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Effect of integrated nutrient management on yield sustainability and soil fertility of forage cropping system

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Abstract
An experiment was conducted to study the influence of inorganic alone and in combination with manures and biofertilizers on productivity of sorghum + cowpea – lucerne forage cropping system during 2006-07 to 2009-10. The four year pooled data revealed significantly higher green forage, dry matter and crude protein yield of sorghum (527.35, 110.50, 9.36 q ha^{-1}), cowpea (286.27, 40.28, 7.13 q ha^{-1}) and lucerne (724.33, 154.02, 29.15 q ha^{-1}), respectively due to treatment T_6-25 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer **+** *biofertilizer* (*Azotobacter/Rhizobium*). However, it was found at par with treatment T_2 -100 % NPK through inorganic fertilizer and T_3 - 25 % N through FYM + 75 % N 100 % P, K through inorganic fertilizer in respect of green forage yield of sorghum and lucerne, whereas, in respect of dry matter and crude protein yield it was at par with treatment T_3 only. Under the sorghum + cowpea – lucerne forage cropping system, treatment T_6 - application of 25 % N through FYM + 50 % NPK through inorganic fertilizer + biofertilizers recorded significantly highest gross returns, net returns and benefit: cost ratio (Rs. 1,91,981, Rs.1,01,815 per hectare and of 2.13, respectively). Similarly, the same treatment recorded maximum values for available N (253.43 kg/ ha), NPK uptake and NPK use efficiency while treatment T_4 - 50 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer registered maximum values of available P and K content (19.43 and 385.13 kg /ha, respectively) in soil at harvest.

Key words: Economics, Fodder productivity, Integrated nutrient management, Nutrient uptake, Productivity, Recommended Dose of Fertilizer

Introduction
The productivity of cereal after cereal cropping sequences has shown constantly declining trend in most occasions and as such the income from such system is hardly sufficient for its continuance on sustainable basis. The main reason of the declining productivity is depletion of essential soil nutrients causing deficiencies. Continuous cropping with cereal after cereal also adversely affects physical properties of the soil (Sharma *et al*., 2002). Inclusion of legumes in cropping system and use of chemical fertilizers and biofertilizers maintain the yield levels. Studies have shown that the inclusion of legumes in cropping systems improves fertility status of soil and helps in increasing the yield of succeeding cereal crops (Balyan, 1997). In view of the declining productivity levels, greater emphasis is now being given to the integrated nutrient supply system which may play an important role in sustaining soil conditions (Meelu and Morris, 1984). Addition of FYM not only supplies the additional nutrients to the growing plants but also affects the availability of native nutrients from soil and chemical fertilizers due to release of organic acids and other microbial products during the decomposition (Stevenson, 1967). Besides FYM, biofertilizers are also known to exert indirect effects on the soil microbial activities which in turn help the plant to grow better besides direct effects on nitrogen fixation and P-mobilization (Camprubi *et al*., 1995). Keeping this fact in view, the influence of integrated nutrient management approach on production potential of sorghum + cowpea – lucerne forage cropping system was studied.

Material and Methods
An experiment was conducted at All India Coordinated Research Project on Forage Crops, MPKV, Rahuri during four consecutive years of 2006-07 to 2009-10. The experiment was laid out in randomized block design with four replications. The seven treatments comprised of different integrated nutrient supply system [T_1- Absolute control; T_2 - 100 % NPK through inorganic fertilizer; T_3 - 25 % N through FYM + 75 % N and 100 % P, K through inorganic fertilizer; T_4 - 50 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer; T_5

- 50 % N and 100 % P, K through inorganic fertilizer + *biofertilizer* (*Azotobacter/ Rhizobium*); T_6 - 25 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer + *biofertilizer* (*Azotobacter/Rhizobium*); T_7 – 75 % N and 100 % P, K through inorganic fertilizer + *biofertilizer* (*Azotobacter/Rhizobium*). The soil of the experimental field was clayey in texture with organic carbon content of 0.36 % and low (197.60 kg /ha), medium (13.28 kg/ ha) and high (369.50 kg/ ha) in available NPK, respectively. The recommended dose of NPK fertilizers for *kharif* sorghum (100:50:40 kg/ ha) and *rabi* lucerne (20:80:40 kg/ ha) were applied. During *kharif* season cowpea *var.* Sweta was intercropped with sorghum *var*. Ruchira in replacement series; hence, separate fertilizer dose to cowpea crop was not applied. On same piece of land, lucerne annual *var*. Anand-2 during rabi season was grown with the fertilizer application of 20:80:40 NPK kg/ha. The NPK was applied through recommended dose of fertilizer and FYM was applied on the basis of nitrogen content in various treatments. The *biofertilizers* (*Azotobactor* for sorghum and *Rhizobium* for cowpea and lucerne) was applied @ 250 g / 10 kg of seed as seed treatment. The sorghum and cowpea were harvested for green forage at 50 % flowering and six cuts of lucerne were taken at 25 days interval. The recommended packages of practices were followed. Standard analytical methods were followed for estimation of available NPK in soil (Olsen *et al*., 1954; Knundsen *et al.,* 1982), nitrogen percent content in FYM (Bremner and Mulvaney,1982), NPK content (Jackson,1973), crude protein content (A.O.A.C., 2005).

Results and Discussion

Growth and yield: The growth attributes *viz*., plant height (223.65 cm) and leaf : stem ratio (0.46) of sorghum were maximum with application of 25 % N through FYM + 75 % NPK through inorganic fertilizer (T_3), however, maximum plant height of cowpea (145.08 cm) and lucerne (75.58 cm) and leaf : stem ratio of cowpea (0.63) and lucerne (1.16) were recorded under the treatment T_6, *i.e.*, 25 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer + biofertilizer (Table 1). Significantly higher green forage yield of sorghum (527.38 q ha^{-1}), cowpea (286.27 q ha^{-1}) and lucerne (724.33 q ha^{-1}) was noticed due to treatment T_6 which was found at par with treatment T_3 and T_2 in respect to sorghum and lucerne only. An increase of green forage yield by 10.05, 11.29 and 7.65 per cent of sorghum, cowpea and lucerne, respectively were observed due to treatment T_6 over treatment T_2.

Similarly significantly highest dry matter yield of sorghum (110.50 q ha^{-1}), cowpea (40.28 q ha^{-1}) and lucerne (154.02 q ha^{-1}) was noticed in treatment T_6 and it was found at par with treatment T_3. The superiority of sorghum+ cowpea-lucerne forage cropping system along with the integrated nutrient approach might be due to beneficial effect of legume crop in each season resulting in more green forage yield. Singh *et al.* (2003) also reported the similar results. The superiority of said forage cropping system along with the integrated nutrient management in terms of dry matter yield was due to the higher combined effect of dry matter content and green forage yield. In case of crude protein yield, treatment T_6 - 25 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer + *biofertilizer* registered statistically more crude protein yield of sorghum (9.36 q ha^{-1}), cowpea (7.13 q ha^{-1}) and lucerne (29.15 q ha^{-1}) than all other treatments under study except treatment T_3 which was found at par with sorghum crude protein only (Table 1). The higher crude protein yield with sorghum+ cowpea-lucerne forage cropping system along with the integrated nutrient management was obtained due to inclusion of legume component in each season, thus combined effect of crude protein content and dry matter yield reflected in enhancement of crude protein yield. These results are in corroboration with the findings of Joshi *et al.* (2012). The same trend was also noticed with regards to sorghum forage equivalent yield. The application of 25 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer + *biofertilizer* (T_6) recorded maximum sorghum forage equivalent yield during *kharif* (813.80 q ha^{-1}), *rabi* (1287.70 q ha^{-1}) and in total (*kharif* + *rabi*) (2133.13 q ha^{-1}) than all other integrated nutrient supply system except treatment T_3 (2016.98 q ha^{-1}) was found at par with sorghum forage equivalent yield. The reasons for increased response to FYM are generally ascribed to beneficial effect associated with soil productivity (Prasad *et al*., 1996). Similar results have been earlier reported by Acharya *et al*. (1988). Farm yard manure directly added an appreciable amount of major micronutrients to the soil, which could have contributed to the enhanced yield.

Economics: The gross and net monetary returns were found to be influenced by different nutrient supply system (Table 2). The application of 25 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer + *biofertilizer* (T_6) recorded significantly maximum gross returns of Rs. 76,088/-, Rs. 1,15,893/- and Rs. 1,91,198/- and net returns of Rs. 41,001/-, Rs. 60,814/- and Rs.1,01,815/- per hectare from *kharif* crops, *rabi* lucerne crop and entire system (sorghum + cowpea - lucerne), respectively.

In case of benefit: cost ratio, 2.17, 2.10 and 2.13 was obtained from *kharif* crops, rabi lucerne crop and entire system (sorghum + cowpea - lucerne), respectively. The obtained result might be due to the higher green forage and dry matter yield in treatment T_6 which was reflected in higher monetary returns and benefit: cost ratio. These results corroborate the findings of Bhilare *et al.* (2002) and Singh *et al.* (2002).

Table 1. Mean plant height (cm), leaf: stem ratio, green forage, dry matter and crude protein yield (q ha^{-1}) of sorghum + cowpea - lucerne cropping system as influenced by different treatments (Pooled data of four years).

Treatments	Plant height (cm)			Leaf : stem ratio			Green forage yield (q ha^{-1})		
	Sorghum	Lucerne	Cowpea	Sorghum	Lucerne	Cowpea	Sorghum	Lucerne	Cowpea
T_1	188.74	119.90	63.05	0.21	0.42	0.90	244.36	208.17	418.77
T_2	219.52	136.26	73.42	0.43	0.59	1.04	479.23	257.23	672.86
T_3	223.65	137.17	73.19	0.46	0.61	1.03	507.23	269.14	681.03
T_4	213.52	133.35	72.47	0.27	0.49	1.01	440.76	242.91	659.60
T_5	213.08	128.72	70.80	0.34	0.49	0.96	397.27	230.86	607.71
T_6	223.20	145.08	75.58	0.45	0.63	1.16	527.35	286.27	724.33
T_7	209.93	137.63	72.32	0.35	0.56	1.01	448.50	247.79	618.25
CD(P=0.05)	8.44	8.88	3.71	0.012	0.036	NS	39.52	15.03	54.25

Treatments	Dry matter yield (q ha^{-1})			Crude protein yield (q ha^{-1})		
	Sorghum	Lucerne	Cowpea	Sorghum	Lucerne	Cowpea
T_1	42.09	23.74	89.59	2.70	3.25	15.48
T_2	97.18	35.30	143.47	7.65	5.95	26.71
T_3	105.78	37.69	145.54	8.69	6.26	26.99
T_4	83.93	33.24	140.88	6.51	5.39	25.86
T_5	72.59	28.07	129.51	5.31	4.44	23.64
T_6	110.50	40.28	154.02	9.36	7.13	29.15
T_7	87.81	33.30	133.24	6.78	5.60	24.50
CD(P=0.05)	10.21	3.32	10.08	0.96	0.81	2.07

Table 2. Mean sorghum forage equivalent yield (q ha^{-1}), gross and net returns (Rs. ha^{-1}) and benefit: cost ratio of sorghum + cowpea - lucerne cropping system as influenced by different treatments (Pooled data of four years).

	Sorghum forage equivalent yield (q ha^{-1})			Gross returns (Rs. ha^{-1})		
	Kharif	*Rabi*	K + R	*Kharif*	*Rabi*	K + R
T_1	475.67	744.48	1220.14	42810	67003	109813
T_2	765.04	1196.20	1961.24	68854	107658	176512
T_3	806.27	1210.72	2016.98	72564	108964	181529
T_4	710.65	1172.63	1883.28	63958	105536	169495
T_5	653.78	1080.37	1734.15	58840	97234	156073
T_6	845.42	1287.70	2133.13	76088	115893	191981
T_7	723.82	1099.11	1822.93	65144	98920	164064
CD (P=0.05)	48.61	100.52	116.68	4196	8680	10502

	Net returns (Rs. ha^{-1})			Benefit : cost ratio		
	Kharif	*Rabi*	K + R	*Kharif*	*Rabi*	K + R
T_1	18534	23310	41844	1.76	1.53	1.62
T_2	31654	51778	83432	1.85	1.93	1.90
T_3	34950	54976	89926	1.93	2.02	1.98
T_4	23593	51229	74823	1.58	1.94	1.79
T_5	28198	46218	74416	1.92	1.91	1.91
T_6	41001	60814	101815	2.17	2.10	2.13
T_7	30862	46560	77422	1.90	1.89	1.89
CD (P=0.05)	4196	8680	10502	0.12	0.15	0.12

Nutrient uptake and nutrient use efficiency: The N, P and K uptake by sorghum + cowpea - lucerne forage cropping system was minimum under control treatment but increased by applying fertilizers alone and in combination with FYM and biofertilizers. The N, P and K uptake were highest with treatment T_6 (630.33, 65.99 and 671.10 kg ha^{-1}, respectively) and was at par with treatment T_3 in respect to P and K uptake only. The total uptake of nitrogen, phosphorus and potassium was found significantly higher in treatment T_6. Higher uptake of N, P and K under these treatments could be owing to higher dry matter yield under these treatments. The application of 25 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer + *biofertilizer* (T_6) increased the soil nutrient concentration and nutrient uptake. These results are in agreement with the findings of Berrala and Westfull (2005).

Addition of dried defoliated leaves of cowpea and their decomposition, role of symbiotic /non symbiotic microorganisms, dead root of crops *etc.* might be cumulatively providing the nutrient in available form to the forage cropping system in addition nutrient added through chemical fertilizer, FYM and biofertilizers.

Nutrient use efficiency: Application of 25 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer + biofertilizer (T_6) recorded significantly higher N, P and K use efficiency of 173.04, 119.80 and 194.68 kg kg^{-1}, respectively, in comparison to all other treatments (Table 3).

Change in soil fertility status

***Organic carbon*:** The highest organic carbon content (0.54 %) in soil at harvest was noticed in treatment T_6 and T_4 by sorghum + cowpea - lucerne forage cropping system. The increased organic carbon content was due to addition of fertilizer along with application of FYM and *biofertilizer* (*Azotobacter/Rhizobium*) which increased the organic matter in soil that leads to increase the organic carbon. The organic carbon was increased with treatment T_6. This might be because of the added fertilizer along with FYM and biofertilizers.

The use of FYM was found beneficial in improving the status of soil micronutrients at the end of four years experimentation as compared to its initial values. Application of FYM and *biofertilizers* was found beneficial as it consisted of all the essential as well as beneficial elements, which might be responsible for producing the organic acids, organic constituents and ultimately fermentation of humus which in turn act as chelating agent for micronutrients. Therefore, addition of FYM and *biofertilizers* increases the micronutrients and organic carbon status of soil at the end of four years cycle. These results are in agreement with Sudhir and Siddaramappa (1995) and Laxminarayana and Patiram (2006).

***Available N, P and K*:** Amongst the different treatments, application of 25 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer + *biofertiliz*er (T_6) had the maximum values for available N (253.43 kg/ ha) in soil at harvest. Sheeba and Chellamuthu (1999) ascribed such increase in available N to the fact that the addition of mineral nitrogen along with organic sources narrowed the C: N ratio of organic manures and this enhanced the rate of mineralization resulting in rapid release of nutrients from the organic sources. While significantly high available P content (19.43 kg/ ha) in soil at harvest was noticed in treatment T_4 (50 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer) and it was found at par with treatment T_3 and T_6. Incorporation of FYM along with inorganic P increases the availability of P and this is attributed to reduction in fixation of water soluble P, increase of organic P due to microbial action and enhanced mobility of P. These results are in conformity with the findings of Acharya *et al*., (1988). Available K content (385.13 kg/ h^1) in soil at harvest was significantly higher in treatment T_4 (50 % N through FYM + 50 % N and 100 % P, K through inorganic fertilizer) than rest of all the treatment except treatment T_5 and T_6 (Table 3). Higher levels of K due to FYM application may be ascribed to reduction of K fixation that increased K content due to interaction of organic matter with clay, besides the direct K addition in the available K pool of the soil (Prasad and Mathur, 1997). The fertilizer level improves the residual soil fertility with increased levels of fertilizer application. Therefore, fertilizer along with application of FYM and *biofertilizer* (*Azotobacter/Rhizobium*) left more amounts of nutrients in soil at the completion of four years experimentation.

Forage crops grown in medium black soils of Maharashtra during kharif season sorghum (Ruchira) along with cowpea (Sweta) in paired row planting 30 cm apart (two lines of sorghum and two lines of cowpea) and during rabi season annual lucerne (Anand-2) forage cropping sequence, gave higher forage yield and 25 % saving in Nitrogen fertilizer and sustain to maintain the soil fertility through integrated nutrient management along with *Biofertilizer* seed treatment along with following fertilizers.

Table 3. Organic carbon (%), available N, P and K (kg/ ha), N, P, K uptake(kg/ ha) and N, P, K use efficiency (kg/ kg) of sorghum + cowpea- lucerne cropping system as influenced by different treatments (Pooled data of four years).

Treatment	Organic carbon (%)	Available 'N' (kg/ ha)	Available 'P' (kg/ ha)	Available 'K' (kg/ ha)	'N' uptake (kg/ ha)	'P' uptake (kg/ ha)	'K' uptake (kg/ ha)	'N' use efficiency (kg/ kg)	'N' use efficiency (kg/ kg)	'N' use efficiency (kg/ kg)
T_1	0.40	224.45	11.94	354.71	356.11	37.63	378.81	-	-	-
T_2	0.46	229.88	17.50	367.36	543.42	58.24	584.94	105.03	96.95	157.54
T_3	0.51	246.65	18.27	355.04	557.24	62.29	648.53	115.89	106.97	173.83
T_4	0.54	240.81	19.43	385.13	508.30	56.93	603.27	91.26	84.24	136.88
T_5	0.51	252.44	17.91	375.14	551.72	50.70	516.07	133.23	61.49	99.92
T_6	0.54	253.43	18.34	382.29	630.33	65.99	671.10	173.04	119.80	194.68
T_7	0.48	237.90	16.37	367.86	508.81	55.38	578.35	114.54	79.29	128.85
CD (P=0.05)	0.02	9.54	1.47	12.07	56.21	4.27	43.04	19.02	17.03	15.42

T_1- Control, T_2 - 100 % NPK inorganic fertilizer, T_3 - 25 % N FYM + 75 % N and 100 % P, K inorg. fert., T_4 - 50 % N FYM + 50 % N and 100 % P, K inorg. fert., T_5 - 50 % N and 100 % P, K inorg. fert. + biofertilizer, T_6 - 25 % N FYM + 50 % N and 100 % P, K inorg. fert. + biofertilizer and T_7-75 % N and 100 % P, K inorg. fert. + biofertilizer.

Kharif season sorghum forage crops out of 75:50:40 kg/ ha NPK.

- 5 ton FYM + 50 kg P_2O_5 + 40 kg K_2O ha^{-1} at sowing.
- 50 kg N/ha after 30 DAS

Rabi season annual Lucerne crop out of 15:80:40 kg / ha^{-} NPK.

- 1 ton FYM + 10 kg N, 80 Kg P_2O_5 + 40 kg K_2O ha^{-1} through chemical fertilizer at the time of sowing.

Conclusion: Addition of FYM and *biofertilizers* along with inorganic fertilizers, not only sustained higher forage yields, but also improved the soil quality. Imbalanced use of inorganic fertilizers on other hand reduced forage crop productivity and deteriorated the soil health.

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