation in both the experiments; however, depletion of phosphorus (P) was highest in maize- annual rye crop rotation in experiment I and sorghum-berseem crop rotation in experiment II. Potash (K) depletion was almost similar in all the crop rotations in both crop sequences. Organic carbon (OC) depletion was not affected in experiment I after one year of rotation; however, in experiment II, berseem-sorghum crop rotation showed the organic carbon level below the critical value (0.5%). Preceding crop had impact on soil fertility and productivity of succeeding crop. So, it may be recommended that multicut varieties of sorghum and berseem may be rotated for round the year fodder production which can sustain 15-16 adult cattle per ha considering the feeding of 20 kg green fodder per head per day.

Keywords: Cereal, Forage, Legume, Soil, Water Productivity

In small holding production system, forage are generally grown on low fertile soil and their production can be increased markedly with recommended Fertigation. Forage biomass yield is governed by the level of nutrients in soil, type of soil, climatic condition and types of forages to be grown. Yield and protein content in forages increase when N is applied (Valiki *et al.,* 2015). But excess doses accumulate in soft plant tissue that may be toxic to animals. Residual N move towards downward in soil and have adverse effect on soil health as well as reduces formation of nodules in legumes crops. Therefore, it is recommended to use N in split doses instead of large one time application to minimize the nutrient depletion (Bruulsema, 2006). Addition of organic manures with N fertilizer produced highest forage dry matter due to more release of P and K from soil (Cherney *et al*., 2010). Maintenance of soil quality is the prime importance in present day agricultural scenario particularly in post green revolution era in India. The suitable crop rotation is also useful for better harvest of fodder. It is reported that sorghum fodder yield increased when sown after legume grain crops like cowpea, green gram and groundnut (Ghosh *et al*., 2007). Considering these points and paucity of information, the experiment was conducted with three objectives: (i) to quantify the biomass and nutrients yield in cereal-legume rotation (ii) to assess the impact of cereal-legume fodder rotation on soil nutrient status and (iii) to assess the water productivity of important fodder crops in cereal-legume rotation.

MATERIALS AND METHODS

The study was conducted at the institute farm in Patna, Bihar, India having tropical agro-climatic conditions, clay-loam type soil with neutral pH. The region is bestowed with high rainfall (1200-1400 mm) of which 80% of rainfall occurs during July to September. Two experiments were conducted following the summer-wintercrop sequence and *vice versa* to study the effect of crop rotation on soil nutrients status and biomass yield during a period of one year.

Experiment I: Summer-winter crop sequence

The first experiment was conducted from June, 2016 to May, 2017. Farmyard manure (FYM) was applied on the plot @2.5 t/ha on dry matter basis and DAP @ 60 kg/ha. Entire Plot (1200 m^2) was prepared and divided into 4 main plots of 300m^2 area each and further each main plot was divided into 3 subplots of 100 m^2 area. Cowpea var. Bundel-2, maizevar. African Tall, multicut sorghum var. MP Chari and soybean var. NRC-37 were sown during last week of June as summer fodder crop in different main plots in three replications and designated as T_1, T_2, T_3 and T_4, respectively. Earthing-up with subsequent urea broadcasting @ 85 kg/ha was made to T_2 plot (maize) at 40 days crop duration, however, in multi-cut sorghum plot (T_3), urea was broadcasted @ 60 kg/ha at the same time. In T_1 and T_4 plots, fertilizer was applied once only as basal dose. Cowpea and soybean fodder crops were harvested at 80 days crop duration and fodder yield was recorded. The yield of first cut of sorghum fodder was recorded at 60 days after sowing and subsequently urea was broadcasted @ 60 kg/ha. The data of second cut fodder of multi-cut sorghum was taken after 45 days from first cut. The maize fodder was harvested at 95 days after sowing and yield data were recorded. After harvesting the summer crops, plots were again ploughed with addition of DAP @30 kg/ha without disturbing the plot-geometry. The fodder crops like wheat var. VL-829, annual rye, berseem var. Wardan and oat var. JHO-822 were sown in the last week of October in different main plots T_1, T_2, T_3 and T_4 that had cowpea, maize, multi-cut sorghum and soybean as preceding crops, respectively. The urea was applied in all crops as top dressing after surface irrigation at 30 days of crop duration. Wheat fodder was harvested at 12cm height from base at 70 days after sowing. Remaining portion was left for further growth for the production of grain. Irrigation was provided just after harvesting of wheat fodder and subsequently urea was applied @ 60 kg/ha. The last irrigation to this crop was provided at 130 days of crop duration when ear head emergence was completed with top dressing of urea @ 60 kg/ha and finally mature wheat crop was harvested at 165 days after sowing and recorded grain and straw yield. Urea as top dressing @ 60kg/ha was applied after irrigation to oat plot (T_4) also at 25, 50 and 70 days after sowing. Oat fodder was harvested two times, first at 60 days and second at 110 days post sowing. However, yield data (4 cuts) was recorded from plots of annual rye and berseem at crop duration of 50, 80, 110 and 140 days. Four surface irrigation was provided at 30, 50, 80 and 110 days crop duration with subsequent application of urea as top dressing @ 60kg/ha each time, however, mild surface irrigation was also provided just after sowing.

Experiment II: Winter-summer crop sequence

Second experiment was conducted in another plot (900 m^2) from November, 2016 to October, 2017 in reverse season mode from the previous experiment. The land was prepared with addition of FYM @ 2.6 t/ha on dry matter basis, DAP @ 60 kg/ha and murate of potash @ 40kg/ha. The recommended dose of N, P_2O_5 and K_2O in experiment II was calculated based on soil fertility rating of post-harvest soil as described by Singh *et al*. (2005). In low and very low or high and very high categories, the fertilizer doses were increased or decreased by 25 to 50 % of the general recommended dose as per situation. Entire plot (900 m^2) was divided into 3 main plot of 300 m^2 area each and further each main plot was divided into 3 subplots of 100 m^2. Oat var. JHO-822, berseem var. Wardan and annual rye was sown with mild surface irrigation during first week of November as fodder crop in different main plots in three replications and designated as T_1, T_2 and T_3, respectively. Urea as top dressing @ 60 kg/ha was applied after irrigation to oat plot (T_1) at crop duration of 25 and 70 days. Oat fodder was harvested at two times, first at 55 days and second at 110 days after sowing and yield data were recorded. However, berseem and annual rye was harvested four times at crop duration of 45, 75, 105 and 130 days and data were recorded. Four surface irrigations were provided at 30, 45, 75 and 105 days crop duration with subsequent application of urea as top dressing @ 60 kg/ha each time. Now, all main plots were again ploughed and further land was prepared without disturbing the plot-geometry. The multi-cut sorghum was sown in all plots in the last week of March, 2017 with surface irrigation. Second surface irrigation was given at crop duration of

40 days. Fodder yield data at 1st cut was recorded at 60 days after sowing with subsequent surface irrigation and top dressing of urea @ 60 kg/ha. The second cut yield data was recorded in the month of July, 2017 with a gap of 50 days from previous cut.

The crop water productivity (WP) was also studied in second experiment by measured quantity of water supplied to the field. The amount of water irrigated was measured by application of flow meter. Nutritional water productivity was calculated as amount of CP produced (kg)/ m^3 of water irrigated and amount of gross energy (GE) produced (Mcal)/ m^3 of water irrigated. Land productivity was calculated as amount of dry biomass t/ ha area.

Analysis of fodder and soil nutrients

Before land preparation and after harvesting of all fodder crops, top 30 cm soil samples from all main plots of both the experiments were collected for estimation and study of soil nutrients status following a standard procedure (Tandon, 2009).Various fodder samples collected at different times were processed for estimation of dry matter, crude protein, phosphorus, potassium and gross energy (AOAC, 2005). Compiled data were analysed for test of significance as per standard methods (Snedecor and Cochran, 1994).

RESULTS AND DISCUSSION

Experiment I: Summer-winter crop sequence

During summer season, significantly ($P<0.01$) higher biomass yield was recorded from cereal fodder i.e. multi-cut sorghum (68.67±1.69 t/ha) followed by maize than leguminous fodder (Table 2). Total yield of fodder biomass was drastically reduced in single-cut legumes like cow pea and soybean. However, multi-cut legumes like berseem and annual rye yielded significantly ($P<0.01$) higher biomass yield 45.47±1.37 and 43.10±0.82 t/ha, respectively but yield was significantly ($P<0.01$) lower than the multicut cereal fodder like sorghum but was at par with another single cut cereal fodder maize. The numbers of cutting, type of cultivar and plant canopy growth are the probable reasons for low biomass yield in single cut legumes. In fact, the biomass yield of leguminous fodder was reported lower than the cereal fodder in various reports (Kumar *et al*., 2012; Gupta *et al*., 2017). Maximum annual fodder yield of 112.13±2.15 t/ha was obtained in multicut sorghum and berseem combination that may sufficient to meet the requirement of 15-16 adult cattle unit round the year. Similarly, significantly ($P<0.01$) highest DM yield was recorded in summer fodder multicut sorghum (13.87±0.34 t/ha) and winter fodder annual rye (6.43±0.12) and berseem (5.31±0.16 t/ha). Among summer fodder lowest dry matter yield was recorded in soybean followed by cowpea, however, among winter fodder significantly ($P<0.01$) lowest dry matter yield was recorded in oat (4.81±0.06 t/ha). As a result, multicut sorghum and berseem combination resulted in significantly ($P<0.01$) highest dry biomass yield (19.18±0.27 t/ha/year) followed by maize-annual rye combination. Whereas, the wheat variety VL-829 is developed for both fodder and grain production and green fodder is harvested at 70 days from the bottom 12 cm. As a result fresh and dry yield of wheat was observed lower.

Though, protein content was estimated higher in leguminous fodder i.e. soybean, berseem, annual rye and cowpea than cereal fodder i.e. oat, maize and multicut sorghum (Table 1). The total protein yield was recorded significantly ($P<0.01$) highest in annual rye followed by multicut sorghum, berseem and soybean fodder. However, round the year protein yield was recorded significantly ($P<0.01$) highest in sorghum-berseem combination (1.94±0.02 t/ha) followed by maize-annual rye combination (1.64 ±0.02 t/ha) and lowest in cowpea–wheat combination (0.77±0.01t/ha). In respect of energy production, it was observed that multicut sorghum yielded significantly ($P<0.01$) highest GE followed by annual rye and maize in comparison to leguminous fodder like berseem and cowpea. However, round the year energy yield was recorded significantly ($P<0.01$) highest in multicut sorghum-berseem combination (72806±1015 Mcal/ha) followed by maize-annual rye combination (47121±315 Mcal/ha).

Experiment II: Winter- summer crop sequence

Second experiment was conducted in another plot from winter season in different leguminous-cereal fodder crop rotation keeping the summer fodder (i.e. multi-cut sorghum) same in all the crop rotation as it is prevalent fodder crop in the region because of its higher biomass yield. Considering

Table 1: Nutrients contents of fodder

Fodder	DM (%)	Crude Protein (g/100g DM)	Gross Energy (Mcal/kg DM)	Phosphorus (g/100g DM)	Potassium (g/100g DM)
Berseem	13.08±0.06	18.10±0.07	3.84±0.04	0.90±0.02	0.87±0.01
Oat	13.59±0.06	10.25±0.03	3.90±0.02	1.01±0.02	1.96±0.03
Annual Rye	13.01±0.14	17.12±0.46	3.94±0.02	0.75±0.02	2.30±0.10
Wheat	15.28±0.08	17.46±0.25	4.06±0.04	0.71±0.04	1.93±0.06
Maize	13.53±0.20	9.15±0.20	3.68±0.05	0.61±0.05	1.33±0.08
Sorghum	20.07±0.11	7.10±0.31	3.78±0.07	0.88±0.07	0.99±0.12
Soybean	19.24±0.20	19.82±0.38	3.83±0.23	0.94±0.09	1.20±0.12
Cowpea	18.12±0.35	13.37±0.45	3.52±0.05	0.95±0.06	1.30±0.10

Table 2: Seasonal and annual yield of biomass and nutrients in summer-winter fodder crop sequence

Particulars		Treatment Means* ± SE			
		T_1	T_2	T_3	T_4
Crop Sequence	Summer	Cowpea-	Maize-	M. Sorghum-	Soybean-
	Winter	Wheat	Annual Rye	Berseem	Oat
Summer fodder yield (t/ha)		$23.83^{a}\pm0.40$	$43.75^{b}\pm0.72$	$68.67^{c}\pm1.69$	$19.49^{a}\pm0.49$
Summer DM yield (t/ha)		$4.32^{a}\pm0.07$	$5.92^{b}\pm0.01$	$13.87^{c}\pm0.34$	$3.75^{a}\pm0.09$
Winter fodder yield (t/ha)		$7.38^{a}\pm0.19$	$43.10^{c}\pm0.82$	$45.47^{c}\pm1.37$	$30.57^{b}\pm0.35$
Winter DM yield (t/ha)		$1.10^{a}\pm0.03$	$6.43^{c}\pm0.12$	$5.31^{b}\pm0.16$	$4.81^{b}\pm0.06$
Annual fodder yield (t/ha)		$31.21^{a}\pm0.59$	$86.85^{c}\pm0.56$	$112.13^{d}\pm2.15$	$50.06^{b}\pm0.22$
Annual DM yield (t/ha)		$5.42^{a}\pm0.10$	$12.35^{c}\pm0.08$	$19.18^{d}\pm0.27$	$8.55^{b}\pm0.05$
Protein yield (t/ha)	Summer	$0.58^{a}\pm0.01$	$0.54^{a}\pm0.01$	$0.98^{c}\pm0.02$	$0.74^{b}\pm0.02$
	Winter	$0.19^{a}\pm0.01$	$1.10^{d}\pm0.02$	$0.96^{c}\pm0.03$	$0.49^{b}\pm0.01$
	Annual	$0.77^{a}\pm0.01$	$1.64^{c}\pm0.02$	$1.94^{d}\pm0.02$	$1.23^{b}\pm0.01$
Gross energy yield (Mcal/ha)	Summer	$15207^{a}\pm247$	$21773^{b}\pm351$	$52416^{c}\pm1291$	$14350^{a}\pm353$
	Winter	$4465^{a}\pm124$	$25347^{c}\pm477$	$20390^{b}\pm614$	$18746^{b}\pm219$
	Annual	$19672^{a}\pm368$	$47121^{c}\pm315$	$72806^{d}\pm1015$	$33096^{b}\pm182$

*Treatment means having different superscripts within row differ significantly (P<0.01)

the depletion of nutrients in experiment-I, doses of FYM and murate of potash (K_2O) were increased to 40kg/ha in soil as the basal fertigation. Among all the winter forage, berseem recorded significantly (P<0.01) higher yield (62.38±0.41 t/ha) than annual rye (Table 3), even after application of same doses of chemical fertilizer in both the crops. Minimum cumulative forage yield was recorded in oat (41.43±1.16 t/ha). However, the forage yield of berseem, annual rye and oat was significantly (P<0.01) higher in winter-summer crop sequence(Experiment II) than the summer-winter crop sequence (Experiment I). It might be due to availability of sufficient soil nutrients after application of FYM and chemical fertilizers that increased the uptake of nutrients by plants and showed luxurious growth (Cherney *et al.,* 1998). Multicut sorghum as forage crop in succeeding crop rotation was taken in all the treatments. Significantly higher (P<0.01)cumulative forage yield of multicut sorghum (79.87±0.21 t/ha)was recorded in T_2 where berseem was grown as preceding crop than oat (47.13±0.69 t/ha), however, yield was not significant when annual rye was taken as succeeding crop (77.25±1.18 t/ha).Yield of multicut sorghum was significantly (P<0.01) higher in experiment II i.e. winter-summer crop sequence except when cereal fodder oat was taken as succeeding crop than experiment I. With respect to yield on dry matter basis, the winter fodder followed the

Table 3: Seasonal and annual yield of biomass and nutrients in winter-summer fodder crop sequence

Particulars		Treatment Means* ± SE		
		T_1	T_2	T_3
Crop Sequence	**Winter** **Summer**	**Oat-** **M.Sorghum**	**Berseem-** **M.Sorghum**	**Annual Rye-** **M.Sorghum**
Winter fodder yield (t/ha)		41.43^a±1.16	62.38^c ±0.41	53.11^b ±0.87
Winter DM yield (t/ha)		5.63^a ±0.16	8.16^c ±0.05	6.91^b ±0.11
Summer fodder yield (t/ha)		47.13^a±0.69	79.87^b ±0.21	77.25^b ±1.18
Summer DM yield (t/ha)		9.46^a ±0.14	15.15^c ±0.03	14.25^b ±0.21
Annual fodder yield (t/ha)		88.57^a±1.82	142.25^c ±0.62	130.35^b ±0.69
Annual DM yield (t/ha)		15.09^a±0.31	23.31^c ±0.08	21.17^b ±0.14
Protein yield (t/ha)	Winter	0.57^a±0.02	1.47^c±0.01	1.18^b±0.02
	Summer	0.67^a±0.01	1.07^b±0.01	1.01^b±0.02
	Annual	1.25^a±0.03	2.55^c±0.01	2.19^b±.01
Gross energy yield (Mcal/ha)	Winter	21970^a±647	31334^c±189	27238^b±442
	Summer	35746^a±548	57254^c±120	53878^b±782
	Annual	57716^a±1177	88589^b±309	81116^b±529

*Treatment means having different superscripts within row differ significantly (P<0.01)

similar trend as on fresh basis. However, yield of multicut sorghum significantly (P<0.05) varied according to preceding crop as yield was significantly (P<0.01) higher when preceding crop was berseem (15.15±0.03 t DM/ha) than annual rye (14.25±0.21 t DM/ha). Gross energy yield of different winter fodder also varied significantly (P<0.01), berseem being highest and oat being the lowest. Annual energy yield was significantly (P<0.01) higher in berseem-sorghum crop rotation (88589±309 Mcal/ha) than oat-sorghum (57716±1177 Mcal/ha) but did not differ significantly (P<0.01) in annual rye-sorghum crop rotation (81116 ±529 Mcal/ha).

Productivity of land and water during winter-summer crop sequence

Annual land productivity was found significantly (P<0.01) highest in berseem-sorghum crop rotation (23.31±0.08 t DM/ha) followed by annual rye-sorghum (21.17±0.14 t DM/ ha) and lowest in oat-sorghum rotation (15.09±0.31 t DM/ha) Table 3. Among all winter forages, significantly highest (P<0.05) water productivity was recorded in oat (19.15± 0.53 kg/m^3) followed by berseem (16.02±0.11 kg/m^3) and annual rye (13.64±0.23kg/m^3) Table 4. The water productivity of multicut sorghum varied from 13.15 to 22.28 kg/m^3 in different preceding crops. The water productivity was observed significantly (P<0.05) highest (22.28±0.06 kg/m^3) when preceding crop was berseem followed by annual rye as preceding crop (21.55±0.33 kg/m^3). However, water productivity of multicut sorghum (13.15 kg/m^3) was significantly (P<0.05) decreased when grown after oat crop. On dry matter basis, the water productivity of oat, berseem and annual rye followed the similar trend as on fresh basis. In Indian condition, Singh *et al*. (2014) reported the water productivity of berseem, oat and sorghum at 2.20, 3.20 and 3.74, kg DM/m^3. The values were at par for berseem and sorghum but higher for oat than the present study.

Nutritional water productivity was also found significantly (P<0.05) highest in berseem (0.37±0.01 kg CP/m^3) and lowest in oat (0.26±0.01 kg CP/m^3). However, for multicut sorghum it was significantly (P<0.05) highest when preceding crop was leguminous like berseem (0.30±0.01 kg CP/m^3) and annual rye (0.28±0.02 kg CP/m^3) but was observed significantly (P<0.05) lowest when preceding crop was cereal like oat (0.19±0.01 kg CP/m^3). Annually, significantly (P<0.05) highest protein yield was recorded in berseem-sorghum crop rotation (0.34±0.01 kg

Table 4: Water productivity of winter-summer fodder crop sequence in experiment II

Particulars		Treatment Means* ± SE	
	T_1	T_2	T_3
Crop Sequence			
Winter	Oat-	Berseem-	Annual Rye-
Summer	M. Sorghum	M. Sorghum	M. Sorghum
Physical Water Productivity (kg/m^3)			
Winter	19.15^c±0.53	16.02^b±0.11	13.64^a±0.23
Summer	13.15^a±0.19	22.28^b±0.06	21.55^b±0.33
Annual	15.41^a±0.32	19.02^c±0.08	17.43^b±0.09
Physical Water Productivity (kg DM/m^3)			
Winter	2.60^c±0.08	2.09^b±0.01	1.78^a±0.03
Summer	2.64^a±0.04	4.22^c±0.01	3.97^b±0.06
Annual	2.63^a±0.05	3.12^c±0.01	2.83^b±0.02
Nutritional Water Productivity (kg CP/m^3)			
Winter	0.26^a±0.01	0.37^c±0.01	0.30^b±0.01
Summer	0.19^a±0.01	0.30^b±0.01	0.28^b±0.02
Annual	0.22^a±0.01	0.34^c±0.01	0.29^b±0.01
Nutritional Water Productivity (Mcal GE/m^3)			
Winter	10.16^c±0.30	8.05^b±0.05	7.00^a±0.11
Summer	9.97^a±0.15	15.97^c±0.03	15.03^b±0.22
Annual	10.04^a±0.20	11.85^c±0.04	10.85^b±0.07

*Treatment means having different superscripts within row differ significantly (P<0.05).

CP/m^3) and lowest in cereal-cereal rotation (0.22±0.01 kg CP/m^3). With respect to gross energy yield (Mcal GE/m^3), significantly highest values were recorded in oat (10.16±0.30) followed by berseem (8.05±0.05) and lowest in annual rye (7.00±0.11). Gross energy yield (Mcal/m^3) of sorghum also varied significantly (P<0.05) depending on the preceding crop and followed the similar trend as on protein yield. On annual basis, the highest energy yield (Mcal GE/m^3) was recorded in berseem-sorghum crop rotation (11.85±0.04) followed by annual rye-sorghum crop rotation (10.85±0.07)) and lowest values in oat-sorghum crop rotation 10.04±0.20).

Soil nutrients status

The initial and final soil nutrients status in experiment-I (Summer-winter crop sequence) has been presented in Table 5. Before the initiation of experiment, the pH of soil was recorded 6.72. The soil N, P and K were observed at 248, 22 and 290 kg/ha, respectively. The organic carbon content was recorded at 0.77%. About 2.5 t dry organic fertilizer, 90 kg DAP and 180-360 kg urea per ha were added in different plots and treatments. After a crop sequence, it has been observed that multicut sorghum-berseem crop rotation (T_3) yielded maximum biomass but was also found suitable in maintaining soil health in terms of content of organic carbon (OC), phosphorus (P) and potassium (K) to the tune of 0.76%, 21.10±0.45 and 162.00±2.64 kg/ha, respectively. The nitrogen content was observed highest in the soil of T2 followed by T_1 and T4 and lowest in T_3 (Table 5). The pH of all the treatment was neutral and varied from 6.57 to 7.11.

In experiment II (Winter-summer crop sequence), initial soil pH was recorded at 6.77 with organic carbon content of 0.75%. Initially, the soil also contained 175 kg N, 31.7 kg P and 145 kg K per ha (Table 5). During the whole crop rotation, an amount of 2.6 t FYM (DM basis), 60 kg DAP, 40 kg murate of potash and 180-300 kg urea per ha were

Table 5: Soil nutrients status of experimental plots after one year of fodder crop rotation

Particulars	Treatments			
	T_1	T_2	T_3	T_4
Experiment I: Summer-winter fodder crop sequence				
Initial Soil Status	N (248 kg/ha), P (22 kg/ha), K (290 kg/ha), OC (0.77 %) and pH (6.72)			
Addition in One Year				
FYM (t/ha on DM basis)	2.5	2.5	2.5	2.5
DAP (kg/ha)	90	90	90	90
Urea (kg/ha)	180	325	360	180
Annual yield (kg/ha)*				
N	211±1.92	174±2.47	240±3.12	172±1.76
P	97±0.62	66±0.90	170±2.36	84±0.43
K	159±2.01	187±2.76	184±2.71	139±0.49
Final Soil Status				
N (kg/ha)	166±1.52	179±2.08	142±2.64	163±2.00
P (kg/ha)	17.10±0.31	15.00±0.33	21.10±0.45	17.40±0.61
K (kg/ha)	177±2.08	172±3.05	162±2.64	179±3.61
OC (%)	0.68±0.17	0.70±0.02	0.76±0.11	0.83±0.02
pH	6.57±0.11	7.11±0.02	6.80±0.03	6.77±0.01
Experiment II: Winter-summer fodder crop sequence				
Initial Soil Status	N (175 kg/ha), P (31.7 kg/ha), K (145 kg/ha), OC (0.75 %) and pH (6.77)			
Addition in One Year				
FYM (t/ha on DM basis)	2.6	2.6	2.6	—
DAP (kg/ha)	60	60	60	—
K_2O (kg/ha)	40	40	40	—
Urea (kg/ha)	180	300	300	—
Annual yield (kg/ha)				
N	156±3.52	322±1.49	251±1.51	—
P	140±2.90	207±0.72	177±1.30	—
K	204±4.63	221±0.74	300±1.67	—
Final Soil Status				
N (kg/ha)	111.20±1.44	97.76±3.31	123.26±1.05	—
P (kg/ha)	27.40±0.81	25.80±0.82	28.90±1.60	—
K (kg/ha)	80.64±1.43	84.37±1.98	82.51±2.51	—
OC (%)	0.59±0.01	0.49±0.01	0.55±0.01	—
pH	7.03±0.01	6.93±0.01	6.87±0.01	—

*Yield of wheat straw (5.45±0.06 t/ha) and wheat grain (2.97±0.05 t/ha) taken in account while calculated annual nutrients yield

Yield and Irrigation Water Productivity of Three Varieties of Buffel; Grass (*Cenchrus ciliaris* L.) in the Southern Coastal Plains of Yemen; Yield and Irrigation Water Productivity of Three Varieties of Buffel; Grass (*Cenchrus ciliaris* L.) in the Southern Coastal Plains of Yemen

added to the soil of different crop rotations. Considering the depletion of nutrients in experiment 1, doses of FYM was increased to 2.6 t DM/ha and murate of potash (K_2O) to 40 kg/ha in soil as the basal fertigation. After a crop sequence, the final soil status was recorded as 111.2±1.44, 97.76±3.31 and 123.26±1.05 kg N/ha in T_1, T_2 and T_3, respectively. Similarly, in case of P, highest retention in the soil was observed in annual rye-sorghum crop rotation (28.90±1.60 kg/ha) which was almost similar to oat-sorghum crop rotation (27.40±0.81 kg/ha). Highest uptake of P was observed in berseem-sorghum crop rotation. However, with respect to the retention of K in the soil, it was observed all most similar values in all the crop rotations which varied from 80.64±1.43 to 84.37±1.98 kg/ha. In the present experiment, after one year of crop sequence, pH of the soil varied from 6.87± 0.00 to 7.03± 0.005. The OC content of soil after one year of different legume-cereal fodder crop rotation, in the present experiment, varied from 0.49± 0.011 to 0.59± 0.005%. The depletion of OC was observed highest in experiment II than the experiment I. It was probably due to exhaustive up-took of nutrients from soil by cereal fodder crops (Sundaram *et al*., 2012)

CONCLUSION

So, it may be recommended that multicut varieties of sorghum and berseem may be rotated for round the year fodder production which can sustain 15-16 adult cattle per ha considering the feeding of 20 kg green fodder per head per day. However, soybean-oat combination may be an alternative for rainfed region considering its higher water productivity and biomass yield. Crop sequence has impact on soil nutrients status but cereal-legume combination has been best option for biomass yield and soil health sustainability. Considering the soil nutrients depletion, fertilizer application rate may be modified and recommended in split doses. Among all the forages, multicut sorghum and cow pea during summer and oat during winter showed the highest water productivity. Preceding crop has impact on water productivity of succeeding crop.

ACKNOWLEDGEMENTS

The authors are thankful to Dr. S.K. Naik (Pr. Scientist) ICAR Res. Complex for Eastern Region, Ranchi Centre for providing the necessary facilities and extending support in analysing soil samples during research work.

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