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Research Article

SUSTAINING GROUNDNUT (*ARACHIS HYPOGAEA* L.) PRODUCTIVITY AND MONETARY RETURNS WITH SHEEP PENNING AND MANURE IN COMBINATION WITH FARM YARD MANURE AND INORGANIC FERTILIZER UNDER ARID *ALFISOLS*

SAHADEVA REDDY B.*[1], RAVINDRANATHA REDDY B.[3], MALLISWARA REDDY A.[2], ASHOKA REDDY Y.[3] AND VIJAYA SANKAR BABU M.[2]

[1]Department Agronomy, Agricultural College, Rajamahendravaram, 533103, East Godavari, Acharya N. G. Ranga Agricultural University, Lam, 522034, Andhra Pradesh
[2]AICRP for dryland Agriculture, ICAR-Agricultural Research Station, DCMS Buildings, Kamalanagar, Ananthapur, 515001, Acharya N. G. Ranga Agricultural University, Lam, 522034, Andhra Pradesh, India
[3]Department of Agronomy, Regional Agricultural Research Station (RARS), Tirupati, 517502, Acharya N. G. Ranga Agricultural University, Lam, 522034, Andhra Pradesh
*Corresponding Author: Email - sahadevardd@gmail.com

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Abstract: Field experiment on groundnut were conducted for four years with 16 treatments as a combination of 4 organic sources (Control, Sheep penning, Sheep manure and FYM) and 4 organic and inorganic sources (Control, 50% FYM, 50% RDF and 50% FYM + 50% RDF) in a split-plot design during *Kharif* 2009 to 2012 under arid *Alfisols* at Anantapur in Andhra Pradesh. Pooled mean indicated that significantly higher pod, haulm yield, gross returns, net returns, Benefit cost ratio and rain water use efficiency was recorded with sheep penning +50% RDF compared to absolute control. Four year pooled mean indicated that significantly higher organic carbon was recorded with sheep penning + 50% FYM application (0.67%) and lowest with absolute control (0.30%). The maximum soil potassium occurred under sheep penning only in all the 4 years. The lowest soil potassium occurred under absolute control in all the years. The maximum pod yield was attained under sheep penning + 50% FYM in 2009, sheep manure + 50% RDF in 2010, FYM + 50% RDF in 2011, sheep manure + 50% FYM in 2012 and sheep penning + 50% RDF when pooled over years. The maximum net returns was attained under sheep penning + 50% FYM in 2009, sheep penning + 50% RDF in 2010 and when pooled over years, FYM + 50% RDF in 2011 and sheep manure + 50% FYM in 2012. The maximum rainwater use efficiency was attained under sheep penning + 50% FYM in 2009, sheep manure + 50% RDF in 2010, FYM + 50% RDF in 2011, sheep manure + 50% FYM in 2012 and when pooled over years. Highest SYI value was attained under sheep penning + 50% RDF when pooled over years. Sheep penning @5000 per ha over night with 50 % RDF will increase the pod and halum yield with higher net returns and sustainable yield index for rainfed groundnut.

Keywords: Sheep penning, Sheep Manure, Gross Returns, Benefit-Cost Ratio, Rainwater Use Efficiency, Sustainability Yield Index, Groundnut

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Introduction

Rainfed agriculture is crucial to country's economy and food security as it contributes to about 40% of total food grain production and supports two-third of livestock [1]. Groundnut (*Arachis hypogaea* L.) being the predominant crop in Anantapur district grows well in red sandy loam soils. The contribution of Anantapur district to groundnut production was 4.11% in the country. The area during kharif season under rainfed is 8.0 lakh ha, production is 3.98 lakh tonnes and average yield is 510 kg/ha. The annual average rainfall of the district is 557mm. The soils are shallow, low fertility and low moisture holding capacity. Soil erosion including sheet, gully, and wind erosion in some areas is a serious constraint. Simultaneously groundnut crop predominantly growing which is an exhaustive crop and removes large amount of macro and micro nutrients from soil. None of the sources of nutrients can meet the total plant nutrient need of crop adequately. Hence integrated use of nutrients from chemical and different locally available organic sources is the most efficient way [2] for the soil fertility enhancement the organic carbon content plays a major role. In the existing climate and soils of Anantapur the enhancement of organic carbon is a tough task however it is necessary for sustainability. The integration of various crops and animals enables synergistic interaction, which has a greater total contribution than the sum of their individual effects. Sheep and goat manure are relatively lower in moisture content and higher in nutrient value than cattle manure. Average nutrient composition (%) of sheep manure 1.93 nitrogen, 0.6 phosphorous and 1.90 potassium. Anantapur district has highest population of sheep and goat (40.0 lakhs) in Andhra Pradesh. In general farmers keep 3750-5000 sheep per ha overnight for one day to fertilize the lands. This method of sheep penning is the cheapest method to manure the soil. This traditional practice still provides a valuable source of manure for maintaining the fertility status of soil and reduced the cost of production of cultivated crops [3]. As there were more sheep cooperative societies in the district, an experiment was conducted to validate the effect of sheep penning on the soil and crop productivity in rainfed *Alfisols* of Scarce Rainfall Zone of Andhra Pradesh.

Materials and Methods:

Field experiments on groundnut were conducted during *Kharif* 2009 to 2012 under arid *Alfisols* at Anantapur located in the scarce rainfall zone of Andhra Pradesh at a latitude of 14°41' N, longitude of 77°40' E and altitude of 350 meters above mean sea level. The study was conducted with 16 treatment combinations super-imposed to 4 main plots and 4 sub plots in a split-plot design with 3 replications

tested for four year (*kharif* 2009 to 2012). The treatments were control, sheep penning @ 5000 per ha overnight, sheep manure (5 tonnes per ha) and FYM (5tonnes per ha) as main plots, control, 50% FYM, 50% RDF (10-20-25 kg N, P_2O_5, K_2O /ha) and 50% FYM+50% RDF as sub plots. Soil samples were collected after harvest of the crop from 0-30 cm depth in each plot every year and were analyzed for soil organic carbon, soil available nitrogen, and phosphorus and potassium nutrients. Groundnut was sown on 17th August in 2009, while it was sown on 21st June in 2010, 7th July in 2011 and 27th June in 2012. The crop was harvested on 13th December in 2009, while it was harvested on 21st October in 2010, 3rd November in 2011 and 22nd October in 2012. Thus, there was crop duration of 119, 123, 120 and 118 days in 2009, 2010, 2011 and 2012 respectively. The crop seasonal rainfall ranged from 290.6 mm received from 23 rainy days in 2009 to 587.4 mm received from 27 rainy days in 2010. There was a crop seasonal rainfall of 296.6 mm from 22 rainy days in 2011 compared to 331.0 mm from 23 rainy days in 2012.The rainwater use efficiency (RWUE, kg ha^{-1} mm^{-1}) could be derived as ratio of pod yield attained by a treatment and crop seasonal rainfall received in a season as described by Rockstrom *et al*., (2003) [4] and Maruthi Sankar *et al*., (2012 and 2013) [5,6] Observations were collected on pod yield, haulm yield, rainwater use efficiency, gross returns, net returns and benefit-cost ratio at harvest every year. Organics were applied two weeks before sowing of the crop. Nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and muriate of potash respectively at the time of sowing. Post-harvest soil samples (0-30 cm) were analyzed for different physico-chemical properties and organic carbon content by following standard procedures [7]. The sustainability yield index (SYI) would indicate the long term sustainability of a treatment and level of yield that we can attain with an application of a treatment over years. The SYI of each fertilizer treatment could be derived and compared based on the procedure discussed by Maruthi Sankar *et a*l., (2012 and 2013) [5, 6] by using monthly precipitation and respective standard error of treatments. Using the mean yield 'Āi' of treatment 'i' over years; standard error 'PE_i' of treatment 'i' based on the model; and maximum yield (Y_{max}) attained by any treatment in the study period, SYI could be given as

$$SYI = [\{\bar{A}i - PEi\} / Ymax] * 100$$

The SYI could be derived for each treatment and compared for efficiency to attain sustainable yield under arid *Alfisols*.

Results and Discussion

In general, during 2009 delayed sowing (17th August) coincided with three dryspells *i.e*., September 3 to 19, October 3 to 29 and November 18 to December 31 resulted lower yields. During 2010 good distribution of rainfall during sensitive stages of groundnut *viz*., flowering (25 days after sowing), pod development (60-65 days after sowing) and pod filling stage (80-85 days after sowing) high yields were recorded. During 2011 groundnut was suffered due to terminal drought. During 2012, four dry spells of 15 to 26 days duration (total 88 days) were experienced coincided with flowering, pegging and pod development stages of groundnut crop resulting low yields.

Effect of treatments on pod and haulm yield in different years

The treatments differed significantly from each other in influencing groundnut pod yield in different years and also when pooled over years. The pod yield ranged from 366 to 607 kg ha^{-1} in 2009, 2031 to 2626 kg ha^{-1} in 2010, 1593 to 2015 kg ha^{-1} in 2011 and 665 to 879 kg ha^{-1} in 2012 and mean pod yield ranged from 1201 to 1441 kg ha^{-1} [Table-1]. The lowest pod yield was attained under absolute control in 2010, 2011 and also when pooled over years, while it was attained under control + 50% FYM in 2009 and 2012. The maximum pod yield was attained under sheep penning + 50% FYM in 2009, sheep manure+50% RDF in 2010, FYM + 50% RDF in 2011, sheep manure + 50% FYM in 2012 and sheep penning + 50% RDF when pooled over years. Pooled data revealed that sheep penning+50%RDF increased the pod yield by 20% compared to absolute control. This indicating that, apart from the beneficial effect of sheep penning, 50% RDF as immediate supplier of nutrients, increased availability of nutrients, microbial activity, conversions from unavailable to available forms and improved physical, chemical and bio-chemical conditions helped to produce more yield as compared to rainfed conditions. In addition to that the increased soil moisture during the long dry spell and at critical stages helped to produce higher number of pods plant^{-1} and pod and haulm yield. These results are in conformity with the findings of Hosmani *et al*., (2000) [8]. The treatments differed significantly from each other in influencing groundnut haulm yield in different years and also when pooled over years. The haulm yield ranged from 860 to 1382 kg ha^{-1} in 2009, 2199 to 3681 kg ha^{-1} in 2010, 1999 to 3403 kg ha^{-1} in 2011 and 1297 to 1921 kg ha^{-1} in 2012 [Table-1]. The mean haulm yield ranged from 1669 to 2537 kg ha^{-1} with variation of 14.0% over years. The lowest haulm yield was attained under control + control in 2009 and control + 50% FYM in 2012, while it was attained under control + 50% FYM + 50% RDF in 2010, 2011 and when pooled over years. The maximum haulm yield was attained under sheep penning + control in 2009, sheep penning + 50% FYM in 2011 and sheep manure + 50% FYM in 2012, while it was attained under sheep penning + 50% RDF in 2010 and when pooled over years. Pooled data revealed that sheep penning + 50 RDF increased the haulm yield by 52% compared to application of 50% FYM +50% RDF. These results revealed that the increased pod and haulm yield in sheep penning treatment and other treatments was attributed to the beneficial effect of combined use of organic manure, addition of sheep urine increased nutrient availability through enhanced microbial activity, conversions from unavailable to available forms and also due to improved physical, chemical and bio-chemical conditions. These results are in conformity with the findings of Babhulkar *et al*., (2000) [9].

Effect of treatments on gross returns, net returns and benefit-cost ratio in different years

The treatments differed significantly from each other in influencing gross returns from groundnut attained in different years and also when pooled over years. The gross returns ranged from Rs.23490 to Rs.38566 ha^{-1} in 2009, Rs.122475 to Rs.158957 ha^{-1} in 2010, Rs.97978 to Rs.121712 ha^{-1} in 2011 and Rs.41814 to Rs.55886 ha^{-1} in 2012 and mean gross returns ranged from Rs.73598 to Rs.89782 ha^{-1} [Table-2]. The lowest gross returns were attained under absolute control in 2010, 2011 and when pooled over years, while it was attained under control + 50% FYM in 2009 and 2012. The maximum gross returns were attained under sheep penning + 50% FYM in 2009, sheep penning + 50% RDF in 2010 and when pooled over years, FYM + 50% RDF in 2011 and sheep manure + 50% FYM in 2012. The treatments differed significantly from each other in influencing net returns attained from groundnut in different years and also when pooled over years. The net returns ranged from (-) Rs.1376 to Rs.12629 ha^{-1} in 2009, Rs.98685 to Rs.133020 ha^{-1} in 2010, Rs.71693 to Rs.94775 ha^{-1} in 2011 and Rs.16830 to Rs.29449 ha^{-1} in 2012 and mean net returns ranged from Rs.50037 to Rs.63845 ha^{-1} [Table-3]. The lowest net returns were attained under FYM + 50% FYM in 2009, control + 50% RDF in 2010, FYM + 50% FYM + 50% RDF in 2011, sheep penning + 50% FYM + 50% RDF in 2012 and control + 50% FYM when pooled over years. The maximum net returns were attained under sheep penning + 50% FYM in 2009, sheep penning + 50% RDF in 2010 and when pooled over years, FYM + 50% RDF in 2011 and sheep manure + 50% FYM in 2012. The treatments differed significantly from each other in influencing the benefit-cost ratio from groundnut attained in different years and also when pooled over years. The benefit-cost ratio ranged from 0.95 to 1.49 in 2009, 4.95 to 6.23 in 2010, 3.54 to 4.66 in 2011 and 1.62 to 2.11 in 2012 and mean benefit-cost ratio ranged from 2.87 to 3.52 [Table-5]. The lowest benefit-cost ratio was attained under FYM + 50% FYM in 2009, while it was attained under control + 50% FYM + 50% RDF in 2010; FYM + 50% FYM + 50% RDF in 2011 and pooled over years and sheep penning + 50% FYM + 50% RDF in 2012. The maximum benefit-cost ratio was attained under sheep penning + 50% FYM in 2009, while it was attained under sheep manure + control in 2010; sheep penning + control in 2011 and when pooled over years; and sheep manure + 50% FYM in 2012.

Effect of treatments on rainwater use efficiency in different years

The treatments differed significantly from each other in influencing the rainwater use efficiency attained from groundnut in different years and also when pooled over years. The rainwater use efficiency ranged from 1.26 to 2.09 kg ha^{-1} mm^{-1} in 2009, 3.46 to 4.47 kg ha^{-1} mm^{-1} in 2010, 5.37 to 6.79 kg ha^{-1} mm^{-1} in 2011 and

Table-1 *Effect of sheep penning with organic and inorganic treatments on pod and haulm yield of groundnut in different years*

Main plot	Sub plot	Pod yield (kg ha^{-1})					Haulm yield (kg ha^{-1})				
		2009	2010	2011	2012	Mean	2009	2010	2011	2012	Mean
Control	Control	443	2031	1593	739	1201	860	2230	2392	1335	1704
Control	50% FYM	366	2221	1611	665	1216	870	2431	2292	1297	1722
Control	50% RDF	484	2033	1633	767	1229	893	2407	2022	1598	1730
Control	50% FYM + 50% RDF	420	2138	1844	749	1288	880	2199	1999	1597	1669
Sheep penning	Control	535	2486	1870	720	1403	1382	3495	2817	1798	2373
Sheep penning	50% FYM	607	2367	1820	714	1377	1316	3572	3403	1852	2536
Sheep penning	50% RDF	550	2595	1852	769	1441	1268	3681	3357	1844	2537
Sheep penning	50% FYM + 50% RDF	583	2421	1670	678	1338	1184	3302	2601	1790	2219
Sheep manure	Control	472	2594	1830	764	1415	893	3024	2601	1659	2044
Sheep manure	50% FYM	566	2471	1832	879	1437	971	2793	2562	1921	2062
Sheep manure	50% RDF	537	2626	1786	809	1439	953	2809	2631	1898	2073
Sheep manure	50% FYM + 50% RDF	475	2483	1718	870	1386	1033	3033	2315	1898	2070
FYM	Control	421	2277	1674	674	1262	880	2485	2392	1382	1785
FYM	50% FYM	403	2461	1768	750	1345	863	2716	2623	1528	1932
FYM	50% RDF	482	2441	2015	717	1414	979	2507	2292	1759	1884
FYM	50% FYM + 50% RDF	456	2454	1647	717	1319	1020	2701	2007	1841	1892
SEm ± (Main plot)		*29*	*78*	*83*	*50*	*42*	*45*	*126*	*108*	*98*	*92*
CD (P=0.05)		*101*	*269*	*289*	*175*	*134*	*155*	*437*	*374*	*339*	*295*
SEm ± (Sub plot)		*31*	*46*	*62*	*24*	*19*	*45*	*65*	*95*	*53*	*42*
CD (P=0.05)		*91*	*134*	*180*	*69*	*54*	*131*	*191*	*276*	*154*	*122*
SEm ± (Main X Sub)		*62*	*102*	*130*	*56*	*45*	*90*	*150*	*193*	*120*	*101*
CD (P=0.05)		*181*	*297*	*378*	*163*	*130*	*262*	*439*	*562*	*350*	*291*

Table-2 *Effect of sheep penning with organic and inorganic treatments on gross and net returns of groundnut in different years*

Main plot	Sub plot	Gross returns (Rs ha^{-1})					Net returns (Rs ha^{-1})				
		2009	2010	2011	2012	Pooled	2009	2010	2011	2012	Pooled
Control	Control	27830	122475	97978	46109	73598	4643	99288	74791	22922	50411
Control	50% FYM	23490	133889	98703	41814	74474	-947	109452	74266	17377	50037
Control	50% RDF	30267	123122	99146	48493	75257	5830	98685	74709	24056	50820
Control	50% FYM + 50% RDF	26600	128463	111104	47504	78418	663	102526	85167	21567	52481
Sheep penning	Control	34659	152168	115059	46414	87075	9972	127481	90372	21727	62388
Sheep penning	50% FYM	38566	145655	113930	46254	86101	12629	119718	87993	20317	60164
Sheep penning	50% RDF	35174	158957	115634	49365	89782	9237	133020	89697	23428	63845
Sheep penning	50% FYM + 50% RDF	36821	147923	102992	44017	82938	9634	120736	75805	16830	55751
Sheep manure	Control	29582	156912	112131	48506	86783	4395	131725	86944	23319	61596
Sheep manure	50% FYM	35213	149226	112128	55886	88113	8776	122789	85691	29449	61676
Sheep manure	50% RDF	33487	158127	109715	51808	88284	7050	131690	83278	25371	61847
Sheep manure	50% FYM + 50% RDF	30173	150648	104871	55266	85239	2486	122961	77184	27579	57552
FYM	Control	26674	137262	102614	42582	77283	987	111575	76927	16895	51596
FYM	50% FYM	25561	148425	108627	47333	82486	-1376	121488	81690	20396	55549
FYM	50% RDF	30448	146640	121712	46165	86241	3511	119703	94775	19228	59304
FYM	50% FYM + 50% RDF	29091	147961	99880	46393	80831	904	119774	71693	18206	52644
SEm ± (Main plot)		*1765*	*4780*	*4868*	*3139*	*2550*	*1765*	*4780*	*4868*	*3139*	*2550*
CD (P=0.05)		*6110*	*16544*	*16848*	*10864*	*8159*	*6110*	*16544*	*16848*	*10864*	*8159*
SEm ± (Sub plot)		*1879*	*2662*	*3532*	*1438*	*1097*	*1879*	*2662*	*3532*	*1438*	*1097*
CD (P=0.05)		*7430*	*7771*	*10310*	*4197*	*3145*	*5484*	*7770*	*10310*	*4197*	*3145*
SEm ± (Main X Sub)		*3730*	*5983*	*7441*	*3441*	*2687*	*3730*	*5983*	*7441*	*3441*	*2687*
CD (P=0.05)		*10887*	*17463*	*21720*	*10044*	*7704*	*10887*	*17463*	*21720*	*10044*	*7703*

2.01 to 2.66 kg ha^{-1} mm^{-1} in 2012 and mean rainwater use efficiency ranged from 3.12 to 3.75 kg ha^{-1} mm^{-1} [Table-5]. The lowest rainwater use efficiency was attained under control + 50% FYM in 2009, 2012 and when pooled over years; control + 50% RDF in 2010 and control + control in 2011. The maximum rainwater use efficiency was attained under sheep penning + 50% FYM in 2009, sheep manure + 50% RDF in 2010, FYM + 50% RDF in 2011, sheep manure + 50% FYM in 2012 and when pooled over years.

Effect of treatments on soil fertility of nutrients

The soil organic carbon was significantly influenced by both main and sub-plot treatments in 2011 and 2012 and when pooled over years, while they did not influence in 2009 and 2010 [Table-4]. The soil organic carbon ranged from 0.38 to 0.56% in 2009, 0.32 to 0.61% in 2010, 0.26 to 0.76% in 2011 and 0.22 to 0.81% in 2012 and pooled mean ranged from 0.30 to 0.67%. The lowest soil organic carbon occurred under absolute control in all the 4 years and also when pooled over years. The maximum soil organic carbon occurred under sheep penning + 50% FYM in 2009, sheep penning + 50% FYM + 50% RDF in 2010, sheep manure + 50% FYM in 2011, while it occurred under sheep penning + 50% FYM in 2012.Four year pooled mean indicated that significantly higher organic carbon was recorded with sheep penning + 50% FYM application (0.67%) and lowest with absolute control (0.36%).The initial organic carbon content of the soils was 0.36%. After imposing the treatments post-harvest soil organic carbon enhanced slightly. Low organic carbon was due to low input of FYM and crop residues as well as rapid rate of decomposition due to high temperature. The organic matter degradation and removal taken place at faster rate coupled with low vegetation cover thereby leaving less chances of accumulation of organic matter in the soil. These observations are in accordance with Srinivasa Rao *et al*., (2009) [10]. Control treatment recorded lowest 0.36% organic carbon as against the initial (0.34%). This slight increase may be attributed to post harvest soil might have got the addition of crop dry matter and also groundnut being the legume might have contributed. Whereas, the highest organic carbon content was observed in with sheep penning + 50% FYM application (0.67%) followed by sheep penning + 50% FYM+50%RDF. It may be due to addition of organic manure and sheep urine overnight in a fixed plots over four consecutive *kharif* which stimulated the growth and activity of microorganisms, also due to better root growth. These observations are in line with the findings of Sudhir *et al*., (1995) [11].

Table-3 *Effect of sheep penning with organic and inorganic treatments on benefit-cost ratio and rainwater use efficiency of groundnut in different years*

Main plot	Sub plot	Benefit-cost ratio					Rainwater use efficiency (kg ha^{-1} mm^{-1})				
		2009	2010	2011	2012	Pooled	2009	2010	2011	2012	Pooled
Control	Control	1.20	5.28	4.23	1.99	3.17	1.52	3.46	5.37	2.23	3.14
Control	50% FYM	0.96	5.48	4.04	1.71	3.05	1.26	3.78	5.43	2.01	3.12
Control	50% RDF	1.24	5.04	4.06	1.98	3.08	1.66	3.46	5.51	2.32	3.24
Control	50% FYM + 50% RDF	1.02	4.95	4.28	1.83	3.02	1.45	3.64	6.22	2.26	3.39
Sheep penning	Control	1.40	6.16	4.66	1.88	3.52	1.84	4.23	6.30	2.18	3.64
Sheep penning	50% FYM	1.49	5.62	4.39	1.78	3.32	2.09	4.03	6.14	2.16	3.60
Sheep penning	50% RDF	1.36	6.13	4.46	1.90	3.46	1.89	4.42	6.24	2.32	3.72
Sheep penning	50% FYM + 50% RDF	1.35	5.44	3.79	1.62	3.05	2.01	4.12	5.63	2.05	3.45
Sheep manure	Control	1.17	6.23	4.45	1.93	3.44	1.62	4.41	6.17	2.31	3.63
Sheep manure	50% FYM	1.33	5.65	4.24	2.11	3.33	1.95	4.21	6.18	2.66	3.75
Sheep manure	50% RDF	1.27	5.98	4.15	1.96	3.34	1.85	4.47	6.02	2.44	3.69
Sheep manure	50% FYM + 50% RDF	1.09	5.44	3.79	2.00	3.08	1.64	4.23	5.79	2.63	3.57
FYM	Control	1.04	5.34	3.99	1.66	3.01	1.45	3.88	5.64	2.04	3.25
FYM	50% FYM	0.95	5.51	4.03	1.76	3.06	1.39	4.19	5.96	2.27	3.45
FYM	50% RDF	1.13	5.44	4.52	1.71	3.20	1.66	4.16	6.79	2.17	3.69
FYM	50% FYM + 50% RDF	1.03	5.25	3.54	1.64	2.87	1.57	4.18	5.55	2.17	3.37
SEm ± (Main plot)		*0.07*	*0.18*	*0.19*	*0.12*	*0.08*	*0.10*	*0.13*	*0.28*	*0.15*	*0.08*
CD (P=0.05)		*0.23*	*0.64*	*0.65*	*0.42*	*0.24*	*0.35*	*0.46*	*0.97*	*0.53*	*0.25*
SEm ± (Sub plot)		*0.07*	*0.10*	*0.13*	*0.06*	*0.05*	*0.11*	*0.08*	*0.21*	*0.07*	*0.05*
CD (P=0.05)		*0.21*	*0.30*	*0.39*	*0.16*	*0.14*	*0.31*	*0.23*	*0.61*	*0.21*	*0.16*
SEm ± (Main X Sub)		*0.14*	*0.23*	*0.28*	*0.13*	*0.10*	*0.21*	*0.17*	*0.44*	*0.17*	*0.12*
CD (P=0.05)		*0.42*	*0.68*	*0.82*	*0.39*	*0.30*	*0.62*	*0.51*	*1.27*	*0.49*	*0.33*

Table-4 *Effect of sheep penning with organic and inorganic treatments on soil organic carbon and soil available potassium in different years*

Main plot	Sub plot	Soil organic carbon (%)					Soil available Potassium (kg ha^{-1})				
		2009	2010	2011	2012	Pooled	2009	2010	2011	2012	Pooled
Control	Control	0.39	0.36	0.36	0.34	0.36	198.0	197.3	193.7	192.3	195.3
Control	50% FYM	0.38	0.41	0.42	0.44	0.41	200.7	208.0	211.7	213.7	208.5
Control	50% RDF	0.40	0.43	0.47	0.53	0.46	205.7	221.3	245.7	247.0	229.7
Control	50% FYM + 50% RDF	0.41	0.45	0.51	0.57	0.48	208.3	228.0	271.0	285.7	248.2
Sheep penning	Control	0.48	0.57	0.61	0.70	0.59	336.3	479.3	485.7	491.7	448.3
Sheep penning	50% FYM	0.59	0.59	0.70	0.81	0.67	240.3	368.7	393.0	398.3	350.0
Sheep penning	50% RDF	0.47	0.53	0.57	0.64	0.55	245.3	361.3	371.7	383.0	340.2
Sheep penning	50% FYM + 50% RDF	0.56	0.61	0.64	0.67	0.62	259.7	288.0	296.0	394.7	309.5
Sheep manure	Control	0.38	0.61	0.63	0.66	0.57	214.3	222.7	223.3	224.7	221.2
Sheep manure	50% FYM	0.38	0.52	0.76	0.77	0.61	218.7	229.3	232.7	242.7	230.7
Sheep manure	50% RDF	0.38	0.60	0.67	0.78	0.61	202.7	214.3	219.3	232.0	217.0
Sheep manure	50% FYM + 50% RDF	0.52	0.56	0.69	0.69	0.61	215.0	219.0	223.3	225.0	220.5
FYM	Control	0.35	0.39	0.45	0.48	0.42	202.0	213.7	215.7	225.3	214.2
FYM	50% FYM	0.45	0.49	0.62	0.67	0.56	203.1	207.3	228.7	246.0	221.2
FYM	50% RDF	0.41	0.46	0.66	0.72	0.56	203.4	208.0	210.7	217.3	209.9
FYM	50% FYM + 50% RDF	0.46	0.57	0.63	0.66	0.58	204.7	205.7	207.0	209.7	206.8
Initial values		0.36					196.0				
SEm ± (Main plot)		0.06	0.08	0.01	0.01	0.04	20.3	14.8	0.8	2.2	24.6
CD (P=0.05)		NS	NS	0.02	0.01	0.12	70.2	51.2	3.2	7.5	78.8
SEm ± (Sub plot)		0.04	0.05	0.01	0.01	0.02	18.8	18.2	3.3	4.7	9.0
CD (P=0.05)		NS	NS	0.02	0.02	0.05	NS	NS	9.6	13.7	25.9
SEm ± (Main X Sub)		0.08	0.11	0.01	0.01	0.04	38.0	35.6	6.1	8.8	23.6
CD (P=0.05)		0.25	0.32	0.04	0.32	0.12	111.1	103.9	18.1	25.9	67.7

The soil potassium ranged from 198.0 to 336.3 kg ha^{-1} in 2009, 197.3 to 479.3 kg ha^{-1} in 2010, 193.7 to 485.7 kg ha^{-1} in 2011 and 192.3 to 491.7 kg ha^{-1} in 2012 and mean soil potassium ranged from 195.3 to 448.3 kg ha^{-1} [Table-4]. The lowest soil potassium occurred under absolute control in all the four years. The maximum soil potassium occurred under sheep penning + control in all the 4 years. The soil potassium was significantly influenced by main plot treatments in all the 4 years and when pooled over years. However, the sub-plot treatments had a significant effect on soil potassium in 2011, 2012 and when pooled over years. A significant interaction effect of main and sub-plot treatments was observed in all the years. Pooled mean indicated that significantly higher soil potassium was recorded with sheep penning compared to all other treatments.

Sustainability yield index of treatments

Using the mean yield of treatments over years, prediction error based on the regression model and maximum yield of 2626 kg ha^{-1} attained by sheep manure + 50% RDF during 2010, the sustainability yield index (SYI) values were determined for each treatment [Table-5]. The SYI values of treatments ranged from 51.9 to 74.6% in 2010, 35.2 to 51.3% in 2011 and 0 to 8.0% in 2012, while the yields could not be sustained in 2009. The SYI values based on the pooled data over years ranged from 20.3 to 29.5% based on the study. The lowest SYI values occurred under control + control in 2010 and 2011 and when pooled over years, compared to control + 50% FYM in 2009 and 2012. The highest SYI values occurred under sheep penning + 50% FYM in 2009, sheep manure + 50% RDF in 2010, FYM + 50% RDF in 2011 and sheep manure + 50% FYM in 2012. However, the highest SYI value was attained under sheep penning + 50% RDF when pooled over years. Based on the SYI values, the treatments were found to have a lower coefficient of variation in 2010 and 2011 compared to 2009 and 2012. In 2010, sheep penning + 50% RDF and sheep manure + control were the 2nd and 3rd best treatments with SYI values of 73.4 and 73.3% respectively. In 2011, sheep penning + control and sheep penning + 50% RDF were 2nd and 3rd best with SYI values of 45.8 and 45.1% respectively. However, based on the pooled data over years, sheep manure + 50% RDF and sheep manure + 50% FYM were 2nd and 3rd best with SYI values of 29.4 and 29.3% respectively. Thus, it can be concluded that sheep penning @5000 per ha over night with 50 % RDF will increase the pod and haulm yield with higher net returns and sustainable yield index for rainfed groundnut.

Table-5 *Sustainability yield index of sheep penning with organic and inorganic treatments in groundnut during 2009 to 2012*

Main plot	Sub plot	2009	2010	2011	2012	Mean
Control	Control	-8.6	51.9	35.2	2.7	20.3
Control	50% FYM	-11.5	59.1	35.9	-0.1	20.9
Control	50% RDF	-7.0	52.0	36.7	3.8	21.4
Control	50% FYM + 50% RDF	-9.4	56.0	44.8	3.1	23.6
Sheep penning	Control	-5.1	69.2	45.8	2.0	28.0
Sheep penning	50% FYM	-2.3	64.7	43.9	1.8	27.0
Sheep penning	50% RDF	-4.5	73.4	45.1	3.8	29.5
Sheep penning	50% FYM + 50% RDF	-3.2	66.8	38.2	0.4	25.5
Sheep manure	Control	-7.5	73.3	44.2	3.7	28.4
Sheep manure	50% FYM	-3.9	68.7	44.3	8.0	29.3
Sheep manure	50% RDF	-5.0	74.6	42.6	5.4	29.4
Sheep manure	50% FYM + 50% RDF	-7.3	69.1	40.0	7.7	27.4
FYM	Control	-9.4	61.3	38.3	0.2	22.6
FYM	50% FYM	-10.1	68.3	41.9	3.1	25.8
FYM	50% RDF	-7.1	67.5	51.3	1.9	28.4
FYM	50% FYM + 50% RDF	-8.1	68.0	37.3	1.9	24.8
Min		*-11.5*	*51.9*	*35.2*	*-0.1*	*20.3*
Max		*-2.3*	*74.6*	*51.3*	*8.0*	*29.5*
Mean		*-6.9*	*65.2*	*41.6*	*3.1*	*25.8*
SD		*2.6*	*7.2*	*4.4*	*2.4*	*3.2*
CV		*-38.5*	*11.0*	*10.7*	*77.0*	*12.3*

Application of research: During 1991-2000, Nutrient Response Ratio declined to 6 kg grain/kg applied nutrient from 17.9 kg grain/kg applied nutrient during 1960-1970. Redressal of the complex problem of multi-nutrient deficiencies is possible through sheep penning. This assumes great significance in enhancing the nutrient use efficiency, reducing amount and cost of fertilizers thereby increasing income with reduced environmental load. There is need to make sheep penning options more cost-effective and user friendly for their widespread adoption by the farmers. There is need to optimize the management of low cost on-farm inputs and minimize the use of costly off-farm inputs to lower the production costs; avoid pollution of surface and ground water; and reduce pesticide residues in food. We should develop and promote location specific cost-effective agro-techniques to harness the yield potential of the variety for realizing higher income.

Research Category: Soil health management

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***Principle Investigator or Chairperson of research: Dr B. Sahadeva Reddy**
University: Acharya N. G. Ranga Agricultural University, Lam, 522034
Research project name or number: AICRP for Dryland Agriculture, ANGRAU, Anantapur

Author Contributions: All author equally contributed

Author statement: All authors read, reviewed, agree and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: *Kharif* 2009 to 2012 under arid *Alfisols* at Anantapur located in the scarce rainfall zone of Andhra Pradesh

Cultivar / Variety name: *Arachis hypogaea* L

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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