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Full Length Research Paper

Long-term effect of manure and fertilizers on the physical and chemical properties of an alfisol under semi-arid rainfed conditions

E. Parvathi[1], K. Venkaiah[1], V. Munaswamy[2], M.V.S.Naidu[1],T.Giridhara Krishna[2] and T. N. V. K. V. Prasad[1]*

[1]Department of Soil Science and Agricultural Chemistry S.V.Agricultural College, Acharya N G Ranga Agricultural University, Tirupati, Andhra Pradesh – 517502, India.

[2] Regional Agricultural Research Station, Acharya N G Ranga Agricultural University, Tirupati-517 502, A.P., India.

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The status of nutrients-their depletion and build up in soil and crop productivity after thirty years (1981-2011) of groundnut intensive cropping were studied under continuous use of various inorganic fertilizers and organic manure in an Alfisol. Results showed that application of NPK (20:10:25 kg ha^{-1}) +gypsum+zinc sulphate recorded highest pod yield of 1499 kg ha^{-1} which was on par with NPK+gypsum and FYM alone treated plot. The soil pH and EC did not change significantly but markedly changed the organic carbon and available nutrient contents of the soil. The available phosphorus and potassium were gradually depleted in all the treatments but the magnitude of depletion was less in the treatments which received P and K respectively. Thus, the balanced use of fertilizers continuously either alone or in combination with organic manure is necessary for sustaining soil fertility and productivity of groundnut under rainfed conditions.

Key words: Groundnut, Alfisol, Long-term effect, manure, fertilizer, Physico-Chemical Properties.

INTRODUCTION

Groundnut is an important oil seed crop grown under rainfed conditions in Andhra Pradesh. An ideal soil for groundnut production is well drained, light colored loose and friable sandy loam, which facilitates peg penetration and pod development. Under rainfed conditions, the productivity is very low due to inadequate use of manures and fertilizers. Andhra Pradesh holds key position with an area of 16.22 lac hectares and with production of 14.57 lac tones and with the productivity of 898 kg ha^{-1}.

Groundnut is a base loving oil seed crop and its demand for basic nutrient elements like K and Ca is substantial. Potassium plays a major role in metabolic process and seed yield, improves the quality of seed (Yeledhalli et al., 2007). The challenging of improving the productivity in rainfed areas can be addressed by efficient utilization of nutrients by crops or cropping systems (Acharya et al., 2002). The productivity of groundnut is low in India as compared to other countries mainly due to rain dependency (85%), monoculture (60%) and cultivation on marginal soils of low fertility.

MATERIAL AND METHODS

The long-term fertilizer experiment was initiated during the season *kharif* 1981 Regional Agricultural Research Station, Tirupati, Chittoor district of Andhra Pradesh. The present investigation was carried out during the season *kharif* 2011 on Alfisol soil (*Typic Rhodustalf*) after 30 years of this experimentation in the same field. The experiment involves 11 treatments each replicated four times in a randomized block design. The experiment is being conducted on same site and same randomization. The nutrients were applied through the fertilizers like urea, single super phosphate and muariate of potash. The farmyard manure and zinc sulphate were not applied in this season. The test crop was groundnut, variety

*Corresponding author. E-mail:tnvkvprasad@gmail.com

Narayani. The crop was sown on 11-07-2011 and harvested on 28-10-2011.

The initial soil characters were as follows, the soil pH 6.7, E.C. 0.08 dSm^{-1}, organic carbon 0.18% and NPK 180.3, 20.2 and 216.5 kg ha^{-1} respectively. Rainfed groundnut was raised during *kharif* 2011 adopting recommended package of practices. Gypsum and lime were applied at first bloom stage. Soil samples were collected before sowing of the crop at two depths i.e., 0-15 and 15-30 cm. soil pH, EC and organic carbon were determined by Jackson(1973), Richards *et al.,* (1954) and Walkley and Black wet oxidation method (1934). The available nitrogen was determined by alkaline permanganate method (Subbaiah and Asija 1956), phosphorus by Olsen's method (1954) and available potassium by Jackson (1973).

The plant samples (haulms, kernels and shells) were collected at harvest and ground in willey mill and stored in labeled brown butter paper bags for further analysis. Total nitrogen in plant sample was determined by Modified kjeldahl's method by using Kel plus digestion and distillation units (Piper, 1996). Diacid extract (9:4 mixture of HNO_3+HClO4) was prepared as per the method outlined by Jackson (1973). This diacid extract was used to determine P and K contents in haulms, kernels and shells. P and K (Jackson, 1973) were estimated by following standard methods.

RESULTS AND DISCUSSION

Physico-chemical properties:

Soil pH:

The pH of the soil was not influenced by different treatments in both the surface and subsurface soil. The pH of the surface soil ranged from 5.27 to 5.57. The highest value was recorded in FYM alone (T_2) (5.57) followed by control (T_1) (5.53) whereas the lowest value was recorded in NPK + lime (T_{10}) (5.27). The pH of the subsurface soil ranged from 5.21 to 5.51. The highest value was recorded in FYM alone treated plot (T_2) (5.51) whereas the lowest was observed in NPK + lime (T_{10}) (5.21). A slight decrease in soil pH was observed (Table1) in all the treatments studied with surface and subsurface soil as compared to the initial soil pH (6.7) studied during the starting of this experiment in the year 1981. This was ascribed to the acidifying effect of different chemical fertilizers and their combinations with inorganics and release of organic acids during decomposition of organics. This was supported by the findings of Srikanth et al. (2000), Pernes A-Debuysier (2004) and Balwinder Kumar et al. (2008).

Electrical conductivity:

The EC of the soil was not significantly influenced by different treatments in the surface and subsurface soil. The EC of surface and soil subsurface ranged from 0.04 to 0.07 dS m^{-1}. The highest was recorded in NPK + gypsum + $ZnSO_4$ (T_{11}) (0.07) and the lowest value was recorded in the treatment control (T_1) (0.04). The trend of variation in EC of the soil between the treatments in both the soil layers was almost negligible and statistically non-significant (Table1). This was supported by several workers (Chawla and Chhabra, 1991, Santhy et al., 1998 and Stalin et al., 2006).

Soil organic carbon:

The highest value was observed in FYM alone treated plot (T_2) followed by N alone treated plot $(T)_3$ and NPK+gypsum (T_9) whereas the lowest was observed in NPK (T_8) (Table1). The increase in organic carbon content in the surface soil as compared to the subsurface soil was mainly due to the accumulation of organic residues over a period of time. This was in accordance with the findings of several workers (Tiwari et al., 1995, Singh et al.,, 1999 and Alok Tiwari et al., 2002). The increase in soil organic carbon content might be attributed to the oxidation of soil organic carbon content (Muneshwar Singh et al., 2008).

Major nutrients:

Available nitrogen:

The highest value of available nitrogen was recorded in FYM alone treated plot (184.3) and N alone treated plot followed by chemical fertilizers with the combination of N (183.5 to 155.5) (Table 2). The highest value of available N due to incorporation of FYM 5 t ha^{-1} once in 3 years over a period of time might be attributed to enhanced mineralization and accumulation of N in surface soil layer. These findings were in accordance with Kaleemulla Sharif, 1984, Bharadwaj and Omanwar, 1994 and Alok Tiwari et al., 2002. Further, it was noticed that the higher amount of N was also registered with the application of chemical fertilizers in combination with N. This was mainly due to the accumulation of available N with the application of nitrogenous fertilizer continuously over a period of time. These results were in conformity with findings of Selvi et al., 2003. The same trend of variation in case of N with respect to the subsurface soil was also noticed.

Available phosphorus:

Available phosphorus content of the soil decreased in all

Treatments	Treatments Details
T_1	Control (no manure and fertilizers)
T_2	Farm Yard Manure@ 5 t ha^{-1} once in 3 years
T_3	20 kg nitrogen ha^{-1}
T_4	10 kg phosphorus ha^{-1}
T_5	25 kg potassium ha^{-1}
T_6	250 kg gypsum ha^{-1} (applied at flowering stage)
T_7	20kg N+10kgP ha^{-1}
T_8	20kg N+10kgP+25 kg K ha^{-1}
T_9	20kg N+10kgP+25 kg K+250 kg gypsum ha^{-1} (applied at flowering stage)
T_{10}	20kg N+10kgP+25 kg K+100 kg lime ha^{-1}
T_{11}	20kg N+10kgP+25 kg K+250 kg gypsum ha-1+25 kg zinc sulphate ha^{-1}

Table 1. Effect of long-term application of manure and fertilizers on soil pH, EC (dSm^{-1}) and organic carbon(%) of Alfisol (kharif, 2011)

Treatments	pH		Electrical conductivity ($dS\ m^{-1}$)		Organic carbon (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1: Control	5.53	5.49	0.04	0.05	0.25	0.21
T_2: Farm Yard Manure@ 5 t ha^{-1} once in 3 years	5.57	5.51	0.06	0.04	0.64	0.40
T_3:20 kg nitrogen ha^{-1}	5.48	5.39	0.05	0.04	0.56	0.38
T_4:10 kg phosphorus ha^{-1}	5.40	5.32	0.05	0.05	0.46	0.24
T_5:25 kg potassium ha^{-1}	5.36	5.27	0.05	0.04	0.54	0.32
T_6:250 kg gypsum ha^{-1}	5.31	5.29	0.06	0.05	0.51	0.29
T_7:20kg N+10kgP ha^{-1}	5.36	5.31	0.06	0.05	0.39	0.22
T_8: 20kg N+10kgP+25 kg K ha^{-1}	5.29	5.29	0.06	0.04	0.22	0.21
T_9: 20kg N+10kgP+25 kg K+250 kg gypsum ha^{-1}	5.30	5.26	0.05	0.04	0.55	0.35
T_{10}: 20kg N+10kgP+25 kg K+100 kg lime ha^{-1}	5.27	5.21	0.05	0.05	0.55	0.37
T_{11}: 20kg N+10kgP+25 kg K+250 kg gypsum ha-1+25 kg zinc sulphate ha^{-1}	5.44	5.35	0.07	0.05	0.32	0.22
SEm$\pm$	0.03	0.03	0.01	0.01	0.07	0.08
CD (P=0.05)	NS	NS	NS	NS	NS	NS

*Each value is the ±SEm of four replications.

Table 2. Effect of long-term application of manure and fertilizers on soil available macronutrients (kharif, 2011)

Treatments	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1: Control	140.0	126.8	5.4	4.2	141.5	100.0
T_2: Farm Yard Manure@ 5 t ha^{-1} once in 3 years	184.3	166.5	6.9	5.3	168.0	119.0
T_3:20 kg nitrogen ha^{-1}	183.5	162.8	9.4	6.3	161.0	113.5
T_4:10 kg phosphorus ha^{-1}	155.0	151.8	10.1	7.0	163.5	117.2
T_5:25 kg potassium ha^{-1}	151.0	138.7	8.3	5.8	203.5	159.8
T_6:250 kg gypsum ha^{-1}	154.0	149.0	6.8	5.1	158.0	112.0
T_7:20kg N+10kgP ha^{-1}	155.5	149.3	10.4	6.7	156.3	106.0
T_8: 20kg N+10kgP+25 kg K ha^{-1}	166.0	161.2	8.0	5.7	197.5	135.8
T_9: 20kg N+10kgP+25 kg K+250 kg gypsum ha^{-1}	161.5	154.8	7.0	5.7	199.3	148.0
T_{10}: 20kg N+10kgP+25 kg K+100 kg lime ha^{-1}	162.0	164.8	9.3	6.1	187.8	125.8
T_{11}: 20kg N+10kgP+25 kg K+250 kg gypsum ha-1+25 kg zinc sulphate ha^{-1}	174.0	166.3	10.9	7.3	184.3	125.0
SEm$\pm$	5.0	3.0	0.2	0.2	3.5	2.4
CD (P= 0.05)	14.3	8.6	0.6	0.7	10.0	6.9

*Each value is the ±SEm of four replications

Table 3. Effect of long-term application of manure and fertilizers on groundnut pod yield and haulm yield

Treatments	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T_1: Control	1204	2153.0
T_2: Farm Yard Manure@ 5 t ha^{-1} once in 3 years	1373	2593.0
T_3:20 kg nitrogen ha^{-1}	1354	2432.0
T_4:10 kg phosphorus ha^{-1}	1357	2520.0
T_5:25 kg potassium ha^{-1}	1281	2157.0
T_6:250 kg gypsum ha^{-1}	1266	2084.0
T_7:20kg N+10kgP ha^{-1}	1262	2310.0
T_8: 20kg N+10kgP+25 kg K ha^{-1}	1338	2413.0
T_9: 20kg N+10kgP+25 kg K+250 kg gypsum ha^{-1}	1467	2455.0
T_{10}: 20kg N+10kgP+25 kg K+100 kg lime ha^{-1}	1342	2509.0
T_{11}: 20kg N+10kgP+25 kg K+250 kg gypsum ha-1+25 kg zinc sulphate ha^{-1}	1499	2543.0
SEm$\pm$	56	66.2
CD (P=0.05)	163	191.1

*Each value is the ±SEm of four replications

Table 4. Effect of long-term application of manure and fertilizers on groundnut dry matter production (kg ha^{-1}) at different stages of crop growth

Treatments	At harvest			
	Haulm	**Kernels**	**Shells**	**Total**
T_1: Control	2153	721	483	3357
T_2: Farm Yard Manure@ 5 t ha^{-1} once in 3 years	2593	858	515	3966
T_3:20 kg nitrogen ha^{-1}	2432	841	512	3785
T_4:10 kg phosphorus ha^{-1}	2520	822	535	3877
T_5:25 kg potassium ha^{-1}	2157	782	499	3438
T_6:250 kg gypsum ha^{-1}	2084	785	480	3349
T_7:20kg N+10kgP ha^{-1}	2310	854	408	3572
T_8: 20kg N+10kgP+25 kg K ha^{-1}	2413	818	521	3752
T_9: 20kg N+10kgP+25 kg K+250 kg gypsum ha^{-1}	2455	910	556	3921
T_{10}: 20kg N+10kgP+25 kg K+100 kg lime ha^{-1}	2509	827	515	3851
T_{11}: 20kg N+10kgP+25 kg K+250 kg gypsum ha-1+25 kg zinc sulphate ha^{-1}	2543	965	534	4042
SEm±	66	44	31	-
CD (P=0.05)	191	127	NS	-

*Each value is the ±SEm of four replications

Table 5. Effect of long-term application of manure and fertilizers on concentration of Nitrogen, Phosphorus and Potassium (%) in groundnut Haulm, Kernels and Shells at harvest

Treatments	Nitrogen			Phosphorus			Potassium		
	Haulm	Kernels	Shells	Haulm	Kernels	Shells	Haulm	Kernels	Shells
T_1	1.47	3.62	1.41	0.145	0.265	0.064	1.82	1.32	1.12
T_2	1.67	3.71	1.32	0.175	0.290	0.087	1.77	1.55	1.14
T_3	1.57	3.98	1.54	0.170	0.200	0.063	1.84	1.43	1.09
T_4	1.86	3.78	1.20	0.160	0.223	0.048	1.85	1.41	0.98
T_5	1.68	3.62	1.12	0.170	0.385	0.115	2.37	1.39	1.29
T_6	1.89	3.93	1.25	0.250	0.290	0.059	2.24	1.47	1.01
T_7	1.53	4.41	1.26	0.145	0.245	0.135	2.24	1.38	1.21
T_8	1.74	4.66	1.13	0.195	0.255	0.065	2.24	1.42	1.35
T_9	1.89	4.52	1.32	0.115	0.225	0.150	1.54	1.39	1.37
T_{10}	1.68	4.42	1.24	0.175	0.285	0.095	2.43	1.24	1.25
T_{11}	1.96	4.34	1.47	0.150	0.340	0.135	2.23	1.55	1.41
SEm±	0.03	0.01	0.01	0.008	0.03	0.010	0.19	0.05	0.08
CD (P=0.05)	NS	NS	NS	0.023	0.087	0.031	0.54	0.15	0.22

*Each value is the ±SEm of four replications

the treatments studied as compared to its initial status of P (20.2 kg ha^{-1}) in both the surface and subsurface soil.
The depletion of available P (Table 2) was mainly due to the crop uptake since 30 years irrespective of its application to the soil. This situation was ascribed to lower dose of P application to crop (10 kg P ha^{-1}) against the recommended dose of 17.5 kg P ha^{-1}. The decrease of soil available P in some treatments where P was included (NPK + lime and NPK + gypsum) might be due to the blocking of available phosphorus which was attributed to formation of tricalcium phosphate due to the presence of considerable amount of calcium of the soils.

Available potassium:

Available K content of the soil decreased (Table 2) in all the treatments studied during *kharif* -2011 compared to the initial status (216 kg K ha^{-1}) in the year 1981. This decrease in available K was mainly due to the more uptake of K from the soil. The higher uptake of K was might be due to the getting higher haulm and pod yield in some of the seasons in which favourable environmental conditions prevailed. Further, the crop suffered with lower dose of K than recommended to the region (33 kg ha^{-1}). This has been happened since inception of the trail.

Dry matter production at harvest:

At harvest, treatments significantly influenced the dry matter production of haulm and kernel (Table 3). The highest quantity of haulm (2593) was found in FYM alone treated plot (T_2) which was on par with NPK + gypsum + $ZnSO_4$ (T_{11}) (2543), P alone treated plot (T_4) (2520), NPK + lime (T_{10}) (2509), NPK + gypsum (T_9) (2455), N alone treated plot (T_3) (2432) and NPK (T_8) (2413) whereas significantly lowest was observed in gypsum alone treated plot (T_6) (2084) which was on par with control (T_1) (2153), K alone treated plot (T_5) (2157) and N + P (T_7) (2310).
However, the highest quantity of kernel production was recorded in NPK + gypsum + $ZnSO_4$ (T_{11}) (965) which was on par with NPK + gypsum (T_9) (910), FYM alone treated plot (T_2) (858), N + P (T_7) (854) and N alone treated plot (T_3) (841) whereas significantly lowest was observed in control (T_1) (721) which was on par with K alone treated plot (T_5) (782), gypsum alone treated plot (T_6) (785), NPK (T_8) (818), P alone treated plot (T_4) (822) and NPK + lime (T_{10}) (827).
The treatments did not influence the shell production significantly (Table 3). Significant increase in dry matter production was observed as the age of the crop increases due to the use of N, P and K fertilizers. From this, it could be inferred that the utility of N, P and K fertilizer was more effective during the active growth stages especially from 25 days after sowing when the plant put forths its root substantive system similar results were reported by the Bhaskar Reddy et al., (1992).

N, P and K Contents in Haulm, Kernels and Shells at Harvest:

The concentration of nitrogen in haulm varied from 1.47 to 1.96. The highest was recorded in NPK + gypsum + $ZnSO_4$ (T_{11}) (1.96) and lowest was in control (T_1) (1.47). In kernels nitrogen concentration ranged from 3.62 to 4.66. The highest was recorded in NPK (T_8) (4.66) and lowest was in control (T_1) (3.62). In shells, nitrogen concentration ranged from 1.12 to 1.54. The highest was recorded in N alone (T_3) (1.54) and lowest was in K alone (T_5) (1.12).
A comparison of nitrogen in plant parts showed that it was more in kernels than that of haulm (Table 5). Kernels had the highest concentration of N and the least was in shells.
The effect of different treatments on concentration of phosphorus in haulm at harvest was significant. The highest concentration of phosphorus was recorded in T_6 (0.250) which was on par with T_8 (0.195). The lowest was found in T_9 (0.115). In kernels, maximum concentration of phosphorus was recorded in T_5 (0.385) which was on par with T_{11} (0.340). All others are significantly lower than T_5 and T_{11} being the lowest in T_3 (0.200).In shells, highest concentration was recorded in T_9 (0.150) followed by T_7 (0.135) and T_{11} (0.135). Phosphorus concentration in shells due to treatments follows the order of T_5 (0.115), T_{10} (0.095) and T_2 (0.087). Significantly lowest was found in T_4 (0.048) which was on par with T_6 (0.059), T_3 (0.063), T_1 (0.064) and T_8 (0.065).
At harvest in haulm the highest concentration of potassium was recorded in T_{10} (2.43) which was on par with T_5 (2.37), T_6 (2.24), T_7 (2.24), T_8 (2.24) and T_{11} (2.23) whereas lowest was found in T_9 (1.54) which was on par with T_2 (1.77), T_1 (1.82), T_3 (1.84) and T_4 (1.85). Highest concentration of K in kernels was observed in T_{11} (1.55) and T_2 (1.55) which was on par with T_6 (1.47), T_3 (1.43), T_8 (1.42) and T_4 (1.41). But significantly lowest concentration was found in T_{10} (1.24) which was on par with T_1 (1.32), T_7 (1.38), T_5 (1.39) and T_9 (1.39). In shells, highest concentration was found in T_{11} (1.41) which was on par with T_9 (1.37), T_8 (1.35), T_5 (1.29), T_{10} (1.25) and T_7 (1.21) whereas significantly lowest was found in T_4 (0.98) which was on par with T_6 (1.01), T_3 (1.09), T_1 (1.12) and T_2 (1.14).

Pod and haulm yield of groundnut:

The highest pod yield of 1499 kg ha^{-1} was obtained with application of NPK (20:10:25 kg ha^{-1}) + gypsum (250 kg ha^{-1}) + zinc sulphate (25 kg ha^{-1}) which was found to be on par with the NPK (20:10:25 kg ha^{-1}) + gypsum (250 kg ha^{-1}) and FYM alone treatments where as lowest yield was obtained in the control (1204 kg ha^{-1}) (Table 4).

The highest haulm yield (2593 kg ha^{-1}) was noticed with the application of FYM alone treatment which was on par with NPK (20:10:25 kg ha^{-1}) + gypsum (250 kg ha^{-1}) + zinc sulphate (25 kg ha^{-1}) where as lowest haulm yield was obtained in gypsum alone treated plot. This indicates that for sustainability of yields, integrated use of organic and inorganic fertilizers are essential. This is further substantiated by the results reported by Khishore Babu *et al*., (2007). They found that conjunctive use of NPK, gypsum and zinc sulphate are advantageous for achieving higher production of pod and haulm yield in groundnut crop.

CONCLUSION

The present study revealed the long-term effect of manure and fertilizers on the productivity of rainfed groundnut grown in semi-arid alfisol. Over a period of time, depletion of the nutrients was observed in the control, whereas, the application of manure and fertilizers has recorded sustainable higher yields. This points to the use of manure and fertilizers even in rainfed conditions to get higher yields of groundnut.

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