The Pharma Innovation Journal 2021; 10(11): 1914-1919

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(11): 1914-1919

www.thepharmajournal.com
Received: 13-08-2021
Accepted: 19-10-2021

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Comparative effect of integrated nutrient management under rainfed and protective irrigated condition on nutrient dynamics and productivity of groundnut (*Arachis hypogaea* L.)

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Abstract
The experiment was conducted during two consecutive *kharif* seasons of 2014 and 2015. During both the years, supply of 100 per cent of nitrogen through sheep penning (T_9) recorded significantly higher pod and haulm yield of groundnut, which was comparable with 50 per cent nitrogen through urea + 50 per cent nitrogen through farm yard manure (T_3) and recommended dose of fertilizer (T_2) under rainfed situation. Under protective irrigation, additionally comparable with application of 50 per cent nitrogen through urea + 50 per cent nitrogen through leaf compost (T_5). Control (T_1) recorded the lower pod and haulm yield of groundnut at both the situations during the two consecutive years of investigation. At all the stages of the crop growth the higher nitrogen and phosphorus uptake of groundnut was registered with100 per cent nitrogen through sheep penning (T_9), which was in parity with recommended dose of fertilizers (T_2) at both the situations during the two consecutive years of investigation. Higher potassium uptake in groundnut was recorded with application of 100 per cent nitrogen through sheep penning (T_9) while lower N, P and K was associated with control (T_1). Significantly higher post-harvest soil available nitrogen status was recorded with 100 per cent nitrogen through organic sources *viz*., FYM, sheep penning, leaf compost, sheep manure and enriched groundnut shells (T_4, T_9, T_6, T_8 and T_{10}) over other nutrient management practices tried during 2014 and 2015 under rainfed and protective irrigated situations. The post-harvest soil available phosphorus recorded with 100 per cent nitrogen through sheep penning, leaf compost, enriched groundnut shells and sheep manure (T_9 T_6 T_{10} and T_8) was comparable among themselves and significantly superior over other treatments. Application of 100 per cent nitrogen through sheep penning (T_9) recorded maximum post-harvest soil available potassium, which was in parity with application of 100 per cent nitrogen either through sheep manure (T_8) or enriched groundnut shells (T_{10}). Whereas, the minimum values of post-harvest soil available nitrogen, phosphorus and potassium were registered with control (T_1).

Keywords: Groundnut, integrated nutrient management, nutrient dynamics, productivity

Introduction
Groundnut (*Arachis hypogaea* L.) is the premier oilseed crop contributing 40 per cent of the total oil seed production in India, but its production and productivity needs to be significantly enhanced to meet the national shortage of availability of edible oil in India, which is about 14.10 kg $head^{-1}$ $year^{-1}$ against the balanced nutritional requirement of 14.80 kg $head^{-1}$ $year^{-1}$ and to meet the vegetable oil requirement of our country, we have to increase the oil seeds production from the present level of 29.75 million tonnes to about 55.0 million tonnes by 2020 AD (Hegde, 2009) [5]. The productivity of *kharif* groundnut is low and highly fluctuating in alfisols of drylands mainly due to low organic matter content, poor fertility status, imbalanced use of high analysis chemical fertilizers accompanied by restricted use of organic manures, which made the soils not only deficient in secondary and micronutrients, but also deteriorated the soil health (Akbari *et al*., 2011) [1]. To alleviate the problem, the effective and integrated use of locally available organic resources such as the farm yard manure, leaf compost, groundnut shells, sheep manure along with inorganic sources are the suitable strategies to improve the yield and quality of groundnut (Rao *et al*., 2103) [9]. Apart from the integrated use of nutrient sources, the exploration of the predominant practice of sheep penning in the region is at most necessary to build the soil fertility for enhanced groundnut productivity in the rainfed alfisols of Andhra Pradesh (Reddy *et al*., 2010) [11].

The nutrient management with organic and inorganic sources along with protective irrigation at critical crop growth stages despite the vagaries of rainfall will sustain the production system. Keeping this in view, the present investigation was carried for two consecutive years (*kharif*, 2014 and 2015) at Agricultural Research Station, Ananthapuramu to find out the most suitable combination of chemical fertilizer from locally available organic sources for hungry, thirsty and poor fertile alfisols of drylands in Andhra Pradesh.

Materials and Methods

A Field experiments was conducted at Agricultural Research Station, Ananthapuramu during *kharif* 2014 and 2015 in a fixed plots for two consecutive seasons to study effect of various nutrient sources on productivity and economics of groundnut (*Arachis hypogaea* L.) in scarce rainfall zone of Andhra Pradesh. The experiment was laid out in completely randomized block design with three replications in two separate blocks *viz.*, purely rainfed block and protective irrigation block. Each block comprised of eleven same treatments *viz.*, T_1: Control (no organics and inorganics), T_2: Recommended dose of fertiliser (RDF) (20 kg N ha^{-1}: 40 kg P_2O_5 $_{ha}^{-1}$: 40 kg K_2O ha^{-1}), T_3: 50% nitrogen through urea + 50% nitrogen through FYM, T_4: 100% nitrogen through FYM, T_5: 50% nitrogen through urea + 50% nitrogen through leaf compost, T_6: 100% nitrogen through leaf compost, T_7: 50% nitrogen through urea + 50% nitrogen through sheep manure, T_8: 100% nitrogen through sheep manure, T_9: 100% nitrogen through sheep penning, T_{10}: 100% nitrogen through enriched groundnut shells and T_{11}: 50% nitrogen through urea + 50% nitrogen through enriched groundnut shell. The soil type of experimental trial was alfisol with pH 6.42, EC 0.42 dS m^{-1}, low available nitrogen (198 kg ha^{-1}), medium available phosphorus (48 kg ha^{-1}), low available potassium (191 kg ha^{-1}) and low organic carbon (0.38%). Organics were applied two weeks before sowing. FYM, well-rotted gliricidia leaf compost and sheep manure was applied as per treatments based on equivalent nitrogen basis to meet the initial nitrogen requirement of the crop. Enriched groundnut shells were prepared by spreading the groundnut shells overnight on the floor of the cattle shed so that groundnut shells get trampled well and mixed with the cattle dung and urine. In the following day, the enriched groundnut shells along with dung and urine were collected and applied to the experimental plots as per the treatments based on equivalent nitrogen basis to meet the initial nitrogen requirement of the crop. In sheep penning plots of the experiment, the sheep (@ 2 no. m^{-2}) was allowed to stay overnight in the field. The sheep penning plots were temporarily netted to keep the flock uniformly in the allocated plots overnight. The droppings of both urine and fecal matter falling on the soil were incorporated to a shallow depth of the soil by running a blade harrow. Nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and muriate of potash respectively at the time of sowing. During 2014, *kharif* season, under protective irrigation block 2 times protective irrigation was given at 55 DAS and at 75 DAS and during 2015 *kharif* protective irrigation given at 75 DAS. Each time 20 mm of irrigation was given with sprinkler irrigation by measuring with water meter. Nutrient uptake and post-harvest soil samples were analyzed for different physico-chemical properties and organic carbon content by following standard procedures. The test variety used in the present experiment Kadiri-6 was sown. All observations on yield and nutrient dynamics were statistically analyzed as suggested by Gomez and Gomez (1984) [4].

Results and Discussion

Pod Yield

Under rainfed condition during *kharif*, 2014 and 2015, the highest pod yield (842 and 1530 kg ha^{-1}) of groundnut was recorded with supply of 100 per cent nitrogen through sheep penning (T_9) (Table.1), which was at par with 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM (T_3) and recommended dose of fertilizer (T_2). Application of 100 per cent nitrogen through sheep penning (T_9) resulted in 69 and 89 per cent higher pod yield during 2014 and 2015 respectively, over control. Pod yield of groundnut is a function of yield attributes, which was significantly higher with these nutrient management practices. Application of 50 per cent nitrogen through urea + 50 per cent nitrogen either through leaf compost (T_5) or FYM (T_4), or sheep manure (T_7) or enriched groundnut shells (T_{11}) were the next best treatments and were comparable among themselves. Under protective irrigation during *kharif*, 2014 and 2015 the highest pod yield of groundnut was recorded with supply of 100 per cent nitrogen through sheep penning (T_9), which was in parity with 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM (T_3), recommended dose of fertilizer (T_2) and 50 per cent nitrogen through urea + 50 per cent nitrogen through leaf compost (T_5). Application of 100 per cent nitrogen through sheep penning (T_9) resulted in 83 and 57 per cent higher pod yield during 2014 and 2015 respectively over control. Pod yield recorded with 100 per cent nitrogen through FYM (T_4), 50 per cent nitrogen through urea + 50 per cent nitrogen either through sheep manure (T_7) or enriched groundnut shells (T_{11}) were comparable among themselves. The lowest pod yield was recorded with control (T_1). Groundnut crop respond well to different organic sources of nutrients under protective irrigation as compared to rainfed situation. Protective irrigation at pod formation and pod development might have resulted in better moisture and nutrient availability thereby, regaining photosynthetic efficiency of the plant, which in turn resulted in elevated stature of yield attributes owing to higher pod yield of groundnut. Rahevar. (2015) [8] reported that pod yield was recorded higher in application of FYM @ 5 t ha^{-1} along with recommended dose of N could be attributed to increase in main contributor of yield like number of pods, pods weight and 100 kernel weight.

Haulm Yield

Under rainfed condition during *kharif*, 2014 and 2015, the highest haulm yield of groundnut was recorded with application of 100 per cent nitrogen through sheep penning (T_9) (Table 1), which was at par with recommended dose of fertilizer (T_2) and 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM (T_3). Among the other organic sources tried, 50 per cent nitrogen through urea + 50 per cent nitrogen through leaf compost (T_5) recorded higher haulm yield, which was however, comparable with 100 per cent nitrogen through FYM (T_4), 50 per cent nitrogen through urea + 50 per cent nitrogen through sheep manure (T_7) and 50 per cent nitrogen through urea + 50 per cent nitrogen through enriched groundnut shells (T_{11}) in the order of descent with no significant disparity between one another. The lowest haulm yield was registered with control (T_1). Under protective irrigation during both the years of the study, the highest haulm yield of groundnut was recorded with application of 100 per cent nitrogen through sheep penning (T_9), which was however comparable with 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM (T_3) recommended dose of fertilizer (T_2) and 50 per cent nitrogen through urea + 50 per cent nitrogen through leaf compost (T_5). The next best treatment was with application of 100 per cent nitrogen through FYM (T_4) among the various organic sources tried. The lowest haulm yield in groundnut was registered with control (T_1). The increased haulm yield under both farming situations was attributed to the beneficial effect of combined use of organic manure and inorganic fertilizers. Nutrient availability was increased through enhanced microbial activity, which aided in conversion of unavailable to available forms and also due to improved physico-chemical properties of the soil. Similar results of higher haulm yield with the application organic manures were reported by Patil *et al*. (2015) [7].

Nutrient Uptake

Nitrogen Uptake

At all the crop growth stages, significantly highest nitrogen uptake by groundnut was recorded with supply of 100 per cent nitrogen through sheep penning (T_9) (Table 2), which was at par with recommended dose of fertilizers (T_2). Uptake of nitrogen registered with 50 per cent nitrogen through urea and substitution of 50 per cent nitrogen either through FYM (T_3) or leaf compost (T_5) was statistically comparable with each other under rainfed condition. Under protective irrigation application of 100 per cent nitrogen through sheep penning (T_9) recorded the highest nitrogen uptake, which was however at par with recommended dose of fertilizers (T_2) and 50 per cent nitrogen through urea + 50 per cent nitrogen either through leaf compost or FYM (T_3 and T_5) at all the stages of crop growth except at 30 DAS, where it was on par with recommended dose of fertilizers (T_2). The higher nitrogen uptake observed under protective irrigation was ascribed due to higher concentration of available nitrogen under optimal soil moisture condition as compared to rainfed condition. The above results are in agreement with those of Singh *et al*. (2006) [12] and Brar *et al*. (2015) [2]. Control (T_1) resulted in the lowest nitrogen uptake by the plant due to reduced availability of nitrogen in rainfed alfisols.

Phosphorus Uptake

Under rainfed condition during *kharif*, 2014 and 2015, at all the stages of crop growth the highest phosphorus uptake of groundnut was recorded with supply of 100 per cent nitrogen through sheep penning (T_9) (Table.3), which was significantly superior over the rest of the treatments tried. Under protective irrigation, at all the stage of crop growth significantly the highest phosphorus uptake by groundnut was recorded with supply of 100 per cent nitrogen through sheep penning (T_9), but it was however comparable with application of recommended dose of fertilizer (T_2), 50 per cent nitrogen through urea and 50 per cent nitrogen either through FYM or leaf compost (T_3 or T_5) at later stages of crop growth i.e. at 90 DAS and at harvest during both the years of experimentation. The enhanced uptake of phosphorus under protective irrigation as compared to rainfed condition was ascribed due to higher pod yield. Further, balanced application of nutrients particularly nitrogen, phosphorus and potassium might have helped in enhanced phosphorus uptake by the plant with recommended dose of fertilizers during the later stages of the crop growth under protective irrigation. The similar results were reported by Rao *et al*. (2013) [9]. The treatment which received no nitrogen (T_1) recorded significantly the lowest phosphorus uptake in groundnut both under rainfed and protective irrigated condition.

Potassium Uptake

At all the stages of crop growth during both the years of study, supply of 100 per cent nitrogen through sheep penning (T_9) recorded significantly higher potassium uptake over rest of the nutrient management practices tried (Table 4). The sheep penning in groundnut could have increased the exchangeable and water soluble potassium in the soil there by better availability resulting in higher potassium uptake. The results were in conformity with Rao *et al*. (2013) [9]. The concentration of potassium increased as plant growth advances up to mid flowering, at later stages, there was some dilution effect. The haulm retained the major part of potassium accumulated during vegetative growth indicating their utilization for structural and developmental processes and allowed little translocation of potassium into pods (Nathiya and Sanjivkumar, 2014) [6]. Significantly lowest uptake of potassium was noticed with no nitrogen (T_1).

Post-Harvest soil fertility status

Soil Available Nitrogen

During both years of the experimentation, significantly higher post-harvest soil available nitrogen was recorded with supply of 100 per cent nitrogen through organics *i.e.*, FYM (T_4) (Table 5), sheep penning (T_9), leaf compost (T_6), sheep manure (T_8) and enriched groundnut shells (T_{10}) in the order of descent. Irrespective of source, all the organic treatments recorded significantly higher post-harvest soil available nitrogen over rest of the nutrient management practices tried. The increase in the available nitrogen content among organic treatments might be due to increase in nodulation and release of higher amount of nitrogen by the root nodules at early stage of crop growth due to favorable soil environment and their subsequent decomposition at later stages (Nagar *et al.*, 2016) [14]. In contrast to this, Rao *et al.* (2013) [9] reported that most crop land soils in India are deficient in nitrogen partly, because of low concentration of soil organic carbon and nutrient losses due to various reasons in light textured red soils. Non application of nitrogen through any source coupled with exhaustion of native nutrients by the crop might have resulted in the lowest soil available nitrogen in control (T_1).

Soil Available Phosphorus

Under both situations during *kharif*, 2014 and 2015, significantly higher post-harvest soil available phosphorus was recorded with supply of 100 per cent nitrogen through sheep penning (T_9) (Table 5), which was however, comparable with 100 per cent nitrogen through leaf compost (T_6), 100 per cent nitrogen through enriched groundnut shells (T_{10}) and 100 per cent nitrogen through sheep manure (T_8) in the order of descent, which maintained parity with each other. Significantly the lowest post-harvest soil available phosphorus was found with control (T_1). Higher available phosphorus content in soil with addition of organic manures was expected, as groundnut crop utilizes only a fraction of the phosphorus in the organic manures. However, incorporation of organic manures increased the availability of phosphorus and this was attributable to reduction in fixation of water soluble phosphorus, eventually increased mineralization of organic phosphorus due to microbial action and enhanced nutrient mobility (Varalakshmi *et al.*, 2005) [13]. In the control plot (T_1) with no application of phosphorus through any source coupled with exhaustion of native phosphorus by the crop might have resulted in the lower soil available phosphorus.

Soil Available Potassium

Under both situations during *kharif*, 2014 and 2015, significantly higher post-harvest soil available potassium was recorded with application of 100 per cent nitrogen through sheep penning (T_9) (Table 5), at par with 100 per cent nitrogen through sheep manure (T_8) and 100 per cent nitrogen through enriched groundnut shells (T_{10}). The higher availability of potassium with organic manures may be ascribed to the reduction of potassium fixation and release of potassium due to the interaction of organic matter with clay, besides the direct addition of potassium to available pool of the soil (CRIDA, 2010). Control plot (T_1) noted with lessor available potassium, which may be due to non-application of potassium through any source coupled with exhaustion of nutrients by the crop.

Table 1: Pod yield, haulm yield (kg ha^{-1}) and harvest index (%) of groundnut as influenced by organic and inorganic sources of nitrogen

Treatments	Rainfed condition						Protective irrigation					
	Pod yield		Haulm yield		Harvest index		Pod yield		Haulm yield		Harvest index	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
T_1	497	807	1018	1746	32.8	31.6	698	1284	1530	2236	31.3	36.5
T_2	780	1429	1550	2823	33.5	33.6	1119	1951	2675	3320	29.5	37.0
T_3	801	1496	1496	2738	34.9	35.3	1209	1997	2763	3401	30.4	37.0
T_4	739	1290	1437	2530	34.0	33.8	1070	1768	2507	3097	29.9	36.3
T_5	758	1319	1471	2612	34.0	33.6	1098	1879	2641	3231	29.4	36.8
T_6	638	1074	1209	2243	34.5	32.4	842	1437	2184	2840	27.8	33.6
T_7	709	1228	1418	2490	33.3	33.0	1012	1715	2361	3004	30.0	36.3
T_8	671	1104	1260	2302	34.7	32.4	869	1528	2291	2961	27.5	34.0
T_9	842	1530	1696	2944	33.2	34.2	1280	2013	2807	3441	31.3	36.9
T_{10}	611	1020	1187	2198	34.0	31.7	817	1395	2156	2750	27.8	33.7
T_{11}	697	1167	1391	2430	33.4	32.4	997	1603	2340	3021	29.3	34.6
S.Em ±	22.1	61.0	69.0	100	1.2	1.1	66.5	77.9	56.8	85.7	1.2	1.2
CD (P=0.05)	65	181	205	298	NS	NS	197	231	169	254	NS	NS

Table 2: Nitrogen uptake (kg ha^{-1}) at various stages of groundnut as influenced by organic and inorganic sources of nitrogen

Treatments	Rainfed condition								Protective irrigation							
	30 DAS		60 DAS		90 DAS		At harvest		30 DAS		60 DAS		90 DAS		At harvest	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
T_1	6.81	12.54	32.61	58.10	60.36	103.39	65.83	114.27	7.33	12.82	36.46	79.19	97.46	131.22	104.44	139.91
T_2	11.87	18.48	64.41	107.72	101.96	171.06	109.20	172.40	12.60	19.54	69.82	125.72	160.24	204.48	170.58	212.19
T_3	11.02	17.66	62.04	102.65	98.56	159.01	104.03	162.88	11.06	17.43	68.56	121.12	154.78	201.80	163.28	208.94
T_4	8.53	14.16	52.12	90.50	83.05	134.35	88.89	151.06	8.80	14.46	53.24	104.35	133.49	168.39	141.41	174.64
T_5	10.22	15.72	55.82	96.76	91.05	148.08	98.05	155.78	10.48	17.30	68.37	123.24	158.86	205.50	168.61	209.55
T_6	8.17	13.65	47.65	80.55	80.10	132.20	87.37	139.65	8.58	14.04	48.31	92.65	126.35	165.85	134.44	170.28
T_7	9.31	16.80	54.39	90.77	84.15	138.43	90.25	144.38	9.93	16.13	56.78	108.52	136.13	173.03	145.97	179.47
T_8	8.23	13.73	50.29	85.61	79.33	129.93	87.13	139.28	8.85	14.02	52.44	97.94	126.20	166.77	133.01	172.41
T_9	12.53	20.29	69.20	115.69	111.04	180.63	118.69	185.14	12.90	20.63	74.36	131.12	167.51	216.47	178.04	221.31
T_{10}	8.50	14.14	47.51	75.34	77.23	127.79	82.66	132.26	9.00	14.83	45.76	86.24	122.79	160.09	134.26	166.55
T_{11}	9.23	15.69	50.68	85.23	81.00	130.85	86.39	138.24	9.60	16.02	52.86	100.45	127.57	170.56	139.98	179.32
S.Em ±	0.42	0.75	2.32	3.94	3.16	4.59	3.31	4.59	0.51	0.69	2.12	3.85	4.91	5.26	4.44	4.67
CD(P=0.05)	1.25	2.24	6.90	11.71	9.40	13.65	9.84	13.64	1.53	2.05	6.32	11.43	14.61	15.64	13.21	13.87

Table 3: Phosphorus uptake (kg ha^{-1}) at various stages of groundnut as influenced by organic and inorganic sources of nitrogen

Treatments	Rainfed condition								Protective irrigation							
	30 DAS		60 DAS		90 DAS		At harvest		30 DAS		60 DAS		90 DAS		At harvest	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
T_1	1.31	2.31	4.00	6.70	7.85	12.79	8.35	13.77	1.39	2.42	4.19	9.13	12.05	16.22	12.59	16.48
T_2	2.05	3.38	7.17	11.13	13.06	19.47	13.90	20.28	2.12	3.40	7.92	13.68	18.87	24.16	20.46	24.98
T_3	1.95	3.12	6.97	11.22	12.89	18.96	13.61	19.41	2.03	3.24	7.68	13.14	18.60	23.98	20.08	24.79
T_4	1.73	2.88	5.91	9.84	10.61	15.78	11.45	16.79	1.76	2.94	6.04	11.84	16.03	19.95	16.05	21.53
T_5	1.81	3.04	6.12	10.24	11.00	17.23	11.95	17.48	2.00	3.19	7.53	12.92	18.16	23.91	19.94	24.72
T_6	1.63	2.79	5.87	9.31	10.28	16.58	11.36	16.94	1.72	2.88	5.88	11.40	15.88	20.81	16.20	21.77
T_7	1.78	2.99	6.10	10.19	10.98	17.10	11.65	17.35	1.84	3.05	6.38	12.18	16.27	21.89	16.67	22.70
T_8	1.70	2.84	5.90	9.57	10.43	16.36	11.40	17.12	1.83	2.90	6.12	11.42	14.28	20.49	16.22	21.82
T_9	2.31	3.93	8.01	13.39	14.47	21.87	15.50	22.91	2.38	3.78	8.64	15.33	19.49	25.10	20.75	25.97
T_{10}	1.73	2.76	5.80	9.46	9.91	14.96	11.30	15.20	1.70	2.86	6.10	11.39	14.97	19.67	15.34	21.44
T_{11}	1.76	2.89	6.06	10.21	10.71	15.86	11.51	17.06	1.79	2.95	6.34	11.96	15.46	19.95	16.04	21.75
S.Em ±	0.07	0.10	0.16	0.32	0.25	0.78	0.23	0.88	0.06	0.08	0.15	0.27	0.49	0.40	0.31	0.41
CD (P=0.05)	0.20	0.30	0.49	0.96	0.74	2.34	0.70	2.61	0.19	0.24	0.45	0.80	1.46	1.21	0.94	1.28

Table 4: Potassium uptake (kg ha^{-1}) at various stages of groundnut as influenced by organic and inorganic sources of nitrogen

Treatments	Rainfed condition								Protective irrigation							
	30 DAS		60 DAS		90 DAS		At harvest		30 DAS		60 DAS		90 DAS		At harvest	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
T_1	8.94	16.23	17.71	31.51	31.35	53.69	33.29	57.85	9.73	16.99	19.73	39.87	50.61	68.12	52.84	72.24
T_2	13.25	21.78	34.51	56.58	54.31	87.57	57.35	90.64	13.80	22.38	36.64	60.14	82.02	110.19	86.77	112.13
T_3	13.10	21.49	32.90	54.60	53.22	86.85	56.13	88.91	13.64	21.98	35.31	59.61	80.70	109.53	84.73	111.37
T_4	11.72	19.54	27.52	47.82	42.92	71.59	44.44	73.84	12.11	19.61	28.13	52.32	68.15	95.16	70.27	98.30
T_5	12.25	19.82	28.67	50.43	44.68	73.23	47.22	77.24	12.61	20.64	30.22	54.95	79.79	108.24	84.41	106.63
T_6	11.68	18.27	27.42	47.98	42.92	69.58	45.75	73.45	11.86	19.30	28.81	51.48	66.37	96.84	68.81	97.05
T_7	12.13	19.74	28.50	49.02	44.21	73.10	46.31	76.58	12.41	20.53	29.45	53.42	69.53	97.91	71.84	101.96
T_8	11.76	19.25	27.29	48.26	42.77	70.09	45.87	73.33	12.18	19.95	28.45	51.08	66.19	96.78	69.50	99.57
T_9	14.50	23.66	36.52	61.06	58.10	94.58	62.26	97.13	14.96	23.94	39.42	69.91	87.70	115.29	93.37	118.64
T_{10}	11.43	18.44	27.08	47.25	42.16	69.44	44.96	73.27	11.71	19.34	27.14	50.86	65.98	94.22	68.09	96.50
T_{11}	11.81	19.57	28.16	48.41	43.37	72.30	46.25	76.39	12.36	20.27	29.38	52.87	68.67	96.90	70.84	99.72
S.Em ±	0.37	0.60	0.59	1.09	0.90	1.30	0.78	1.39	0.36	0.47	0.86	1.40	1.42	1.60	1.53	1.94
CD (P=0.05)	1.12	1.80	1.78	3.24	2.67	3.87	2.34	4.14	1.07	1.41	2.56	4.17	4.24	4.75	4.55	5.76

Table 5: Post-harvest soil available nitrogen, phosphorus and potassium (kg ha^{-1}) as influenced by organic and inorganic sources of nitrogen

Treatments	Rainfed condition						Protective irrigation					
	Available N		Available P_2O_5		Available K_2O		Available N		Available P_2O_5		Available K_2O	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
T_1	192.2	195.3	48.8	49.2	201.6	189.7	190.7	194.1	47.7	48.5	208.6	198.2
T_2	211.3	213.8	52.4	53.1	235.3	238.7	208.6	206.4	50.4	54.2	236.4	237.6
T_3	243.7	260.1	54.7	56.5	256.5	261.1	235.5	257.9	53.4	57.1	259.2	263.3
T_4	281.3	290.4	56.8	57.4	275.2	279.4	263.3	288.2	54.5	58.5	279.0	283.4
T_5	255.7	263.4	55.9	58.9	321.4	324.4	234.7	251.2	55.1	59.8	325.7	330.5
T_6	273.1	283.6	62.2	63.8	333.0	338.0	247.7	279.5	61.8	64.5	338.6	341.9
T_7	250.4	260.9	57.7	59.2	328.9	333.7	226.4	249.2	56.8	60.1	332.8	336.5
T_8	266.6	272.7	60.2	62.5	350.3	354.4	250.9	270.3	59.8	63.7	355.3	360.4
T_9	277.3	286.3	64.5	65.3	366.3	370.6	252.1	280.5	63.7	66.3	370.3	375.3
T_{10}	263.3	271.5	61.8	63.3	355.6	359.7	249.4	264.6	60.9	64.7	357.4	362.1
T_{11}	252.3	262.1	54.2	55.3	329.9	335.5	230.8	253.8	53.8	57.2	334.5	337.8
S.Em ±	7.72	6.72	1.63	1.87	5.80	5.58	5.93	8.46	1.68	1.84	5.07	5.50
CD (P=0.05)	22.93	19.99	4.84	5.55	17.24	16.60	17.62	25.14	5.00	5.48	15.06	16.36

Conclusion

The better performance of groundnut with higher pod yield and sustained soil health were realized with supply of 100 per cent nitrogen through sheep penning or 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM . Hence, it is recommended that sheep penning (@ 2 no. m^{-2} stay overnight) is the most promising, economically viable, environmentally safe and ecologically sustainable option for rainfed alfisols.

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