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Soil Physical Properties and Groundnut (*Arachis hypogae* L.) Yield under Long Term Application of Manure and Fertilizers under Rainfed Condition

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Authors' contributions

This work was carried out in collaboration between all authors. Author DS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KV and MVSN managed the analyses of the study. Author YRR managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

In the long term experiment of continuous use of various inorganic fertilizers and manure in an alfisol the status of soil physical properties their deterioration and improvement in the soil and crop yield of groundnut were studied during *kharif* 2015 being conducted at Regional Agricultural Station, Tirupati. The soil of experimental area was sandy loam in texture, slightly acidic, non-saline, low in organic carbon content. Results showed that physical properties like porosity, maximum water holding capacity, mean weight diameter, geometric mean diameter, per cent water stable aggregates (>0.25 mm) were recorded highest with the application of FYM@ 5 t ha^{-1} followed by the different treatments receiving gypsum, lime, $ZnSO_4$ in combination with NPK nutrients over the control. However, infiltration rate, saturated hydraulic conductivity were recorded higher in control plot followed by the FYM alone treated plot. The application of NPK (20:10:25 kg ha^{-1}) + lime (100

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kg ha^{-1}) recorded highest pod yield of 1950.75 kg ha^{-1} which was on par with NPK+gypsum, NPK+gypsum+$ZnSO_4$, NPK and FYM alone treated plot. Thus, the balanced use of fertilizers continuously either in combination with other nutrient source or with organic manuring is necessary for improving soil physical properties and yield of groundnut under rainfed conditions.

Keywords: Groundnut; long-term application; manure; fertilizer; physical properties; yield.

1. INTRODUCTION

Globally, India is ranked first in groundnut cropping land and second in its production after China. In Andhra Pradesh, it is grown in a total surface area of 1.38 million ha with a production of 1.23 Mt and an average grain yield of 890 kg ha^{-1} [1]. It is the major oilseed cum cash crop for millons of small scale farmers in the semi-arid tropics and is an important oil seed crop grown under rainfed conditions in Andhra Pradesh. The uses of groundnut are diverse; all parts of the plant could be used. The kernel is a rich source of edible oil, containing 36 to 54 per cent and 25 to 32 per cent protein [2]. Young pods may be consumed as a vegetable, shells may be used for fuel and as soil conditioner. Monocropping of groundnut is prevalent in sandy loam soils of Rayalaseema region in Andhra Pradesh. The productivity of groundnut grown under rainfed situation is low in India, reaching the lowest yield of 0.8 t ha^{-1}. The low productivity in India is mainly due to poor soil fertility, deterioration of soil physical properties, monocropping, irregular rainfall and frequent occurrence of dry spells, imbalanced use of organic and inorganic fertilizers for plant nutrients. Thus Long-term evaluation of manure and fertilizers application provides valuable information on impact of continuous use of fertilizers with varying combination of organics and inorganics on soil physical, chemical properties and crop productivity. Long term application of inorganic fertilizer along with organic fertilizer changes physical properties like infiltration rate, cumulative infiltration, per cent water stable aggregates and productivity [3]. This paper therefore seeks to evaluate the influence of long-term application of manure and fertilizers on the soil physical properties, yield and yield component of groundnut on groundnut base system.

2. MATERIALS AND METHODS

The permanent manurial experiment at Regional Agricultural Research Station, Tirupati of Acharya N. G. Ranga Agricultural University (Andhra Pradesh) started in the year 1981 to study the effect of continuous application of fertilizers and manure to rainfed groundnut on Alfisols. Data were collected 34 years later, that is during *Kharif* season in 2015, in the sexperimental field laid out in Randomized Block Design, replicated four times with eleven treatments. The treatments include : T_1: Control (no manure and inorganic fertilizers), T_2: Farm yard manure @ 5 t ha^{-1} (once after every 3 years), T_3: 20 kg nitrogen (N) ha^{-1}, T_4: 10 kg phosphorus (P) ha^{-1}, T_5: 25 kg potassium (K) ha^{-1}, T_6: 250 kg gypsum ha^{-1} as top dressing at flower initiation, T_7: 20 kg N + 10 kg P ha^{-1}, T_8: 20 kg N + 10 kg P + 25 kg K ha^{-1}, T_9: 20 kg N + 10 kg P + 25 kg K + 250 kg gypsum ha^{-1}, T_{10}: 20 kg N + 10 kg P + 25 kg K + 100 kg lime ha^{-1} (lime as top dressing at flower initiation), T_{11}: 20 kg N + 10 kg P + 25 kg K + 25 kg zinc sulphate ha^{-1} (as basal, once in 3 years).The farmyard manure and Zinc sulphate were not applied in this *Kharif* season.The test crop was groundnut, variety Dharani with crop period of 110 days. The crop was sown on 24-07-2015 and harvested on 7-11-2015.

The soil of the experimental field was red sandy loam (Haplustalf). Soil samples were collected from each plot at two depths *viz.,* 0-15 and 15-30 cm before sowing of crop during *kharif's* cropping season in 2015. Soil pH, EC and organic carbon were determined by methods outlined by Jackson [4], Richards et al. [5] and Walkley and Black wet oxidation [6], respectively. The physical properties like bulk density, particle density, water holding capacity and pore space were determined with Keen- boxes as per the procedure laid down by Piper (1950). Infiltration rate was determined by using the double ring infiltrometer method (Black, 1965). Hydraulic conductivity of soil was estimated in the laboratory after saturation with water for 24 hours with a constant head arrangement [7]. Darcy's equation was employed to calculate the k value. Water aggregates stability was done by wet sieving method developed by Yoder [8] and was expressed in mean weight diameter, geometric mean diameter and per cent water stable aggregates (0.25 mm).

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Properties of Experimental Site

The experimental field was slightly acidic with a pH ranging from 5.24 to 5.61, non-saline and low in organic carbon (0.28-0.53%) content.

3.2 Soil Physical Properties

3.2.1 Bulk density

The bulk density obtained with FYM alone treated plot @ 5 t ha^{-1} (T_2) (1.37) in surface soil was on par with P alone treated plot (T_4) (1.41), NPK (T_8) (1.41) NPK+lime (T_{10}) (1.41) and NPK + gypsum (T_9) (1.39). With respect to sub soil, lowest value was observed in FYM alone treated plot (T2) (1.37) which was on par with NPK+gypsum+$ZnSO_4$ (T11) (1.44), N alone treated plot (T3) (1.42), N+P (T7) (1.42), NPK+lime (T_{10}) (1.42) and gypsum alone treated plot (T_6) (1.42), P alone treated plot (T_4) (1.41) and NPK+gypsum (T_9) (1.39).However, lowest bulk density values were recorded both in 0-15 cm and 15-30 cm soil depth with FYM alone treated plot. The lowest bulk density value obtained with the FYM alone treated plot might be attributed to the accumulation of organic matter. The higher organic matter itself or its decomposed products in FYM alone treated plot might have bound the primary soil particles to form soil aggregates resulting in an increase in total pore space as evidenced from the data presented in Table 1 and decrease in the mass of unit volume of soil in both 0-15 cm and 15-30 cm depth. Similar results were also reported by Havangi and Mann [9], Lal and Mathur [10] and Anderson et al. [11]. The lowest bulk density values of surface and sub surface soil with P, lime and gypsum treatmental combinations in the study were relevant to the study of Mahimairaja et al. [12].

3.2.2 Porosity and water holding capacity

The porosity of both the 0-15 cm (44.71%) and15-30cm (40.97%) depth was obtained high with the application of FYM @ 5 t ha^{-1} followed by NPK+gypsum+$ZnSO_4$, NPK+gypsum, P alone treated plot, gypsum alone treated plot were higher. The higher organic matter content might have helped to form stable soil aggregates which resulted in the increase of the total porosity. The improvement of the soil structure was also evidenced by obtaining the significantly higher values of structural indices *viz.,* MWD, GMD, per cent water stable aggregates, water holding capacity in this study with the application of FYM (Table 1). This was also supported by Verma et al. [13]. The higher values of maximum water holding capacity were also obtained with the application of FYM @ 5 t ha^{-1} once in three years for the past 34 years both in surface and sub surface soil. The treatments *viz.,* NPK, NPK+gypsum, NPK+lime, NPK+gypsum+$ZnSO_4$ with respect to the surface soil were also recorded significantly higher values over the rest of the treatments but when compared with FYM these were on par. Similar trend of results were also obtained with NPK+lime, NPK+gypsum+$ZnSO_4$ with respect to the sub surface soil. Like FYM, P and Ca might have helped in the formation of soil aggregates which inturn decreased the macro pore space and increased the micro pore space of sandy loam soil. This causes the increase in the maximum water holding capacity of soil in the aforesaid treatments. Bhattacharayya et al. [14] also observed the effect of P and FYM in the improvement of the aggregates in the soils of rainfed system.

3.2.3 Hydraulic conductivity and infiltration rate

The data in (Table 2) indicate that with respect 0-15 cm depth, significantly highest hydraulic conductivity was recorded with control (T1) (4.53) followed by FYM alone (T2) (3.55) which was on par with NPK + lime (T10) (3.51) and NP (T_7) (3.32) and in sub surface soil significantly highest hydraulic conductivity was recorded with control (T_1) (4.35) followed by FYM alone (T2) (3.44), N treated plot (T_3) (2.47). Significantly higher hydraulic conductivity was reported in the control with respect to surface (4.53 cm hr^{-1}) and 15-30 cm depth (4.35 cm hr^{-1}) as compared to the rest of the treatments. The saturated hydraulic conductivity and permeability of control plot were said to be moderate and rapid with respect to surface and sub surface soil respectively as per the limits given by Smith and Browning, 1946. The lowest values of saturated hydraulic conductivity obtained with different treatmental combinations as compared to the control, might be due to the effect of cations like Ca, K, Zn and anions like phosphates supplied through different inorganic fertilizers. The trend of variation with respect to the saturated hydraulic conductivity among the treatmental plots was mainly due to the individual effect of cations and anions supplied through different fertilizers. Similar trend of variation with respect to the sub surface was also observed in this study.

Table 1. Effect of long term application of manure and fertilizers on bulk density (Mg m^{-3}) of the soil

Treatments	Bulk density (Mg m^{-3})		Porosity (%)		Water holding capacity (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 Control	1.47	1.47	36.33	37.27	34.79	27.21
T_2 FYM @ 5 t ha^{-1} (once in 3 years)	1.37	1.37	44.71	40.97	39.10	34.98
T_3 N @ 20 kg ha^{-1}	1.42	1.42	41.79	38.45	35.94	31.04
T_4 P @ 10 kg ha^{-1}	1.41	1.41	41.86	39.41	36.16	31.34
T_5 K @ 25 kg ha^{-1}	1.46	1.46	38.49	39.17	37.32	33.90
T_6 Gypsum @ 250 kg ha^{-1}	1.42	1.42	41.06	40.70	37.96	32.80
T_7 NP	1.42	1.42	40.52	37.93	37.54	32.70
T_8 NPK	1.41	1.41	40.01	40.36	38.68	33.23
T_9 NPK+G	1.39	1.39	42.09	40.38	38.55	33.18
T_{10} NPK+L	1.41	1.41	39.94	40.90	37.80	32.72
T_{11} NPK+G+$ZnSO_4$	1.44	1.44	43.82	40.55	38.75	34.59
SEm±	**0.016**	**0.016**	**1.058**	**0.813**	**0.496**	**0.551**
CD (P=0.05)	**0.045**	**0.046**	**3.055**	**2.348**	**1.433**	**1.592**

G: Gypsum; L: Lime @ 100 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1}

Table 2. Effect of long term application of manure and fertilizers on hydraulic conductivity ($cm\ hr^{-1}$), infiltration rate ($cm\ hr^{-1}$) of the soil

Treatments	Hydraulic conductivity ($cm\ hr^{-1}$)		Infiltration rate ($cm\ hr^{-1}$)
	0-15 cm	15-30 cm	
T_1 Control	4.53	4.35	3.47
T_2 FYM @ 5 t ha^{-1} (once in 3 years)	3.55	3.44	2.67
T_3 N @ 20 kg ha^{-1}	2.45	2.47	2.59
T_4 P @ 10 kg ha^{-1}	2.19	1.93	1.80
T_5 K @ 25 kg ha^{-1}	1.51	1.59	2.22
T_6 Gypsum @ 250 kg ha^{-1}	3.10	2.20	2.65
T_7 NP	3.32	1.02	2.02
T_8 NPK	1.96	1.56	2.52
T_9 NPK+G	1.89	1.56	2.20
T_{10} NPK+L	3.51	1.69	2.64
T_{11} NPK+G+$ZnSO_4$	2.28	2.04	2.63
SEm±	**0.111**	**0.083**	**0.007**
CD (P=0.05)	**0.320**	**0.241**	**0.020**

G: Gypsum; L: Lime @ 100 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1}

3.2.4 Per cent water stable aggregates

The mean weight diameter of soil aggregates in this study ranged from 0.88 to 0.99 mm (Table 3). Long term application of FYM (T_2) (0.99 mm resulted in highest value followed by treatments receiving gypsum, lime, $ZnSO_4$ in combination with NPK. The geometric mean diameter of soil aggregates ranged from 0.60 to 0.73 mm. Long term application of FYM (T_2) (0.73 mm) resulted in highest value followed by treatments receiving NP, NPK alone and gypsum, lime and $ZnSO_4$ in combination with NPK. The lowest value was observed with control, which was significantly lower than the other treatments. The Per cent Water stable aggregates (>0.25 mm) in all the treatments studied ranged from 40.87 to 50.87 %. The Per cent water stable aggregates were higher with the long term application of FYM (T_2) (50.87) NPK+gypsum+$ZnSO_4$ (T_{11}) (50.41) The other combinations *viz.,* NPK+gypsum, NPK, NP, gypsum, K alone, NPK+lime, P alone treated plots recorded significantly higher values as compared with control. Relatively and significantly highest soil structure indices values obtained with the continuous application of 5 t ha^{-1} of FYM since inception of the experiment was mainly indicating the profound influence of FYM on soil structure. Soil organic matter is the major binding agent and aggregation is hierarchial in which primary particles and clay domains are cemented together. FYM has long been recognized as a good source of organic matter which played an important role in the formation of the water stable aggregates. Similar results were in accordance with Verma et al. [13] who reported that treatment receiving 20 t ha^{-1} of FYM recorded maximum water stable aggregates under maize-wheat cropping system. The inclusion of the P, gypsum, K, lime and $ZnSO_4$ in the treatmental combinations or alone could be attributed to the development of the soil structure. The cementation effect due to phosphate ion, flocculation effect due to Ca, K, Zn might have helped in increasing the soil structural indices relatively and significantly in the FYM treated plot and lime, gypsum, P, K and $ZnSO_4$ treated plots. The foregoing discussion clearly indicate that FYM alone and integrated use of chemical fertilizers increased the structural indices *viz.,* MWD (mm), GMD (mm), per cent water stable aggregates (>0.25 mm). This could be attributed to the beneficial effects of certain polysaccharides by microbial activity as well as cementing action of bacteria and fungi [15].

3.2.5 Pod and haulm yield of groundnut

The pod yield of groundnut crop was significantly varied with treatments. It ranged from 1304.75 (T_1) to 1950.75 (T_{10}). The highest pod yield was obtained with NPK+lime (1950.75 k g ha^{-1}).The treatments NPK+ gypsum, NPK+g+$ZnSO_4$, NPK and FYM @ 5 t ha^{-1} were also recorded comparatively higher yield over the control. The highest pod yield obtained in this study with NPK+lime treated plot might be attributed to the good supply of nutrients like N, P, K to meet the requirements of the crop during growth period. It was confirmed by the yield obtained with this treatment (Table 4). The lime which was included

Table 3. Effect of long term application of manure and fertilizers on Mean weight diameter, geometric mean diameter and per cent water stable aggregates of the soil aggregates

Treatments	Mean weight diameter (mm)	Geomertic mean diameter (mm)	Per cent water stable aggregates (>0.25 mm)
T_1 Control	0.88	0.60	40.87
T_2 FYM @ 5 t ha^{-1} (once in 3 years)	0.99	0.73	50.87
T_3 N @ 20 kg ha^{-1}	0.91	0.63	50.08
T_4 P @ 10 kg ha^{-1}	0.92	0.64	50.15
T_5 K @ 25 kg ha^{-1}	0.93	0.65	50.29
T_6 Gypsum @ 250 kg ha^{-1}	0.95	0.68	50.53
T_7 NP	0.94	0.68	50.44
T_8 NPK	0.96	0.70	50.60
T_9 NPK+G	0.95	0.70	50.64
T_{10} NPK+L	0.94	0.67	50.41
T_{11} NPK+G+$ZnSO_4$	0.97	0.72	50.76
SEm±	**0.008**	**0.004**	**0.034**
CD (P=0.05)	**0.024**	**0.011**	**0.112**

G: Gypsum; L= Lime @ 100 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1}

Table 4. Effect of long term application of manure and fertilizers on yield attributes and yield of groundnut

Treatments	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T_1 Control	1304.75	2304.00
T_2 FYM @ 5 t ha^{-1} (once in 3 years)	1804.25	2919.00
T_3 N @ 20 kg ha^{-1}	1602.50	2519.00
T_4 P @ 10 kg ha^{-1}	1690.00	2373.00
T_5 K @ 25 kg ha^{-1}	1477.25	2232.50
T_6 Gypsum @ 250 kg ha^{-1}	1355.25	2460.00
T_7 NP	1711.25	2565.00
T_8 NPK	1815.00	2736.00
T_9 NPK+G	1892.00	2230.00
T_{10} NPK+L	1950.75	2762.50
T_{11} NPK+G+$ZnSO_4$	1840.75	2911.75
SEm±	**79.5106**	**8.5261**
CD (P=0.05)	**229.6126**	**24.6219**

G: Gypsum; L: Lime @ 100 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1}

in this treatment might have helped in creating the favourable chemical, physical and biological environment of the soil. Enrichment of the calcium in the soil was also another beneficial effect on pod yield due to the inclusion of lime in the NPK treatment. Inclusion of gypsum and $ZnSO_4$ with NPK might have created good environment in the soil. The cumulative effect of balanced nutrition, well supplied nutrients and good soil environment favoured the highest pod yield in the aforesaid treatments. Babu et al. [16] reported that highest yield of groundnut was observed with application of NPK+gypsum+$ZnSO_4$ in a long term experiment. Similar results were also reported by Parvathi et al. [17] An extra pod yield of 500 q ha^{-1} was obtained due to the application of FYM @ 5 t ha^{-1} once in three years continuously for the past 34 years over the control.

From the data presented in Table 4, it was noticed that the haulm yield varied significantly from 2919 to 2230 due to different treatments. Highest value of haulm yield of groundnut was recorded with FYM alone treated plot which was on par with NPK+gypsum+$ZnSO_4$ (T_{11}) (2911.75). The next best treatment was NPK + lime (T_{10}) (2762.50) however comparable with the application of NPK (T_8). This might be due to improvement of soil physical, chemical and biological properties there by improved availability of nutrients in balanced proportion owing to higher dry matter production resulting in higher haulm yield in groundnut. These results were in accordance with Babu et al. [16].

4. CONCLUSION

From the foregoing discussion, it is clear that physical properties *viz.,* bulk density, soil porosity, maximum water holding capacity and water aggregate stability improved due to the continuous application of FYM @ 5 t ha^{-1} and NPK+gypsum+$ZnSO_4$. The application of NPK(20:10:25 kg ha^{-1}) + lime (100 kg ha^{-1}) recorded highest pod yield of 1950.75 kg ha^{-1} which was on par with NPK+gypsum, NPK+gypsum+$ZnSO_4$, NPK and FYM alone treated plot. This clearly indicated the complete supply of all the essential nutrients in sufficient amounts in balanced ratio during the crop growth period. These results showed that application of any single nutrient will not be able to sustain the yield of groundnut crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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