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Effect of Tillage and Nutrient Management Practices on Physico-chemical and Biological properties of Sandy Clay Loam Soils of Southern Agro-climatic Zone of Andhra Pradesh

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ABSTRACT: A field experiment was conducted in sandy clay loam soils of Dryland farm at S.V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University, Andhra Pradesh in split-plot design with three replications to study the performance of groundnut under different tillage and nutrient management practices *viz*., conventional tillage (M_1), deep ploughing with disc plough upto a depth of 30 cm (M_2), vertical tillage with subsoiler upto a depth of 40 cm at 1 m interval (M_3), vertical tillage with subsoiler upto a depth of 60 cm at 1 m interval (M_4) and control (S_1), 50 % RDF (S_2), 75 % RDF (S_3), 100 % RDF (S_4), 125 % RDF (S_5), respectively. The results revealed that minimum bulk density, maximum aggregate stability and soil water content, higher count of total microbial mass in soil, groundnut pod yield, nutrient uptake as well as post harvest nutrient availability in soil after groundnut was obtained with vertical tillage with subsoiler upto 60 cm depth at 1 m interval (M_4) during both the years of experimentation. Soil chemical properties *viz*., pH, electrical conductivity and soil organic carbon were not significantly influenced by both tillage and nutrient management practices during both the years of study. Among the nutrient management practices studied, maximum soil moisture content was observed with control (S_1) while minimum was with 125 % RDF (S_5) during two years of study at all stages of observations whereas, maximum aggregate stability, higher count of total microbial mass in soil, groundnut pod yield, nutrient uptake as well as post harvest nutrient availability in soil after groundnut was recorded with 125 % RDF (S_5) followed by 100 % RDF (S_4) while lower with control (S_1) during both the years of experiment.

Keywords: Groundnut, Nutrient management, Tillage, Vertical tillage, Yield.

INTRODUCTION

Groundnut (*Arachis hypogeae* L.) is one of the major oilseed crops of the country, but its production and productivity needs to be significantly enhanced. India is the second largest producer of groundnut after Brazil. In India, Andhra Pradesh ranks second both in area and production with an average productivity of 564 kg/ha. Tillage is one of the fundamental agro-technical operations in agriculture because of its influence on soil properties and crop growth which involves physical modification of soil properties for the purpose of promoting crop production. Soil physical properties like bulk density, water holding capacity and aggregate stability are strongly influenced by tillage practices. In recent years soil compaction in the plow layer of soils is becoming a serious concern because of conventional tillage practices adopted by most of the farmers particularly in medium to heavy textured soils. Continuous use of machinery causes compaction in the plow layer; thus strategic tillage practices have become an essential component in intensive agriculture (Shukla *et al*., 2021). Vertical tillage (subsoiling) with subsoiler, which loosens the subsoil without inverting it is aimed at stimulating greater and faster penetration of roots at increasing the availability of nutrients and moisture to plants. Vertical tillage enhances or re-establishes the soil profile structure allowing rapid infiltration. Hard pan could be alleviated with the help of deep soil loosening equipment like subsoiler. Subsoiler improves soil structure by establishing a system of deep cracks and fissures in the subsoil, facilitating downward movement of water, air and roots. In-situ rain water conservation is a critical factor in stabilizing and stepping up of rainfed crop production. A tillage practice like vertical tillage breaks the hard pan and helps in sinking down of the rain water in lower layers of soil from where it is not easily lost by evaporation and aids to deeper rooting, which helps in better exploitation of stored soil moisture and applied nutrients from soil profile (Vaghasia *et al*., 2007). Groundnut productivity is low due to inadequate fertilizer applications. Though the response of crop to fertilizer applications is well known, most of the farmers seldom apply higher doses of fertilizers resulting in lower yields. Like any other crop, the productivity of groundnut in light soils is very low which can be improved with optimum nutrient management practices. Keeping in-view, the present experiment was conducted to find-out the best tillage and nutrient management practice for groundnut cultivation during *kharif* in sandy clay loam soil conditions.

MATERIAL AND METHODS

A field experiment was conducted at Dryland farm of S.V. Agricultural College, Tirupaticampus (13.5^{o}N latitude and 79.5^{o}E longitude at an altitude of 182.9 m above mean sea level) of Acharya N.G. Ranga Agricultural University, Andhra Pradesh, during *kharif*, 2015 and 2016. The soil was sandy clay loam in texture and neutral in soil reaction with available nitrogen of 212 kg/ha and medium in available phosphorous of 23 kg/ha and potassium of 221 kg/ha. Twenty treatmental combinations of four tillage practices *viz*., and four levels of plant populations *viz*., conventional tillage (M_1), deep ploughing with disc plough upto a depth of 30 cm (M_2), vertical tillage with subsoiler upto a depth of 40 cm at 1 m interval (M_3) and vertical tillage with subsoiler upto a depth of 60 cm at 1 m interval (M_4) and five nutrient management practices *viz*., control (S_1), 50 % RDF (S_2), 75 % RDF (S_3), 100 % RDF (S_4) and 125 % RDF (S_5) were laid out in split-plot design with three replications.The groundnut crop of variety '*Dharani*' was sown on 25 June 2015 during *kharif*, 2015 and on 06June 2016 during *kharif*, 2016.The experimental field was ploughed as per the treatment details *i.e*., M_1- field was ploughed twice with a tractor drawn cultivator; M_2 - field was initially ploughed with disc plough uptoa depth of 30 cm followed by tractor drawn cultivator; M_3 - the field was initially subsoiled with a subsoiler upto a depth of 40 cm at 1.0 m interval followed by tractor drawn cultivator; M_4 - the field was initially subsoiled with subsoiler upto a depth of 60 cm at 1.0 m interval followed by tractor drawn cultivator. The field was finally levelled with tractor drawn levelling blade. Fertilizer doses were applied as per the treatments *i.e*., S_1 - control where no fertilizers were applied; S_2 - 50 % RDF - 10 kg N, 20 kg P_2O_5, 25 kg K_2O, 12.5 kg $ZnSO_4$ as basal application and 250 kg gypsum at 40 DAS ha^{-1} were applied; S_3 - 75 % RDF - 15 kg N, 30 kg P_2O_5, 37.5 kg K_2O, 18 kg $ZnSO_4$ as basal application and 375 kg gypsum at 40 DAS ha^{-1} were applied; S_4 - 100 % RDF - 20 kg N, 40 kg P_2O_5, 50 kg K_2O, 25 kg $ZnSO_4$ as basal application and 500 kg gypsum at 40 DAS ha^{-1} were applied; S_5 - 125 % RDF - 25 kg N, 50 kg P_2O_5, 62.5 kg K_2O, 32 kg $ZnSO_4$ as basal application and 625 kg gypsum at 40 DAS ha^{-1} were applied through urea, single super phosphate, muriate of potash, zinc sulphate and gypsum, respectively to the respective plots as per the treatments. No major pest and disease problems were observed. All the agronomic management practices were followed as per the university recommendations for raising the crop. The rainfall received during crop growing period was 644.9 mm within 32.0 rainy days during *kharif*, 2015 and 476.2 mm within 25 rainy days during *kharif*, 2016.

RESULTS AND DISCUSSION

Among the four tillage practices evaluated, soil bulk density was significantly lower with M_4 and M_3 compared to M_2 and M_1 with significant disparity among treatments, that means bulk density was similar to that of original field beyond 30 cm in M_2 and M_1 treatments. In general, it could be seen that the effect of vertical tillage in reducing bulk density persisted throughout the growing season. This might be due to that the soil was disturbed to deeper depths *i.e.,* upto 40 and 60 cm in vertical tillage without any inversion of top soil. But in deep and conventional tillage practices the soil was disturbed only upto 30 cm depth which involved inversion of top soil. Similar findings were also reported by Mathukia *et al*., (2015); Kumar *et al*., (2014).

Maximum aggregate stability was recorded with vertical tillage upto 60 cm depth at 1 m interval (M_4) which was on par with vertical tillage upto 40 cm depth at 1 m interval (M_3) which in turn differed significantly in increasing aggregate stability compared to deep ploughing with disc plough (M_2). Similar results that aggregate stability was higher with subsoiling was reported by Felix *et al*., 2008. Minimum aggregate stability was recorded with conventional tillage (M_1) in both the years of experiment. The reason for higher aggregate stability is due to that in vertical tillage the soil was not disturbed but a deep cut was made with subsoiler, but in deep ploughing with disc plough there was complete inversion of top soil where soil particles were cut so that the stability of aggregation between the soil particles was reduced in deep ploughing and conventional tillage practices. Maximum value of aggregate stability was recorded with 125 % RDF followed by 100, 75 and 50 % RDF and control with no significant disparity among them. The improvement in aggregate stability with increase in nutrient concentration was attributed to higher organic matter content owing to better crop growth with concomitant higher root biomass generation. Similar results were also reported by Hati *et al*., 2015 that aggregate stability increased with increase in nutrient dose.

Table 1: Soil bulk density (g cc^{-1}) at different depths before sowing and after harvest of groundnut as influenced by tillage practices during *kharif* , 2015 and 2016.

Treatments		2015		2016	
Tillage practices	**Depth (cm)**	**Before**	**After**	**Before**	**After**
M1 = Conventional tillage	0-10	1.27	1.19	1.19	1.11
	10-20	1.77	1.42	1.55	1.29
	20-30	1.87	1.83	1.87	1.66
	30-40	1.90	1.90	1.91	1.89
	40-50	2.08	2.08	2.08	2.08
M2 = Deep tillage with disc plough upto a depth of 30 cm	0-10	1.09	0.89	0.96	0.86
	10-20	1.55	1.14	1.25	1.11
	20-30	1.88	1.53	1.60	1.48
	30-40	1.99	1.95	1.94	1.93
	40-50	2.11	2.10	2.10	2.11
M3 = Vertical tillage with subsoiler upto a depth of 40 cm at 1 m interval	0-10	0.97	0.58	0.86	0.69
	10-20	1.71	0.82	1.04	0.92
	20-30	1.96	1.06	1.14	1.06
	30-40	2.02	1.23	1.79	1.45
	40-50	2.10	2.04	2.12	2.11
M4 = Vertical tillage with subsoiler upto a depth of 60 cm at 1 m interval	0-10	0.90	0.51	0.78	0.55
	10-20	1.37	0.73	0.99	0.82
	20-30	1.56	0.95	1.15	0.98
	30-40	1.77	1.24	1.52	1.31
	40-50	2.09	1.81	1.99	1.73
SEm+		0.076	0.056	0.084	0.036
CD (P=0.05)		NS	0.17	0.29	0.12

Treatments:
Main plot: Tillage practices - 4
M_1= Conventional tillage
M_2= Deep ploughing with disc plough upto a depth of 30 cm
M_3= Vertical tillage with subsoiler upto a depth of 40 cm at 1 m interval
M_4= Vertical tillage with subsoiler upto a depth of 60 cm at 1 m interval
Sub plot : Nutrient management practices - 5
Control (S_1), 50 % RDF (S_2), 75 % RDF (S_3), 100 % RDF (S_4) and 125 % RDF (S_5)

Soil pH and electrical conductivity was not significantly influenced by tillage and nutrient management practices during both the years of experimentation. This might be due to that different tillage implements have no significant influence in changing soil pH and electrical conductivity. These results are in agreement with findings of Kumar *et al*., 2013b. Higher pH and electrical conductivity of soil was observed with 75 % RDF followed by 50 % RDF, control, 100 and 125 % RDF with no significant disparity among the nutrient management practices that were studied. This might be due to that increase in concentration of chemical fertilizers may not be able to influence pH and electrical conductivity of soil.

Table 2: Aggregate stability (%) and Soil moisture content (%) of groundnut as influenced by tillage practices during *kharif* , 2015 and 2016.

Treatment	Aggregate stability (%)				Soil moisture content (%) at harvest					
	2015		2016		2015			2016		
Tillage practices	**Before**	**After**	**Before**	**After**	**0-20**	**20-40**	**40-60**	**0-20**	**20-40**	**40-60**
M1	46.01	48.25	47.21	50.54	10.69	10.48	9.14	7.69	7.44	7.19
M2	46.05	58.87	52.19	59.62	11.72	11.36	9.25	8.02	7.89	7.63
M3	46.18	66.75	58.55	67.71	12.72	12.64	10.05	9.16	8.25	8.38
M4	46.25	67.23	60.74	69.89	13.76	13.68	10.91	9.96	8.78	8.63
SEm+	2.538	5.563	6.882	4.531	0.105	0.127	0.177	0.06	0.118	0.055
CD (P=0.05)	NS	6.29	NS	8.38	0.37	0.44	0.62	0.22	0.41	0.19
Nutrient management practices										
S1	45.01	53.70	50.16	58.25	11.65	11.47	10.58	9.71	9.58	8.55
S2	46.21	55.19	51.25	60.38	11.24	10.81	9.57	9.35	9.05	8.86
S3	46.24	56.08	52.56	63.51	10.90	10.50	9.11	8.91	8.05	7.60
S4	46.46	57.34	52.78	65.42	10.00	9.15	9.04	8.04	7.65	7.40
S5	46.78	57.51	53.32	66.14	9.58	9.37	8.24	7.89	7.32	6.86
SEm+	2.231	3.315	3.115	6.742	0.109	0.106	0.136	0.04	0.045	0.054
CD (P=0.05)	NS	NS	NS	NS	0.31	0.30	0.39	0.12	0.13	0.15
Interaction										
S at M										
SEm+	4.871	9.182	8.762	8.623	0.236	0.284	0.396	0.14	0.264	0.123
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mat S										
SEm+	4.623	10.22	11.21	10.54	0.222	0.228	0.301	0.10	0.143	0.111
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Treatments:
Main plot: Tillage practices - 4
M_1= Conventional tillage
M_2= Deep ploughing with disc plough upto a depth of 30 cm
M_3= Vertical tillage with subsoiler upto a depth of 40 cm at 1 m interval
M_4= Vertical tillage with subsoiler upto a depth of 60 cm at 1 m interval
Sub plot : Nutrient management practices - 5
Control (S_1), 50 % RDF (S_2), 75 % RDF (S_3), 100 % RDF (S_4) and 125 % RDF (S_5)

Organic carbon was recorded before sowing and harvest of groundnut crop. Vertical tillage with subsoiler upto 40 cm depth at 1 m interval (M_3) and vertical tillage with subsoiler upto 60 cm depth at 1 m interval (M_4) recorded maximum organic carbon content followed by deep ploughing with disc plough (M_2) and conventional tillage (M_1) with no significant disparity among the treatments. These results are in agreement with findings of Felix *et al*., 2008 and Lammerding *et al*., 2011. Higher soil organic carbon content was observed with 125 and 100 % RDF, followed by 75, 50 % RDF and control with no significant disparity among the nutrient management practices that were studied. These results are in accordance with findings of Balasubramaniyan, 1997. This might be due to that increase in concentration of chemical fertilizers may not be able to influence soil organic carbon content.

Overall two years of experiment, in all depths of sampling, maximum soil moisture content at harvest was observed with vertical tillage with subsoiler upto 60 cm depth at 1 m interval (M_4) followed by vertical tillage with subsoiler upto 40 cm depth at 1 m interval (M_3) tillage practices as compared to deep ploughing with disc plough (M_2) and conventional tillage (M_1). This might be attributed to in M_4 and M_3 vertical tillage (subsoiling) could have provided improved physical environment *viz*., lower bulk density, less penetration resistance, higher aggregate stability in the root zone resulting in higher infiltration of rain water and its storage in deeper soil layers there by improving the soil moisture status. These results are in agreement with findings of those Mathukia *et al*., 2015 and Prieto *et al*., 2009. While conventional tillage with lower soil moisture content could have created higher vapour pressure gradient between atmosphere and crop canopy resulting in more evaporation loss of water which is due to poor infiltration and storage of rainwater because of higher bulk density and lesser porosity of soil. While, with respect to nutrient management practices, maximum soil moisture content was recorded with control followed by 50, 75, 100 and 125 % RDF with a significant disparity among the treatments during both the years of study. This might be due to that, in 125 and 100 % RDF treatments plant growth was maximum with higher plant height, leaf area index, dry matter production and relative leaf water content that made the plants to absorb more moisture from soil profile for their growth hence, the available soil moisture content was minimum with 125 and 100 % RDF. In contrast, growth of groundnut crop was minimum in control treatment thus, soil moisture content was maximum which has not been properly utilized by the crop.

Among tillage practices studied during both *kharif*, 2015 and 2016 total microbial mass in soil *viz*., bacteria, fungi and actinomycetes were significantly higher with vertical tillage with subsoiler upto 60 cm depth at 1 m interval (M_4) compared to rest of the tillage practices tried. This might be due to the favourable soil conditions resulted from vertical tillage that made the microbial population to be well developed in rhizosphere. Similar findings were reported by Shukla *et al*. (2021); Munkholm *et al*. (2005). Maximum count of total microbial population *viz*., bacteria, fungi and actinomycetes were recorded with 125 % RDF treatment that has significant difference from rest of the nutrient management practices tested during both the *kharif* seasons. This might be due to higher root activity in rhizosphere due to more availability of nutrients. These results are in conformity with findings of Babu*et al*. (2008).

Table 3: Influence of tillage and nutrient management practices on soil chemical properties before sowing and after harvest of groundnut during *kharif*, 2015 and 2016.

Treatments	pH				Electrical conductivity (dS m^{-1})				Organic carbon (%)			
	2015		2016		2015		2016		2015		2016	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Tillage practices												
M1	6.85	6.82	6.82	6.81	0.89	0.86	0.88	0.85	0.34	0.35	0.34	0.34
M2	6.82	6.81	6.81	6.81	0.89	0.87	0.89	0.86	0.34	0.36	0.35	0.35
M3	6.82	6.80	6.80	6.80	0.91	0.89	0.90	0.87	0.36	0.36	0.36	0.36
M4	6.81	6.80	6.80	6.80	0.91	0.89	0.90	0.87	0.35	0.36	0.35	0.35
SEm+	0.012	0.015	0.011	0.016	0.015	0.012	0.015	0.012	0.005	0.006	0.008	0.007
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management practices												
S1	6.81	6.80	6.80	6.80	0.87	0.85	0.86	0.85	0.34	0.34	0.34	0.34
S2	6.81	6.81	6.81	6.81	0.88	0.86	0.87	0.86	0.34	0.35	0.35	0.35
S3	6.82	6.84	6.82	6.82	0.89	0.87	0.88	0.87	0.35	0.35	0.35	0.36
S4	6.80	6.79	6.80	6.80	0.90	0.88	0.88	0.87	0.35	0.36	0.36	0.36
S5	6.80	6.79	6.80	6.80	0.90	0.89	0.89	0.88	0.35	0.36	0.36	0.36
SEm+	0.015	0.017	0.015	0.017	0.018	0.020	0.019	0.018	0.004	0.003	0.005	0.005
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction												
S at M												
SEm+	0.031	0.034	0.033	0.032	0.034	0.031	0.030	0.026	0.012	0.013	0.013	0.014
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
M at S												
SEm+	0.032	0.033	0.034	0.036	0.033	0.030	0.032	0.034	0.010	0.008	0.009	0.011
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Nutrient uptake (kg/ha) and post harvest nutrient status (kg/ha) of soil as influenced by tillage and nutrient management practices.

Treatments	Nutrient uptake (kg/ha) by groundnut crop						Post harvest nutrient status (kg/ha) of soil after groundnut					
	Nitrogen		Phosphorous		Potassium		Nitrogen		Phosphorous		Potassium	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Tillage practices												
M_1	110.3	112.8	12.5	13.4	65.5	66.5	151.5	153.4	33.7	34.9	181.9	184.3
M_2	112.1	116.1	13.6	15.7	67.2	68.3	154.3	159.4	35.9	37.8	186.9	188.6
M_3	114.4	117.8	15.0	17.1	69.0	70.6	156.6	161.2	37.3	39.4	188.7	191.6
M_4	117.2	118.9	17.2	19.6	74.0	72.7	158.4	164.3	38.4	41.6	190.4	194.8
SEm+	0.19	0.23	0.12	0.21	0.24	0.26	0.19	0.24	0.13	0.19	0.23	0.29
CD (P=0.05)	0.6	0.8	0.4	0.7	0.8	0.9	0.6	0.9	0.4	0.7	0.8	1.1
Nutrient management practices												
S_1	108.7	109.6	11.5	12.1	62.9	63.4	146.0	149.2	11.4	13.6	158.0	160.2
S_2	110.5	112.5	12.9	14.7	65.3	67.1	154.2	152.4	30.1	31.6	180.6	183.7
S_3	113.0	115.6	14.5	16.3	68.1	69.1	156.7	155.3	38.4	40.5	190.3	192.4
S_4	116.2	121.0	16.4	19.1	72.3	71.6	158.5	158.7	46.5	48.2	198.7	202.6
S_5	119.0	123.5	17.8	20.2	76.1	76.3	160.7	161.8	55.1	53.4	207.3	205.9
SEm+	0.13	0.15	0.08	0.15	0.18	0.22	0.19	0.26	0.57	0.70	0.65	0.89
CD (P=0.05)	0.4	0.5	0.2	0.5	0.5	0.9	0.5	0.9	1.6	1.9	1.8	2.1
Interaction												
S at M												
SEm+	0.43	0.56	0.27	0.31	0.53	0.59	0.43	0.52	0.30	0.38	0.53	0.72
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
M at S												
SEm+	0.31	0.36	0.20	0.24	0.40	0.48	0.39	0.46	1.03	1.12	1.18	1.24
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Among tillage practices studied during both the years of experiment maximum uptake as well as maximum availability of nitrogen, phosphorous and potassium in soil after harvest of groundnut was recorded with vertical tillage with subsoiler upto 60 cm depth at 1 m interval (M_4), followed by vertical tillage with subsoiler upto 40 cm depth at 1 m interval (M_3), deep ploughing with disc plough (M_2) and conventional tillage (M_1) with a significant disparity between any two of the treatments. This might be due to more availability of nutrients and moisture in vertical tillage treatments that favoured more mineralisation and translocation of nutrients especially phosphorous and potassium which helped in higher uptake of nutrients compared to deep ploughing and conventional tillage treatments. Similar results stating that significant effect of vertical tillage on nutrient uptake by plants were reported by Cai *et al*. (2014); Mathukia and Khanpara, (2007). Among the nutrient management practices studied during both the years of study, higher nitrogen, phosphorous and potassium uptake as well as maximum availability of nitrogen, phosphorous and potassium was obtained with 125 % RDF application, which was significantly higher than rest of the nutrient management practices tried. Higher nutrient uptake might be due to higher availability of nitrogen, phosphorous and potassium. These results are in agreement with the findings of Pacharne *et al*. (2015) and Elayaraja and Singarvel (2009).

Among the tillage practices tried, the highest number of filled pods plant^{-1} and pod yield were recorded with vertical tillage with subsoiler upto 40 cm depth at 1 m interval (M_3), which was significantly higher than with rest of the tillage practices during two years of investigation. This might be due to better translocation of photosynthates from source to developing pods on account of overall improvement in vegetative growth which favourably influenced the flowering and fruiting in groundnut. In addition, the favourable soil conditions *viz*., more availability of nutrients and moisture provided better growth thus producing maximum number of filled pods plant^{-1} and pod yield of groundnut. The results supported the findings of Rajitha *et al*. (2017); Mathukia *et al*. (2015); Kumar *et al*. (2014).The vertical tillage with subsoiler upto 60 cm depth at 1 m interval (M_4) was the next best treatment in producing higher yield attributes and pod yield of groundnut followed by deep ploughing with disc plough (M_2) with significant difference between them. The lowest pod yield was obtained with conventional tillage (M_1) during both season of *kharif*, 2015-2016. The highest number of filled pods plant^{-1} and pod yield were produced with 100 % RDFwith a significant disparity among the treatments. These results are in accordance with findings of those Jamprangi *et al*., (2014); Sharma *et al*. (2013). This might be due to adequate availability of nutrients to the crop to put its maximum potential in producing higher number of filled pods plant^{-1}, hundred pod and kernel weight. Fertilizer dose of 100 % RDF was sufficient for realisation of higher pod yield of groundnut. This result indicated that gypsum and zinc sulphate along with N, P and K fertilizer at recommended level brought about a positive effect on pod yield of groundnut.

Table 5: Total microbial mass (CFU g^{-1} soil) at harvest of groundnut as influenced by tillage and nutrient management practices.

Treatments	Bacteria (x 10^6)		Fungi (x 10^4)		Actinomycetes (x 10^5)	
	2015	2016	2015	2016	2015	2016
Tillage practices						
M1	48.1	52.1	16.5	17.0	34.9	46.1
M2	50.1	55.6	20.6	20.5	72.5	74.5
M3	53.2	63.9	24.2	24.9	79.8	80.9
M4	56.0	65.5	28.7	30.6	85.6	84.6
SEm+	0.52	0.82	0.65	0.78	1.33	1.42
CD (P=0.05)	2.4	2.1	3.0	3.2	3.1	3.3
Nutrient management practices						
S1	40.6	45.3	15.6	16.2	36.4	39.4
S2	46.1	49.7	18.8	20.8	48.6	50.6
S3	52.5	51.5	21.5	23.4	56.1	59.8
S4	58.7	60.6	26.8	27.9	65.8	68.2
S5	62.5	65.4	29.1	32.7	71.0	75.5
SEm+	0.34	0.55	0.65	0.81	1.35	1.45
CD (P=0.05)	1.5	1.6	1.9	3.4	3.0	3.1
Interaction						
S at M						
SEm+	1.16	1.25	1.46	1.62	4.55	4.36
CD (P=0.05)	NS	NS	NS	NS	NS	NS
M at S						
SEm+	0.80	0.98	1.33	1.78	3.78	3.51
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Treatments:
Main plot: Tillage practices - 4
M_1= Conventional tillage
M_2= Deep ploughing with disc plough upto a depth of 30 cm
M_3= Vertical tillage with subsoiler upto a depth of 40 cm at 1 m interval
M_4= Vertical tillage with subsoiler upto a depth of 60 cm at 1 m interval
Sub plot : Nutrient management practices - 5
Control (S_1), 50 % RDF (S_2), 75 % RDF (S_3), 100 % RDF (S_4) and 125 % RDF (S_5)

Higher haulm yield of groundnut was recorded with vertical tillage with subsoiler upto 60 cm depth at 1 m interval (M_4) followed by vertical tillage with subsoiler upto 40 cm depth at 1 m interval (M_3), deep ploughing with disc plough (M_2) with significant difference among them. The lowest haulm yield was obtained with conventional tillage (M_1) during both seasons of *kharif*, 2015 and 2016. Similarly higher haulm yield was obtained with 125 % RDF followed by 100, 75, 50 % RDF and control treatments with a significant disparity among them during both the years of experimentation.

Table 6: Yield attributes and yield of groundnut as influenced by tillage and nutrient management practices.

Treatments	Number of filled pods plant^{-1}		Pod yield (kg ha^{-1})		Haulm yield (kg ha^{-1})	
	2015	2016	2015	2016	2015	2016
Tillage practices						
M_1	20	17	3279	2427	3980	3719
M_2	21	17	3468	2625	4024	3818
M_3	26	22	3695	2757	4026	4105
M_4	25	18	3547	2727	4042	4246
SEm+	0.37	0.90	34.3	14.3	29.71	114.65
CD (P=0.05)	1.0	3.0	121	50	NS	NS
Nutrient management practices						
S_1	21	16	2965	2180	3938	3757
S_2	23	18	3378	2488	3970	3862
S_3	24	19	3734	2885	4017	3995
S_4	24	21	3815	2994	4058	4042
S_5	23	18	3595	2673	4106	4204
SEm+	0.39	0.91	44.6	16.9	27.47	296.64
CD (P=0.05)	1.0	2.0	130	49	9.0	102.0
Interaction						
S at M						
SEm+	0.84	2.01	76.7	32.1	66.44	256.38
CD (P=0.05)	NS	NS	267	102	NS	NS
M at S						
SEm+	0.79	1.86	86.8	33.6	34.22	216.27
CD (P=0.05)	NS	NS	260	101	NS	NS

Treatments:
Main plot: Tillage practices - 4
M_1= Conventional tillage
M_2= Deep ploughing with disc plough upto a depth of 30 cm
M_3= Vertical tillage with subsoiler upto a depth of 40 cm at 1 m interval
M_4= Vertical tillage with subsoiler upto a depth of 60 cm at 1 m interval
Sub plot : Nutrient management practices - 5
Control (S_1), 50 % RDF (S_2), 75 % RDF (S_3), 100 % RDF (S_4) and 125 % RDF (S_5)

CONCLUSION

The present investigation revealed that the highest pod yield and the economic returns were obtained with the cultivation of groundnut under vertical tillage with subsoiler at 40 cm depth at 1 m interval (M_3) in combination with 100 % RDF (S_4) which was comparable with vertical tillage with subsoiler at 60 cm depth at 1 m interval (M_4) at 100 % RDF (S_4) on sandy clay loam soils of Southern Agro-climatic Zone of Andhra Pradesh.

FUTURE SCOPE

To develop a tillage model that could predict tillage effect both for tilled and subsurface compact layer. Inclusion of vertical tillage in natural farming system. Vertical tillage in combination with organic nutrient management could be done.

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Conflicts of Interest. None.

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