International Journal of Bio-resource and Stress Management 2015, 6(6):765-777
DOI: 10.5958/0976-4038.2015.00096.2

Short Research Article

Effect of Tillage Management Practices on Soil Physical Properties and Yield of Groundnut in Rice-based Cropping System

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Article History

Manuscript No. AR1504
Received in 1st December, 2015
Received in revised form 7th December, 2015
Accepted in final form 7th December, 2015

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Keywords

Tillage methods, planting methods, direct seeding rice, groundnut

Abstract

A Field experiment was conducted to investigate the influence different tillage practices in groundnut yield after different planting method of rice on changes in soil physical properties. Experiment was conducted in a split-plot design with three planting methods of rice viz., Direct seeding of rice, transplanting of rice after puddling and *in situ* green manuring and transplanting of rice after puddling as main plots and three tillage treatments for groundnut ploughing i.e., Ploughing once+harrowing twice; Ploughing twice+harrowing thrice and Ploughing twice+rotavator twice as sub plots. The result showed that lower bulk density and penetration resistance, MWD and higher porosity, hydraulic conductivity and infiltration rate were influenced by tillage and planting method as well as their interaction. Among tillage methods, ploughing twice+rotavator twice registered higher pod yield of 2.17 t ha^{-1} which was higher than other tillage treatments. Among planting methods, *in situ* green manuring and transplanting of rice after puddling recorded significantly higher ground nut pod yield of 2.26 t ha^{-1} which was 9.49 and 19.6% higher than other planting methods treatments respectively. Ploughing twice+rotavator twice with direct seeding of rice was the superior combination than other treatment combinations with respect to pod yield and yield attributes which in turn indicated by congenial soil physical properties. It was inferred that ploughing with mould board plough followed by rotavator in direct seeding of rice planting it was method favorable for improve groundnut productivity in rice-groundnut system.

1. Introduction

Groundnut (*Arachis hypogaea* L.) is one of the major oilseed crops in India and holding second largest producer after China with production of 5.53 mt (DAC, 2010-11), which is around 25% of the total oilseed production of the country. Among the states, Gujarat is 1st followed by Andhra Pradesh largest producer of groundnut in productivity, whereas the maximum area under rainfed condition is in Southern part of Andhra Pradesh (DAC, 2008). However, in wetland condition groundnut is cultivating during winter (*rabi*) season after harvested of rainy (*kharif*) season rice. For cultivation of Groundnut, soil must be well conditioned for getting better yield, but puddled paddy field condition much more challenging for better groundnut production. However, puddling process destroys soil aggregates and forms a dense layer underneath (Tripathi, 1992; Tripathi et al., 2003) which limit root growth and their distribution. It also resulted in poor soil structure (Oussible et al., 1992) by through poor clod formation with high breaking strength (Sharma and Bhagat, 1993), thus creates a poor physical condition for the sequence cropping system (Boparai et al., 1992).

Better management of soil resources has always relationship with maintaining the soil quality in field. The key for successful management of paddy based cropping system is the adoption of suitable tillage practice (Bajpai and Tripathi, 2000), which influences seed germination and root distribution. Tillage practice brings several changes in soil physical properties and essential for developing economically viable and easily adoptable tillage practices to increase yields of groundnut crop in rice fallow cropping system (Prasadini et al., 1993).

For better cultural practices, knowledge of the dynamics of soil physical properties will thus appear to be of paramount importance. Therefore, an attempt was made to grow paddy under different methods of cultivation (direct sowing, puddled and puddled in *in situ* green manures) and *rabi* groundnut cultivation under different tillage practices. In spite of the large number of field studies already conducted towards tillage effects on the physical structured soils by many researchers, even though information is lacking in long term tillage effect on crop growth (Green et al., 2003). Keeping these in view, the present study investigated the effect of different methods of tillage and in rice–groundnut cropping system on soil physical properties and groundnut yield.

2. Materials and Methods

2.1. Experimental site

The field experiment was conducted during *rabi* season of (2005-06) at the Agricultural College Farm, Acharya N G Ranga Agricultural University (ANGRAU) Rajendranagar, Hyderabad, India. It is located at 17° 19´ North Latitude and 75° 23´ East Longitude and altitude of 534 m above the MSL. The study area falls under Deccan hot semi-arid with average annual rainfall of 850 mm. The climate characterized by hot dry summer (May-June) and winter (December-January) with minimum and maximum temperatures being 29.8 and 40.0 °C in summer and 11.9 to 26.7 °C in winter respectively.

2.2. Soil sample collection and analysis

The soil of the experimental field belongs to Alfisols, non-saline alkaline, sandy clay loam in texture class. Before initiating the experiment, soil sample was collected plot wise, air-dried in shade, passed through a 2-mm sieve and analyzed for initial physio chemical properties. The particle size was determined by hydrometer method (Bouyoucos, 1962). The soil reaction (pH) and Electrical Conductivity (EC) was determined in 1:2.5 soils: water suspension as described by Jackson (1973). Soil organic carbon content was determined by wet digestion method (Walkley and Black, 1934). Available nitrogen analysed by alkaline permanganate method (Subbaiah and Asija, 1956). The Olsen-P ($NaHCO_3$-P) was extracted as per the procedure outlined by Olsen et al. (1954) and the P content in the soil extract was determined using ascorbic acid as the reducing agent (Watanabe and Olsen, 1965) using a spectrophotometer. The available K content of the soils was determined by a flame photometer (Muhr et al., 1963). The bulk density and porosity with different depths was determined by using core sampler suggested by Black (1965). Penetration resistance measured by cone penetrometer (Davidson, 1965), Infiltration rate by infiltrometer method (Jalota et al., 1998). Hydraulic conductivity measured by using constant pressure head method as per the procedure outlined by Jalota et al. (1998). Some important physicochemical characteristics of the initial soil are presented in Table 1.

The experiment was conducted in Split Plot Design (SPD) with

Table 1: Some important physicochemical properties of the experimental soil

Characteristics	Values (depth)		Method/ Reference
	0-15 cm	15-30 cm	
pH (soil: water 1:2.5)	8.55	8.68	Jackson (1973)
EC (soil: water 1:2) (dS m^{-1})	0.35	0.28	Jackson (1973)
Mechanical analysis			Bouyoucos (1962)
Sand (%)	68.2	65.3	
Silt (%)	8.9	10.2	
Clay (%)	22.9	24.5	
Textural class	Sandy clay loam	Sandy clay loam	
Bulk density (Mg m^{-3})	1.59	1.64	Black, 1965
Porosity (%)	34.89	32.06	Black, 1965
Hydraulic conductivity (cm hr^{-1})	2.32	1.51	Jalota et al. (1998
Infiltration rate (cm hr^{-1})	1.12	-	Jalota et al. (1998
Organic carbon (%)	0.83	0.56	Walkley and Black (1934)
Available N (kg ha^{-1})	240.42	174.50	Subbaiah and Asija, 1956
Available P_2O_5 (kg ha^{-1})	47.95	31.35	Olsen et al. (1954)
Available K_2O (kg ha^{-1})	408.62	291.22	Muhr et al., 1963

the three methods of tillage in main plots and three methods of rice planting with three replications each. Three Planting methods of rice (*Kharif*) viz., P_1: Direct seeding of rice (no puddling), P_2: transplanting of rice after puddling and P_3: *In situ* green manuring and transplanting of rice after puddling as main plots and three tillage treatments for groundnut (*Rabi*) viz., T_1: Ploughing once (M.B. plough)+harrowing twice, T_2: Ploughing twice (M.B. Plough)+harrowing thrice and T_3: Ploughing twice (M.B. Plough)+rotavator twice as sub plots treatments. Groundnut variety K-134 of 135 days duration was used as a test crop. All the 27 plots were surrounded by 0.5 m wide bund to prevent lateral water movement and nutrient diffusion between plots. During the crop growing period, soil samples were collected at random spots from the experimental field from surface (0-15 cm) and subsurface (15-30 cm) depth at three stage viz., sowing, flowering and after harvest of groundnut crop.

Aggregate analysis was done from surface soil by wet sieving technique as described by Yoder (1937). The per cent aggregates>0.25mm diameter and the per cent aggregate stability were calculated from the following equation

$$\text{Per cent Aggregates} >0.25\text{ mm diameter} = \frac{\text{Weight of aggregates}>0.25\text{ mm diameter}}{\text{Weight of the soil}} \times 100$$

$$\text{Per cent Aggregates stability} = \frac{\text{Weight of aggregates}>0.25\text{ mm diameter} - \text{Weight of sand}}{\text{Weight of the sample} - \text{Weight of sand}} \times 100$$

Infiltration rate of the soil was determined in situ during 60 DAS and after harvest by using double ring infiltrometer (Bertrand, 1965). Cone penetrometer used to determine the strength of soil as stated by Davidson (1965). Soil samples were analyzed from 0-15 cm and 15-30 cm depths at sowing, 60 DAS and harvest of groundnut. A core sampler of size 5.25 ×6 cm used to determine soil bulk density by using the method suggested by Black (1965) and hydraulic conductivity using constant pressure head method as per the procedure outlined by Jalota et al. (1998). Groundnut pods obtained from the net plot were sun dried to constant weight. The pod yield from each net plot was recorded and expressed in kg ha^{-1}.

2.3. Statistical analysis

Data were analyzed in a split plot design using tillage as main factor and determine significance (*p=0.05*) by F test (Gomez and Gomez, 1984). Mean separation for different treatments was performed for using the least significant difference (LSD) test at 0.05 level of probability. Pearson's correlation matrix for yield and physical properties of soil was also computed by using the R-statistical programme software (R Core Team, 2013).

3. Results and Discussion

3.1. Pod yield of groundnut

The results of statistical analysis of the pod yield of ground nut as influenced by the tillage and planting methods has been presented in Table 2. The result had revealed that among the different tillage methods, ploughing twice (MB Plough)+rotavator twice (T_3) had registered significantly higher pod yield (2173 kg ha^{-1}), followed by ploughing twice (MB Plough)+harrowing thrice (T_2) and ploughing twice (MB Plough)+harrowing twice (T_1). With respect to the planting method, the highest pod yield was recorded in direct seeding rice (no puddling) (P_1) followed by transplanting rice+puddling with in situ green manuring (P_3), which were comparable but superior to transplanting rice+puddling alone (P_2).

Table 2: Effect of planting and tillage methods on dry pod yield (kg ha^{-1}) of groundnut

Tillage treatment	Planting method			Mean
	P_1	P_2	P_3	
T_1	2150	1780	1950	1960
T_2	2275	1910	2073	2086
T_3	2362	1984	2174	2173
Mean	2262	1891	2066	
	P	T	P at T	T at P
SEm±	92.1	12.8	130.9	22.1
CD (*p*=0.05)	256	28	360	48

P_1: Direct seeding of rice (no puddling); P_2: Transplanting of rice after puddling; P_3: In situ green manuring and transplanting of rice after puddling; P: Ploughing; T_1: Ploughing once (M.B Plough)+harrowing twice; T_2: Ploughing twice (M.B Plough)+harrowing thrice; T_3: Ploughing twice (M.B Plough)+rotavator twice; T: Tillage; P at T: Interaction between ploughing and tillage; T at P: Interaction between tillage and ploughing

The interaction of Tillage and planting methods was significant. It was revealed that under ploughing twice (MB Plough)+rotavator twice and transplanting rice+puddling with *in situ* green manuring recorded significantly higher pod yield, followed by other planting methods, which were comparable and inferior to this treatment. The T_1P_2 plot recorded the lowest pod yield. However, among planting methods, P_3 registered significantly higher pod yield under T_3 Treatment. Paddy-groundnut cropping system it is revealed that yield of groundnut increased significantly due to planting and tillage methods (Table 2). This might be due to higher supply of plant nutrients attributed by better soil environment as indicated by lower bulk density and higher porosity and lower penetration resistance, which resulted in higher emergence of seedling which in turn resulted in higher pod yield. Similar results were reported by Nagender Rao et al. (2004) in groundnut. Among planting methods, highest (2262 kg ha^{-1}) dry pod yield of groundnut was obtained in P_1 which was significantly higher than P_2 (1891 kg ha^{-1}) and on par with P_3 (2066 kg ha^{-1}). The pod yields of P_2 and P_3 were on par with each other (Table 2).

Pod yield of groundnut was the highest (2173 kg ha^{-1}) in T_3 treatment which was significantly higher than other treatments. Higher yield in rotavator treatment (T_3) could be due to higher smaller sized clods with lower MWD, this resulted in lower bulk density and penetration resistance, which created favorable physical environment leading to better growth ultimately resulted in higher pod yield in the treatment. The lowest pod yield (1960 kg ha^{-1}) was recorded in T_1 treatment because the tillage was less vigorous, which resulted in higher big sized clods with higher MWD, which resulted in lesser seed soil content leading to lower pod yield. Similar results were reported by Prasandini et al. (1993), Pratibha (1992); Nagender Rao et al. (2004); Mukundam (2005).

Interaction effect of planting and tillage methods on pod yield was significant (Table 8). Among the treatment combinations, highest pod yield (2362 kg ha^{-1}) was recorded in P_1T_3 followed by P_1T_2 treatment and the lowest yield was recorded in P_2T_1 treatment. The effect of puddling has significantly reduced the pod yield of groundnut compared to non-puddling condition.

3.2. Bulk density

The bulk density (BD) of soil at both depths i.e., 0-15 and 15-30 cm was significantly influenced by tillage and planting methods at all stages (Table 3). Direct seeding of rice (P_1) registered lowest (1.46 Mg m^{-3}) BD of surface soil at sowing, which was significantly lower than P_2 (1.51 Mg m^{-3}) and P_3 which recorded 1.50 Mg m^{-3} which was comparable with P_2. This result is coinciding with McDonald et al., 2006, under rice-wheat cropping system. Similar trend was observed at 60 DAS and harvest. The higher BD value of P_2 and P_3 might be lower pore space recorded due to puddling effect in P_2 and P_3. Subsurface (15-30 cm) soils similar trend to surface soil was observed, at both the stages. Brady (1990) and Agbede (2008) was found that BD value is higher in lower profile layers because of lower concentration of the organic matter, less aggregation and higher compaction. Similar results were reported by Nagender Rao et al. (2004); Peeyush Sharma et al. (2004).

At surface soil, among the tillage methods, T_3 resulted in lowest (1.44 Mg m^{-3}) BD at all the stages of crop growth, which was significantly lower than T_1 and T_2 treatments. The highest (1.54 Mg m^{-3}) bulk density was recorded in T_1 treatment which was significantly higher than T_3 followed by T_2 treatment. Similar trend was observed at 60 DAS and harvest. This might be due to vigorous and more inversion type of tillage in T_3 treatment. which pulverized and loosened the soil to a greater extent and increased porosity, thereby appreciably reduced the bulk density. In subsurface soils, T_3 recorded lowest BD (1.47 Mg m^{-3}) which was significantly lower than T_1 (1.62 Mg m^{-3}) and T_2 (1.51 Mg m^{-3}) at sowing. Similar trend was observed at 60 DAS and harvest. In sub-surface layer bulk density was higher while porosity was lower. These findings are in agreement with those reported by Khan (1984), AICRP (1986-87), Nagender Rao et al. (2004); Praveen Kumar (2004).

Interaction effect of planting and tillage methods was significant at all the stages (Table 3). Among treatment interaction, lowest bulk density (1.40 Mg m^{-3}) was recorded in P_1T_3 at sowing in 0-15 cm depth, which was significantly lower than other treatment combinations. This was followed by P_3T_3 (1.45 Mg m^{-3}) which was on par with P_1T_2 and P_2T_3. The highest (1.55 Mg m^{-3}) BD was recorded in P_2T_1 at the time of sowing. Similar trend was observed in subsurface soil. No puddling with vigorous tillage in P_1T_3 and puddling and less vigorous tillage in P_2T_1 might be the reasons for differences in the bulk density and porosity values. In general, bulk density of soil increased with the depth and also with advancement of crop growth. BD increased while porosity decreased gradually with the advancement of crop growth period in both soil depths. BD at harvest was higher than sowing and 60 DAS stage. This might be due to consolidation of soil particles and decrease in macro pore space with increase in age of crop growing period which resulted in increasing the bulk density and decreasing the porosity of soil. This is in conformity with the findings of Awadhwal and Thierstein (1984), Diaz-Zortia (2000) in maize and Praveen Kumar (2004) in sunflower.

Table 3: Effect of planting and tillage methods on bulk density (Mg m^{-3}) at different stages of crop growth

Treatment	Sowing				60 DAS				Harvest			
0-15 cm depth												
Tillage method	Planting methods			mean	Planting methods			mean	Planting methods			mean
	P_1	P_2	P_3		P_1	P_2	P_3		P_1	P_2	P_3	
T_1	1.52	1.55	1.54	1.54	1.57	1.64	1.61	1.61	1.60	1.64	1.63	1.62
T_2	1.46	1.52	1.51	1.50	1.54	1.59	1.57	1.57	1.56	1.62	1.58	1.59
T_3	1.40	1.46	1.45	1.44	1.52	1.54	1.52	1.53	1.54	1.57	1.54	1.55
Mean	1.46	1.51	1.50		1.54	1.59	1.58		1.57	1.61	1.58	
	P	T	P at T	T at P	P	T	P at T	T at P	P	T	P at T	T at P
SEm±	0.005	0.004	0.009	0.007	0.007	0.004	0.010	0.006	0.004	0.002	0.006	0.004
CD (*p*= 0.05)	0.02	0.01	0.02	0.02	0.02	0.01	0.03	0.01	0.01	0.01	0.01	0.01
15-30 cm depth												
T_1	1.61	1.63	1.61	1.62	1.60	1.65	1.61	1.63	1.64	1.66	1.66	1.65
T_2	1.50	1.53	1.51	1.51	1.58	1.61	1.57	1.59	1.61	1.65	1.64	1.63
T_3	1.46	1.49	1.47	1.47	1.55	1.58	1.52	1.55	1.57	1.63	1.61	1.60
Mean	1.52	1.55	1.53		1.58	1.61	1.58		1.61	1.65	1.64	
	P	T	P at T	T at P	P	T	P at T	T at P	P	T	P at T	T at P
SEm±	0.004	0.005	0.007	0.009	0.008	0.004	0.011	0.006	0.006	0.002	0.009	0.003
CD (*p*=0.05)	0.01	0.01	0.02	0.02	0.02	0.01	0.03	0.01	0.02	0.00	0.02	0.01

3.3. Pore space

The pore space of soil at different stages of crop growth was significantly influenced by planting and tillage methods (Table 4). The mean percent porosity in 0-15 cm soil depth at time of sowing was highest (44.9%) in P_1, which was significantly higher than P_2 (43.0%) and P_3 (43.4%). Similar trend was observed at 60 DAS and harvest. In 15-30 cm depth, P_1 registered significantly highest (42.5%) pore space which was comparable with P_3 (42.3%) but higher than P_2 (34.37%). At 60 DAS and harvest stage, P_1 and P_3 were at par and significantly higher than P_2. The reason for lower pore space in P_2 and P_3 treatment was due to puddling effect. Zero tillage resulted higher pore space than other puddling treatments Similar results were reported by Nagender Rao et al. (2004); Peeyush Sharma et al. (2004).

The highest porosity (45.8%) at 0-15 cm sowing depth was recorded in T_3 these result was supported by Alem et al., 2013. which was significantly higher than T_2 and T_1. T_2 which recorded 43.5% was also significantly higher than T_1 (42.01%). Cogle et al. (1997) has reported that deep tillage increases soil porosity. Similar trend was observed at 60 DAS and harvest stage. In 15-30 cm soil depth, similar trend was observed at all the stages of crop growth. This might be due to vigorous and more inversion type of tillage in T_3 treatment which pulverized and loosened the soil to a greater extent and increased porosity, thereby appreciably reduced the bulk density. These findings are in agreement with those reported by Khan (1984), AICRP (1986-87), Nagender Rao et al. (2004) and Praveen Kumar (2004). The total porosity was significantly higher with the conventional tillage than with the no tillage under the sole sorghum. It has been reported specifically under sorghum (Omer and Elamin, 1997).

Among the interaction effects, the higher porosity was recorded in P_1T_3 (47.2% and 44.9%), and lower porosity were recorded in P_2T_1 (41.5% and 38.5%) in both (0-15 cm and 15-30 cm) depths. No puddling with vigorous tillage (P_1T_3) and puddling with less vigorous tillage (P_2T_1) could be the reasons for differences in the porosity percent. Porosity decreased gradually with the advancement of crop growth period in both the soil depths. Consolidation of soil particles and decrease in macro pore space with increase in age of crop growth period, resulted in increasing the bulk density and decreasing the porosity of soil. This is in conformity with the findings of Awadhwal and Thierstein (1984), Diaz-Zortia (2000) in maize and Praveen Kumar (2004) in sunflower.

3.4. Hydraulic conductivity

The planting and tillage methods significantly influenced hydraulic conductivity (HC) at all the stages of crop growth in both soil depths (Table 5). Highest HC was recorded (6.07 cm hr^{-1}) in Direct seeding of rice with no puddling (P_1) which was significantly superior to P_2 (5.85 cm hr^{-1}) and P_3 (6.00 cm hr^{-1})

Table 4: Effect of planting and tillage methods on total pore space (%) at different stages of crop growth

Treatment	Sowing				60 DAS				Harvest			
	0-15 cm depth											
Tillage method	Planting methods			mean	Planting methods			mean	Planting methods			mean
	P_1	P_2	P_3		P_1	P_2	P_3		P_1	P_2	P_3	
T_1	42.6	41.5	41.9	42.0	40.8	38.1	39.3	39.4	39.6	38.1	38.5	38.7
T_2	44.9	42.6	43.0	43.5	41.9	40.0	40.8	40.9	41.1	38.9	40.4	40.1
T_3	47.2	44.9	45.3	45.8	42.6	41.9	42.6	42.3	41.9	40.8	41.9	41.5
Mean	44.9	43.0	43.4		41.8	40.0	40.9		40.9	39.2	40.4	
	P	T	P at T	T at P	P	T	P at T	T at P	P	T	P at T	T at P
SEm±	0.1	0.43	0.45	0.75	0.27	0.15	0.41	0.27	0.56	0.41	0.81	0.71
CD (*p*=0.05)	0.3	0.9	1.0	1.6	0.7	0.3	1.0	0.6	1.5	0.9	2.2	1.5
	15-30 cm depth											
T_1	39.3	38.5	39.3	39.0	39.6	37.7	39.3	38.9	38.1	37.4	37.4	37.6
T_2	43.4	42.3	43.0	42.9	40.4	39.3	40.8	40.1	39.3	37.7	38.1	38.4
T_3	44.9	43.8	44.5	44.4	41.5	40.4	42.6	41.2	40.8	38.5	39.3	39.5
Mean	42.5	41.5	42.3		40.5	39.1	40.9		39.4	37.9	38.2	
	P	T	P at T	T at P	P	T	P at T	T at P	P	T	P at T	T at P
SEm±	0.32	0.4	0.51	0.7	0.42	0.34	0.68	0.59	0.35	0.19	0.53	0.33
CD (*p*=0.05)	0.9	0.9	1.2	1.5	1.2	0.7	1.7	1.7	1.0	0.4	1.3	0.7

while P_3 was significantly superior to P_2 at 0-15 cm soil depth. Same trend was observed at 60 DAS and harvest stage, in 15-30 cm depth similar trend was observed for HC. Lower bulk density and higher porosity in P_1, and higher bulk density and lower porosity in P_2 and P_3 and could be the reason for higher hydraulic conductivity in P_1. According to Bhattacharyya et al. (2006), the saturated hydraulic conductivity was highly dependent upon the size, continuity and arrangement of pores. This was also to plant root growth and other biological activity in the topsoil (e.g., earthworms, insects, etc.) have created a better pore connectivity and improving the HC.

Among tillage methods at 0-15 cm sowing depth, the highest (7.05 cm hr^{-1}) hydraulic conductivity were recorded in T_3 which was superior to other tillage methods. T_1 treatment resulted the lowest HC in (4.79 cm hr^{-1}) which was significantly lower than T_2 (6.09 cm hr^{-1}). Similar trend was observed at 60 DAS and harvest stage. In 15-30 cm depth, similar trend was observed at all the stages of crop growth. Among the tillage methods, T_3 recorded the highest hydraulic conductivity in both the depths at all the stages of crop growth. This was attributed to more vigorous and vertical mixing of tillage in T_3, which loosened the soil and decreased bulk density and increased porosity resulting in higher HC. These results are in conformity with those reported by Pratibha (1992), Aggarwal et al. (1997), Gurumurthy (2000); Dharmajith Kananga (2001). Also, loosening and mixing of the soil normally associated with conventional tillage (CT) causes alteration in the soil pore geometry. The results help to explain the result (Obalum and Obi, 2010) in the sole sorghum and their intercrops. Besides, the pulverized soil may reconsolidate in favour of macroposity, thereby enhancing HC. Many authors (Chang and Lindwall, 1990; Cresswell et al., 1993; Laddha and Towatat, 1997; Guzha, 2004; Anikwe and Ubochi, 2007; Martinez et al., 2008) have also reported higher HC with the CT.

Interaction effect of planting and tillage methods was significant at all the stages of crop growth (Table 5). The highest hydraulic conductivity (7.21 cm hr^{-1}) at sowing in 0-15 cm depth was recorded in P_1T_3, followed by P_3T_3 (7.09 cm hr^{-1}). The lowest HC recorded in P_2T_1 (4.69 cm hr^{-1}). Hydraulic conductivity at 60 DAS was the highest (6.23 cm hr^{-1}) in P_3T_3 and the lowest (3.22 cm hr^{-1}) in P_2T_1 which was significantly lower than all other treatment combinations. Similar trend was observed at 60 DAS and harvest stage. During early stage, hydraulic conductivity was found to be higher which gradually decreased with advancement of crop growth. It was due to loosening of soil by different tillage treatments (Unger and Cassel, 1991) at the early stages. The decrease during crop growth could be due to solidation of the soil mass with time (Pelegrin et al., 1990). Similar findings were reported by Ray and Gupta (2001). Hydraulic conductivity was higher in 0-15 cm depth compared to subsurface layer (15-30 cm).

Table 5. Effect of planting and tillage methods on hydraulic conductivity (cm hr^{-1}) at different stages of crop growth

Treatment	Sowing				60 DAS				Harvest			
	0-15 cm depth											
Tillage method	Planting methods			mean	Planting methods			mean	Planting methods			mean
	P_1	P_2	P_3		P_1	P_2	P_3		P_1	P_2	P_3	
T_1	4.86	4.69	4.81	4.79	3.50	3.22	3.32	3.35	2.56	2.51	2.53	2.53
T_2	6.14	6.03	6.10	6.09	5.27	5.03	5.22	5.17	3.89	3.56	3.80	3.75
T_3	7.21	6.84	7.09	7.05	6.23	6.06	6.07	6.14	4.25	4.13	4.22	4.20
Mean	6.07	5.85	6.00		5.00	4.77	4.87		3.57	3.40	3.52	
	P	T	P at T	T at P	P	T	P at T	T at P	P	T	P at T	T at P
SEm±	0.02	0.01	0.03	0.02	0.04	0.01	0.06	0.02	0.005	0.006	0.009	0.010
CD (p=0.05)	0.05	0.02	0.07	0.04	0.12	0.03	0.17	0.05	0.01	0.01	0.02	0.02
	15-30 cm depth											
T_1	3.57	3.50	3.52	3.53	2.86	2.51	2.52	2.63	1.61	1.49	1.54	1.55
T_2	4.28	4.09	4.11	4.16	3.60	3.28	3.48	3.45	2.41	2.28	2.32	2.34
T_3	5.27	5.01	5.21	5.16	4.43	4.03	4.30	4.25	2.88	2.72	2.81	2.80
Mean	4.37	4.20	4.28		3.63	3.27	3.43		2.30	2.16	2.22	
	P	T	P at T	T at P	P	T	P at T	T at P	P	T	P at T	T at P
SEm±	0.02	0.02	0.03	0.03	0.050	0.013	0.075	0.025	0.015	0.017	0.027	0.030
CD (p=0.05)	0.05	0.04	0.08	0.07	0.10	0.03	0.15	0.05	0.041	0.038	0.064	0.066

This could be due to higher porosity and lower bulk density in 0-15 cm depth than lower porosity and higher bulk density in subsurface layer throughout the crop growth period.

3.5. *Infiltration rate*

Planting and tillage methods and their interaction significantly influences Infiltration Rate (IR) of the soil at different stages of crop growth (Figure 1). Highest (2.70 cm hr^{-1}) infiltration rate was recorded in P_1 which was on par with P_3 (2.65 cm hr^{-1}) and significantly superior to P_2 (2.51 cm hr^{-1}). Similar trend was observed at 60 DAS and harvest stage. Among the planting methods, P_1 recorded significantly higher infiltration rate at all the stages of crop. This was due to no puddling, low bulk density and higher porosity (Table 6). Bajpai and Tripathi (2000) and Peeyush Sharma et al. (2004) reported high infiltration rate in non-puddled conditions in rice-based system. Increase in infiltration rate due to favorable physical environment was earlier reported by Vijaya Kumar (1991), Aggarwal et al. (1997), Ray and Gupta (2001) and Praveen Kumar (2004). In general, infiltration rate reduced gradually

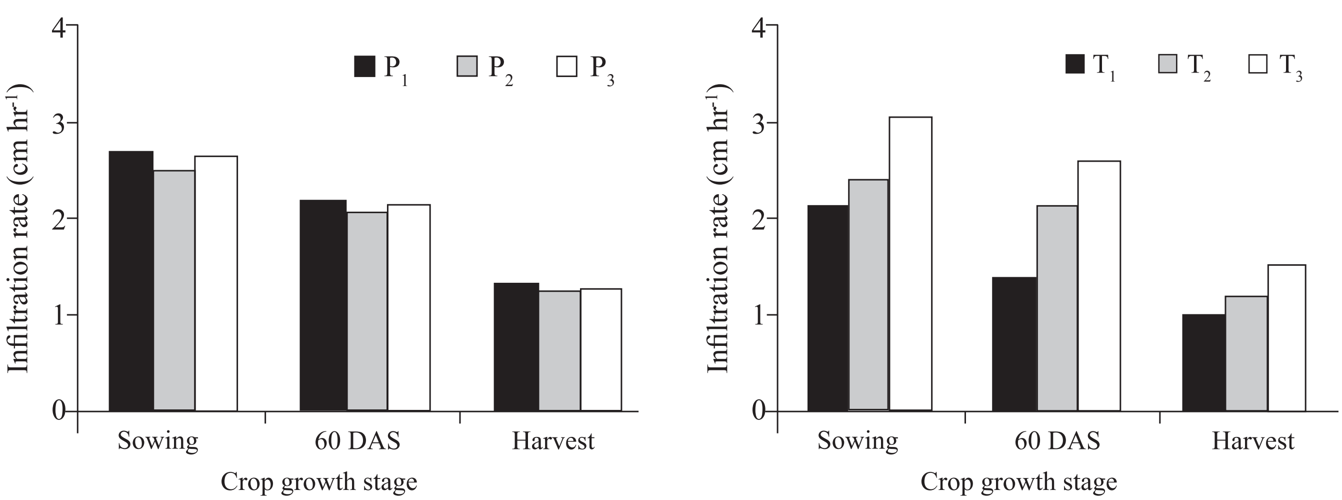

Figure 1: Effect of planting and tillage methods on infiltration rate of groundnut in rice – groundnut system

Table 6: Effect of planting and tillage methods on infiltration rate (cm hr^{-1}) at different stages of crop growth

Treatment	Sowing				60 DAS				Harvest			
Tillage method	Planting methods			mean	Planting methods			mean	Planting methods			mean
	P_1	P_2	P_3		P_1	P_2	P_3		P_1	P_2	P_3	
T_1	2.32	2.10	2.20	2.21	1.51	1.40	1.43	1.45	1.08	1.00	1.03	1.04
T_2	2.57	2.41	2.55	2.51	2.29	2.20	2.27	2.24	1.24	1.16	1.21	1.20
T_3	3.22	3.03	3.20	3.15	2.77	2.62	2.77	2.69	1.62	1.52	1.56	1.57
Mean	2.70	2.51	2.65		2.19	2.07	2.16		1.31	1.23	1.27	
	P	T	P at T	T at P	P	T	P at T	T at P	P	T	P at T	T at P
SEm±	0.03	0.06	0.08	0.11	0.01	0.01	0.02	0.02	0.02	0.03	0.04	0.05
CD (p=0.05)	0.08	0.14	0.17	0.24	0.03	0.03	0.05	0.05	0.06	0.06	0.10	0.10

with the advancement of crop growth. This could be due to increase in bulk density and decrease in porosity.

Among tillage methods, the highest IR rate was registered in T_3 (3.15 cm hr^{-1}) which was significantly higher than T_2 (2.51 cm hr^{-1}) and T_1 (2.21 cm hr^{-1}) at sowing Similar trend was observed in 60 DAS and harvest. Among the tillage methods, T_3 recorded significantly higher infiltration rate at all the stages. This was due to favorable soil physical environment created by lower bulk density and higher porosity because of more vigorous tillage. Similar results were reported by Pratibha (1992), Dharmajith Kanungo (2001), Praveen Kumar (2004) and Lipiec *et al.* (2006). Among the interaction (Figure 1), at time of sowing, the infiltration rate was highest in (3.22 cm hr^{-1}) in P_1T_3 followed by P_3T_3 (3.20 cm hr^{-1}) which were comparable. Lower IR recorded in P_2T_1 (2.10 cm hr^{-1}) all the stages. This was due to favourable soil physical environment created by no puddling and vigorous tillage. Also, higher organic matter and with the differences in pore size improves IR (Goameza et al., 1999)

3.6. Soil aggregate stability

Data reveled that Planting and tillage methods and their interaction significantly improved the soil aggregate stability (per cent) are presented in Table 7.

Among planting methods, P_3 recorded significantly higher aggregate stability (46.3%) which was comparable with P_2 (44.5%) followed by P_1 (41.2%) at sowing. Similar trend was observed at 60 DAS and harvest. Among tillage method, Highest (46.5%) aggregate stability was recorded at sowing in T_1 which was on par with T_2 (45.1%) and significantly higher than T_3 (40.3%). Similar trend was observed at 60 DAS and harvest. Among interaction effects of planting and tillage methods at sowing, the treatment combination of P_3T_1 recorded highest (49.3%) aggregate stability followed by P_3T_2 (48.3%). while lowest (37.4%) was recorded in P_1T_3. Similar trend was obtained at 60 DAS and harvest stage.

The percentage of soil aggregate stability was significantly influenced by planting and tillage methods at all the stages (Table 7). Higher aggregate stability was observed in planting method (P_3) and tillage method, (T_1). Since aggregate stability is derived from the soil aggregates>0.25 mm, similar trend as that of soil aggregates>0.25 mm was observed in aggregate stability in planting and tillage methods and their interaction.

3.7. Per cent soil aggregates>0.25 mm diameter

Planting and tillage methods and their interaction significantly

Table 7: Effect of planting and tillage methods on soil aggregate stability (%) at different stages of crop growth

Treatment	Sowing				60 DAS				Harvest			
Tillage method	Planting methods			mean	Planting methods			mean	Planting methods			mean
	P_1	P_2	P_3		P_1	P_2	P_3		P_1	P_2	P_3	
T_1	44.2	45.9	49.3	46.5	49.3	49.6	53.1	50.7	54.5	56.5	58.2	56.4
T_2	41.9	45.2	48.3	45.1	46.5	48.9	52.3	49.2	51.5	55.6	56.7	54.6
T_3	37.4	42.4	41.2	40.3	41.7	46.3	44.6	44.2	46.2	52.7	50.0	49.6
Mean	41.2	44.5	46.3		45.8	48.2	50.0		50.7	54.9	55.0	
	P	T	P at T	T at P	P	T	P at T	T at P	P	T	P at T	T at P
SEm±	0.78	1.2	1.62	2.07	0.67	0.52	1.08	0.9	0.31	0.93	1.03	1.62
CD (p=0.05)	2.2	2.6	3.7	4.5	1.9	1.1	2.6	2.0	0.9	2.0	2.3	3.5

influenced per cent soil aggregates>0.25 mm diameter at all the stages of crop growth (Figure 2). The highest per cent (71.0%) aggregates were recorded at sowing in P_3 which was significantly higher than P_2 (69.7) and as on par with P_1 (66.6), which in turn was on par with P_1 similar trend was observed at 60 DAS. At harvest, P_3 and P_2 were on par and significantly higher than P_1. Higher percentage of aggregates >0.25 mm diameter found in P_3 could be attributed to higher organic carbon in the treatment and also due to clay dispersion which decreased by the incorporation of green manure in crop rotation. Joshi et al. (1994) also found that green manuring reduced aggregate dispersion in puddled soil. Similar observations were reported by Ray and Gupta (2001) in wheat crop. In tillage highest (71.4) per cent soil aggregates were recorded at sowing in T_1 which was on par with T_2 (69.9) and significantly higher than T_3 (65.9). Similar trend was observed at 60 DAS and harvest stage.

Among the interaction effects, the treatment combination of P_3T_1 recorded the highest (74.0) per cent of soil aggregates at sowing; while P_1T_3 recorded the lowest (63.1) percent of soil aggregates. Similar trend was observed at 60 DAS and harvest. Higher soil aggregate stability was recorded in P_3T_1 combination while lowest was obtained in P_1T_3 at both the stages of crop growth. Higher soil organic carbon along with less vigorous tillage in P_3T_1 was responsible for higher aggregate stability.

3.8. Penetration resistance

Cone penetrometer was used to measure penetration resistance (PR), it observing the force required to insert an object into the soil. Penetration resistance is an important characteristic for plant growth; several studies have negatively correlated root development with increasing resistance (Hasegawa et al., 1985; Martino and Shaykewich, 1994; Busscher et al., 2000). Penetration resistance was significantly influenced by tillage and planting methods at all the stages of crop growth. Among tillage methods, P_1 resulted Lowest (28.8 kg cm^{-2}) penetration resistance at sowing was found in which was significantly lower than P_2 (32.4 kg cm^{-2}) and P_3 (29.8 kg cm^{-2}). Similar trend was observed at 60 DAS and harvest of crop. Similar result was observed by McDonald *et al.*, 2006, under rice-wheat cropping system. The highest penetration resistance was observed in P_2 where bulk density was higher due to the effect of puddling. Penetration resistance in P_3 was intermediate which could be attributed to in situ green manuring in that treatment. Similar results were reported by Ray and Gupta (2001) in wheat crop.

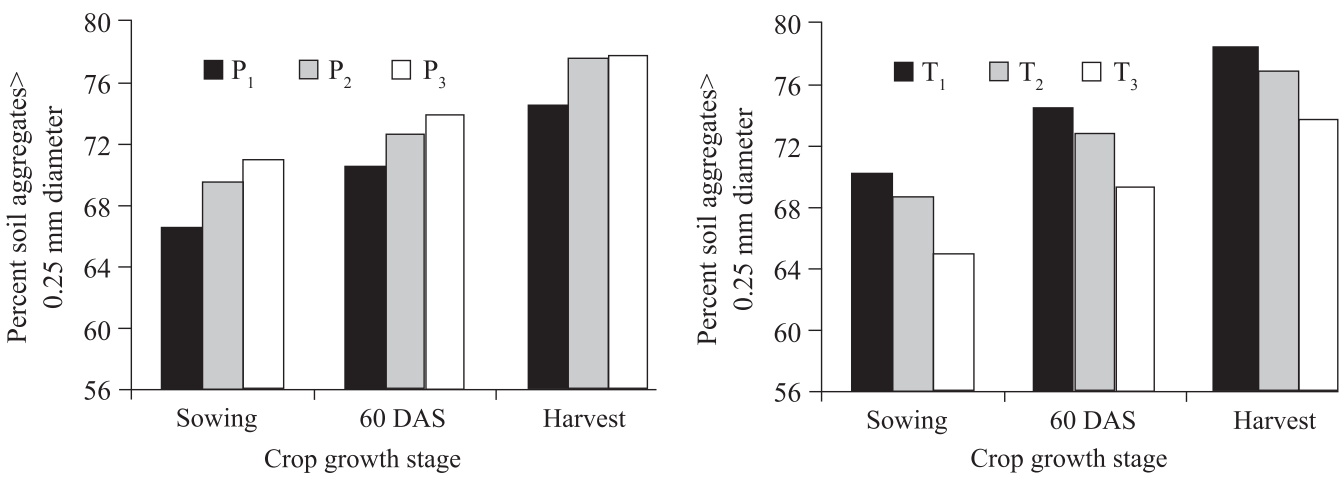

Figure 2: Effect of planting and tillage methods on percent soil aggregates>0.25mm diameter of groundnut in rice–groundnut system

The lowest (26.5 kg cm^{-2}) penetration resistance was recorded at sowing with T_3 which was significantly lower than T_2 (30.1 kg cm^{-2}) and T_1 (34.4 kg cm^{-2}). Similar trend was observed at 60 DAS and harvest stage. T_3 recorded significantly lower penetration resistance compared to T_2 and T_1 tillage methods; which was attributed to fine tilth in T_3 because of pulversing effect by rotavator. Soil penetration resistance varies mainly with bulk density and soil moisture content. Since the bulk density was lower in T_3, the penetration resistance of soil was also lower. The highest penetration resistance was recorded in T_1 where bulk density was higher. Pratibha et al. (1995), Gajri et al. (1997); Gurumurthy (2000); Praveen Kumar (2004) reported similar results showing the relation between bulk density and soil strength under different tillage methods.

Interaction effect of planting and tillage methods was significant at all the stages of crop growth (Figure 3). Lowest (25.2 kg cm^{-2}) penetration resistance at sowing was recorded in P_1T_3. Highest (37.4 kg cm^{-2}) penetration was recorded in P_2T_1. The penetration resistance at 60 DAS and harvest was lowest in P_1T_3 and highest in P_2T_1 while the lowest

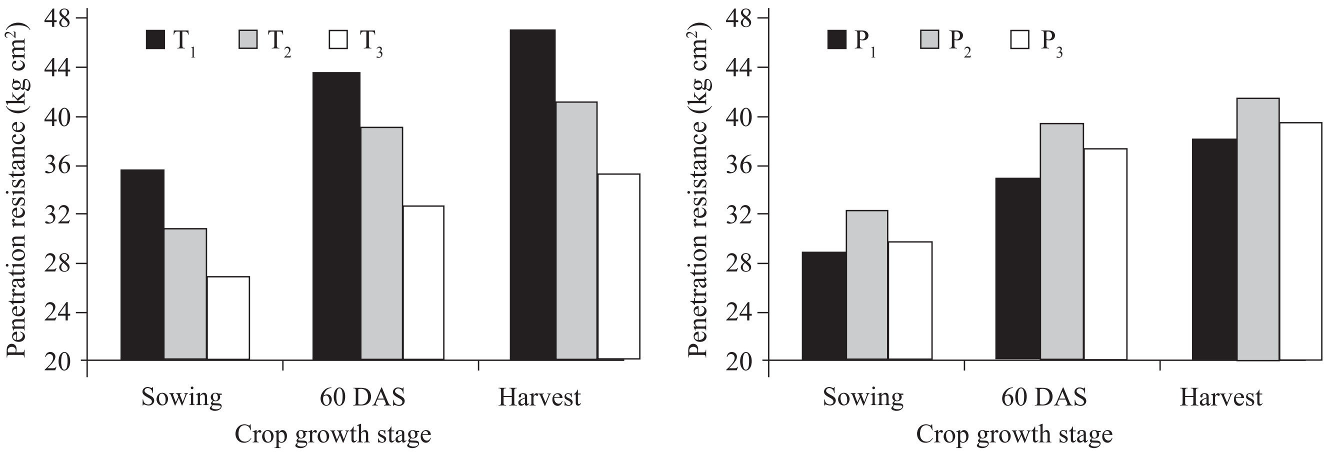

Figure 3: Effect of planting and tillage methods on penetration resistance of groundnut in rice–groundnut system

penetration resistance was recorded in P_1T_3 and the highest in P_2T_1. This could be attributed to lower and higher bulk densities recorded in these combinations. It was observed that penetration resistance of soil increased gradually with advancement of the crop growth. This was mainly because of increase in the bulk density due to consolidation of soil particles with advancement of crop growth proceed.

3.9. Correlation Matrix

Physical properties of the soil viz., Bulk density (BD), porosity (P), penetration resistance (PR), aggregate stability (AS), and percent soil aggregate (PSA), have significant influence on groundnut yield (Table 8). Data on Pearson's correlation matrix revealed that yield of groundnut was significantly and positively correlated (p=0.01) with porosity

Table 8: Correlation matrix between yield, soil physical parameters as influenced by planting and tillage methods in a rice-groundnut cropping sequence

Parameter	BD	Porosity	HC	IR	PR	AS	PSA	MWD	Yield
At Sowing									
BD	1.00								
Porosity	-1.00	1.00							
HC	-0.89**	0.89**	1.00						
IR	-0.93	0.92	0.95	1.00					
PR	0.93	-0.93	-0.93	-0.93	1.00				
AS	0.90**	-0.90**	-0.73*	-0.79*	0.72*	1.00			
PSA	0.91	-0.91	-0.75*	-0.80**	0.74*	1.00	1.00		
MWD	0.88**	-0.88**	-0.77*	-0.81**	0.94	0.71*	0.72*	1.00	
Yield	-0.81**	0.81**	0.58	0.63	-0.80**	-0.70*	-0.72*	-0.91	1.00
At 60 DAS									
BD	1.00								
Porosity	-1.00	1.00							
HC	-0.87**	0.87**	1.00						
IR	-0.87**	0.87**	1.00	1.00					
PR	0.98	-0.98	-0.91	-0.92	1.00				
AS	0.76*	-0.76*	-0.73*	-0.75*	0.83**	1.00			
PSA	0.78*	-0.78*	-0.75*	-0.77*	0.84**	1.00	1.00		
MWD	0.79*	-0.79*	-0.51	-0.51	0.74*	0.63	0.65	1.00	
Yield	-0.84**	0.84**	0.57	0.58	-0.80*	-0.64	-0.66	- 0.97	1.00

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed) at sowing (r= 0. 0.81**) and 60 DAS (r=0.84**). The Yield of groundnut negatively correlated with BD (r=-0.81** and r=-0.84**) at sowing and 60 DAS respectively, On the other hand, AS and PAS significantly (p=0.05) negatively correlated at sowing stage only. A strong relationship existed between the BD, porosity, PR, AS, PSA and yields of groundnut at sowing whereas at 60 DAS BD, porosity and PS have influence crop growth. The results indicate that porosity had significant role in enhancing yields and nutrients uptake.

Availability of nutrient is directly influenced by pores space and it is important both in soil–plant–water relationships and maintaining good soil structure. It is, important for holding water needed for plants and microorganisms (Pagliai *s*, 1995) which might have been responsible for observed positive correlations. Close relationships between the BD, porosity and PR in soil were noticed, suggesting that soil physical environment could be maintained by those physical parameter to enhance the nutrient uptake by plant and yield.

4. Conclusion

The study indicated that productivity of groundnut significantly increased under rice-groundnut cropping system due to combination of direct seeding of rice alone or mould board ploughing twice with rotavator twice or their combination. The tillage methods after planting methods of rice plant is changing the soil physical properties, which favors succeeding groundnut crop to achieve higher yield on rice based system. Therefore, use of proper tillage and planting method is a part of soil management practices for rice followed crop to sustain a better soil physical health and higher productivity, particularly in Andhra Pradesh, India, where there ground nut is a important upland crop after rice.

5. Acknowledgement

This study was made possible through the support provided by the All India Co-ordinated Research Project, Acharya N. G. Ranga Agricultural University and Department of Soil Science and Agricultural Chemistry, Rajendra Nagar, Hyderabad. Finally, I thank to ICAR given me an opportunities to study in Andra Pradesh.

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