Introduction

Soil productivity is a complex phenomenon governed by physical, chemical and biological characteristics, climatic conditions and management practices. Productivity of coarse textured sandy soil and loamy sand soils are relatively low due to its extreme permeability, which permits deep percolation of water and nutrients. Onattukara sandy tract is a fluvial and marine sand area of Alappuzha and Kollam districts of Kerala state in India, which covers about 72550 hectares. The cropping system practiced here is Rice-Rice-Sesame. The soil is coarse textured (>80% sand) with low nutrient and water retention capacity. Because of their low water holding capacity and high susceptibility to leaching of mobile nutrients, crops grown in these soils are more prone to water and nutrient stresses leading to low crop yields. For such soils of high hydraulic conductivity and infiltration rate, reduction of seepage losses by reducing the relative proportion of macro pores through compaction has an important beneficial effect on growth and yield of rice(*Oryza sativa*) and Sesame(*Sesamum indicum*). Soil compaction using rollers increases soil strength and volumetric water conduct, decreases macro porosity, infiltration and saturated hydraulic conductivity. Along with compaction, application of farm yard manure, coir pith (waste material from coconut husk) and kayal silt (lake sediments) will definitely improve soil physical properties such as water holding capacity, nutrient retention and soil structure. In order to alleviate the physical constraints of sandy soil and to enhance the nutrient and water use efficiencies, soil compaction along with the addition of farmyard manure, coir pith and kayal silt were been tried to develop a new technology.

Materials and methods

The present investigation was undertaken with the objective of evolving a management practice to improve the use efficiency of major nutrients and water in a sandy kaolinitic isohyperthermic psammaquent .The experiment aimed at studying the effect of soil compaction along with organic manures and soil amendments on nutrient uptake, rooting pattern, yield and quality of different crops under rice based cropping system of Onattukara sandy tract of Kerala. The field experiment was conducted in a rice-rice-sesame cropping system for three consecutive years at the Rice Research Station, Kayamkulam, Kerala. The experiment field is located at $9^0$80' N latitude and 76^0 20' E longitudes and at 3.05 m above mean sea level. The soil in this tract is sandy in nature, highly permeable leading to high loss of nutrients and water. Design of the experiment was Factorial Randomized Block Design. The treatments consist of the following factors :C_0-No compaction;C_1-Compaction with 400kg roller passing 4 times;F_0-No farm yard manure;F_1-2.5 t FYM ha^{-1};F_2-5t FYM ha^{-1};S_0-No kayal silt;S_1-5 tonnes ha^{-1}Kayal silt;P_0-No coir pith;P_1-5 t ha^{-1}coir pith(sieved).There are 18 treatments consisting of combinations of all the above factors excluding the combinations of S_1 and P_1 with other factors and the number of replications was three. The treatments included are

T_1	$C_0F_0S_0P_0$	T_{10}	$C_1F_0S_0P_0$
T_2	$C_0F_0S_0P_1$	T_{11}	$C_1F_0S_0P_1$
T_3	$C_0F_0S_1P_0$	T_{12}	$C_1F_0S_1P_0$
T_4	$C_0F_1S_0P_0$	T_{13}	$C_1F_1S_0P_0$
T_5	$C_0F_1S_0P_1$	T_{14}	$C_1F_1S_0P_1$
T_6	$C_0F_1S_1P_0$	T_{15}	$C_1F_1S_1P_0$
T_7	$C_0F_2S_0P_0$	T_{16}	$C_1F_2S_0P_0$
T_8	$C_0F_2S_0P_1$	T_{17}	$C_1F_2S_0P_1$
T_9	$C_0F_2S_1P_0$	T_{18}	$C_1F_2S_1P_0$

The experiment area was ploughed with a power tiller and the plots were laid out according to the design of the experiment. FYM, Coir pith and Kayal silt were applied according to the treatments and incorporated with the soil after leveling the plots. The compaction treatment was given by four passes of 400kg roller. After compacting the soil the first crop was raised. The package of practices recommendation for rice is 70 N: 35 P: 35 K ha^{-1} and 5 t ha^{-1} farmyard manure. Half the dose of N & K and full dose of P were applied as basal dressing at the time of final ploughing. 25% N was applied 30 days after sowing and remaining 25% N and 50% K was given at 45 days after sowing. The fertilizer dose for Sesame is 30 N: 15P:30K kg ha^{-1}. At the time of land preparation. 75% of N and full dose of P & K were applied as basal dressing, the remaining 25% N was applied 20 days after sowing. Dry sowing of seed of first crop rice (short duration variety Bhagya) along lines was done during May. Second crop rice was a transplanted one during the month of October. Sowing of Sesame (variety-Kayamkulam1) along lines is been done during February. Compaction treatment was applied only once during a year i.e. before the start of first crop rice. After harvest of each crop soil physical properties, chemical properties, yield of crop and uptake of nutrients were analyzed using standard procedures outlined by Jackson (1973), Black etal (1965), Gupta and Dakshinamurthy (1980).

Results & Discussion

The salient results obtained after conducting the experiments for three consecutive years were as follows.

Yield and uptake of nutrients

The first crop (Rice), second crop (Rice) and third crop (Sesame) recorded higher yield in compacted treatments when compared to non-compacted treatments. Compacting the soil of Onattukara sandy tract using 400kg roller passing 4 times at Procter moisture level with farmyard manure, coir pith and kayal silt has resulted in improvement of physical environment of the soil. In coarse textured soils, use of organic manures is the only way of improving soil structure. Addition of organic matter will result in better aggregation of soil particles, decrease of macropores with increase in micropores, thus reducing hydraulic conductivity and increasing water retention. Application of lake sediments is also helpful in this respect. Soil compaction is also a process, which leads to the destruction of larger pores and better orientation of soil particles (Acharya and Sood 1992).Soil compaction changes pore space size, distribution, and soil strength. Soil compaction can increase root branching and secondary root formation, allowing roots to more thoroughly explore the soil for nutrients.

In the first crop rice the highest yield (3.15 t ha^{-1}) was recorded by $C_1F_1S_0P_1$(compaction+2.5t FYM+5t coir pith) treatment where as the same treatment without compaction gave only 1.60 t ha-1,only half of the former(Table1).About 97% increase in yield was observed. Hydraulic conductivity values of surface and sub surface also revealed that compaction has got favourable effect in reducing the permeability of soil.$C_0F_0S_0P_0$ treatment recorded a hydraulic conductivity of 6.86 cm/hr (Fig.4) where as the same treatment with compaction reduced hydraulic conductivity to about half (3.24 cm/hr).The total uptake of N, P and K was increased significantly in compacted plots. The treatment $C_1F_1S_0P_1$ recorded lowest hydraulic conductivity in surface and sub surface layers and highest nutrient uptake(fig4&2).The yield increase in this treatment was due to reduction in leaching loss of nutrients by lowering the hydraulic conductivity and thereby increased uptake of nutrients.

Table 1.Effect of soil compaction, FYM, kayal silt & coir pith on yield of rice and uptake of nutrients (first crop)

Treatment	Grain yield t ha^{-1}	Straw yield t ha^{-1}	N uptake $kgha^{-1}$	P uptake $kgha^{-1}$	K uptake $kgha^{-1}$
T1	1.63	3.36	28.16	7.46	55.61
T2	1.60	2.66	28.60	8.16	53.47
T3	1.33	1.76	20.46	7.36	57.35
T4	1.61	3.33	33.19	11.4	68.55
T5	1.60	3.25	34.06	10.66	56.34
T6	1.49	2.35	27.22	9.13	46.80
T7	1.59	2.99	30.33	11.53	58.06
T8	1.67	2.97	33.80	12.03	58.42
T9	1.65	2.79	35.60	12.53	71.77
T10	2.06	2.50	35.03	12.40	95.88
T11	1.94	2.23	35.73	12.63	102.82
T12	2.67	2.12	49.53	14.16	102.09
T13	2.33	2.95	38.86	12.76	91.73
T14	3.15	2.12	49.90	19.23	104.25
T15	2.39	2.06	40.60	12.30	70.38
T16	2.43	2.02	35.10	17.90	121.93
T17	2.18	2.19	39.50	15.50	159.94
T18	2.28	2.28	45.90	14.76	134.32
C.D	0.27	0.71	6.15	2.30	2.61

Figure 1. Effect of soil compaction, FYM & coir pith on rice yield(first crop)

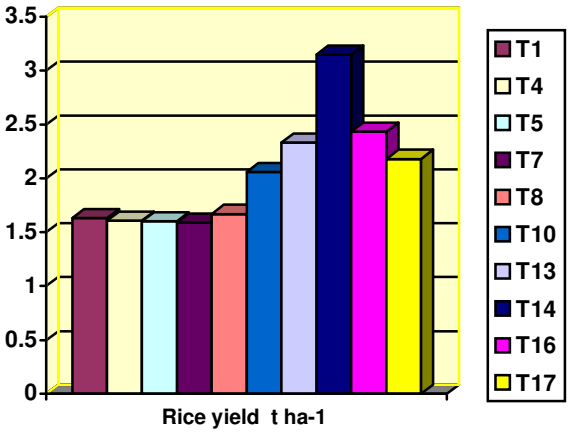
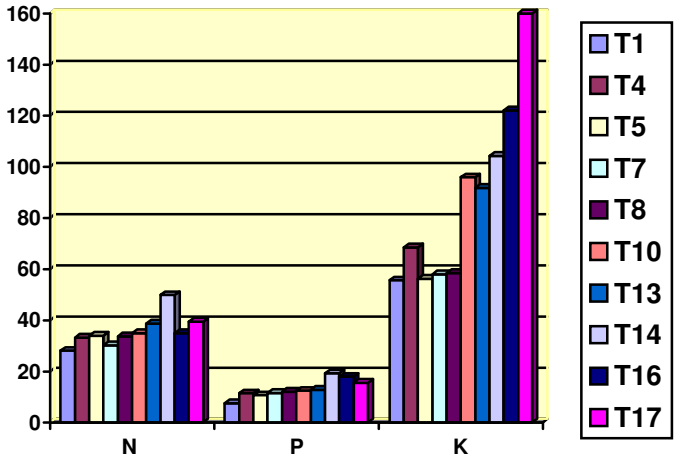


Figure 2. Effect of soil compaction, FYM & coir pith on nutrient uptake by rice $kgha^{-1}$



In second crop rice, the highest grain yield and straw yield is been noticed in the $C_1F_2S_0P_1$ treatment. Highest root volume, leaf area index and N, P, K uptake were recorded by this treatment (Table.2).Lowest hydraulic conductivity was also registered by this treatment. All these factors contributed for obtaining maximum yield in this treatment. About 100% increase in yield as well as uptake of major nutrients is been observed.

Table 2. Effect of soil Compaction, FYM, Kayal silt, & Coir pith on yield of rice and uptake of nutrients (second crop)

Treatment	Grain yield t ha-1	Straw yield t ha^{-1}	Root volume cm^3	Leaf area index	Uptake of nutrients kg ha^{-1}		
					N	P	K
T_1	1.18	1.43	13.66	1.03	16.31	2.57	27.81
T_2	1.07	1.33	13.0	1.04	15.58	2.42	28.10
T_3	1.16	1.37	15.1	1.11	17.69	2.70	29.25
T_4	1.18	1.64	19.33	1.07	20.71	3.36	35.55
T_5	1.22	1.29	23.33	1.14	19.25	3.28	27.62
T_6	0.91	1.11	17.0	1.13	16.04	2.72	24.74
T_7	1.16	1.36	26.0	1.22	20.69	3.61	29.06
T_8	1.13	1.32	18.66	1.22	21.09	3.62	29.22
T_9	1.39	1.54	23.0	1.35	27.42	4.77	35.82
T_{10}	2.09	1.85	24.0	1.49	38.56	6.67	50.12
T_{11}	1.97	2.0	31.33	1.57	39.49	6.54	57.56
T_{12}	1.92	1.97	27.66	1.43	42.00	6.37	57.12
T_{13}	1.93	1.63	26.0	1.46	36.21	6.18	55.00
T_{14}	2.10	2.04	22.0	1.48	42.04	6.94	59.20
T_{15}	1.99	2.13	26.66	1.48	42.54	6.83	40.81
T_{16}	2.17	2.22	27.33	1.56	46.26	7.47	62.80
T_{17}	2.72	2.85	32.66	1.57	56.37	9.54	80.00
T_{18}	2.38	2.44	26.0	1.56	52.38	8.48	70.24
CD	0.33	0.26	9.15 (0.1)	0.07 0.1)	5.43 (0.1)	0.86 (0.1)	2.61(0.1)

Soil physical properties

Soil physical properties like bulk density, soil strength, mean weight diameter, micro porosity, water holding capacity and field moisture content were found to be increased in compacted plots (Table3) .Addition of FYM and coir pith enhanced the structural, and moisture retention properties of soil. They helped in increasing the binding between the soil particles and the stability of aggregates. The improvement of soil physical fertility enhanced the uptake of nutrients and yield of crops.

Table3.Effect of soil Compaction, FYM, kayal silt, and coir pith on soil physical properties

Treatment	Bulk density Mg m^{-3}	Soil strength kg m^{-2}	Mean weight diameter	Micro porosity % 0-15 cm	Micro porosity % 15 - 30 cm	Saturated hydraulic conductivity cm hr^{-1} 0 -15 cm	Saturated hydraulic conductivity cm hr^{-1} 15 -30 cm	Field moisture content %
T_1	1.46	1.0	0.32	17.58	18.39	6.86	5.02	12.26
T_2	1.55	1.0	0.33	16.20	21.90	7.63	5.22	11.15
T_3	1.49	1.0	0.33	14.82	14.77	7.03	4.79	11.63
T_4	1.57	1.0	0.39	13.07	18.98	7.69	4.14	13.37
T_5	1.36	1.33	0.36	15.49	15.85	7.07	4.97	11.15
T_6	1.60	1.33	0.32	16.39	11.83	8.35	6.28	12.03
T_7	1.58	1.33	0.37	18.88	25.28	8.89	4.84	12.92
T_8	1.43	1.33	0.30	16.84	13.53	9.93	4.02	11.94
T_9	1.50	1.33	0.34	15.94	15.31	8.28	4.48	11.98
T_{10}	1.55	2.58	0.41	19.17	17.06	3.24	2.81	16.14
T_{11}	1.49	3.0	0.51	19.61	22.38	3.99	2.45	17.43
T_{12}	1.51	3.0	0.43	30.03	15.69	3.65	2.32	17.06
T_{13}	1.55	3.16	0.44	26.90	18.48	3.49	2.25	17.90
T_{14}	1.53	3.08	0.42	27.67	14.44	4.16	2.09	17.33
T_{15}	1.51	3.0	0.43	19.98	20.97	3.35	2.25	17.49
T_{16}	1.51	3.41	0.57	21.03	17.90	3.56	2.81	17.94
T_{17}	1.39	3.03	0.41	37.49	17.61	3.33	2.17	18.45
T_{18}	1.49	3.03	0.42	19.27	20.40	2.64	2.84	18.60
CD	NS	0.44 (0.1)	0.02(0.05)	7.60 (0.1)	5.80 (0.1)	0.77 (0.1)	0.61 (0.1)	2.31(0.1)

Figure 3: Effect of soil compaction, FYM and coir pith on water holding capacity (%) of soil

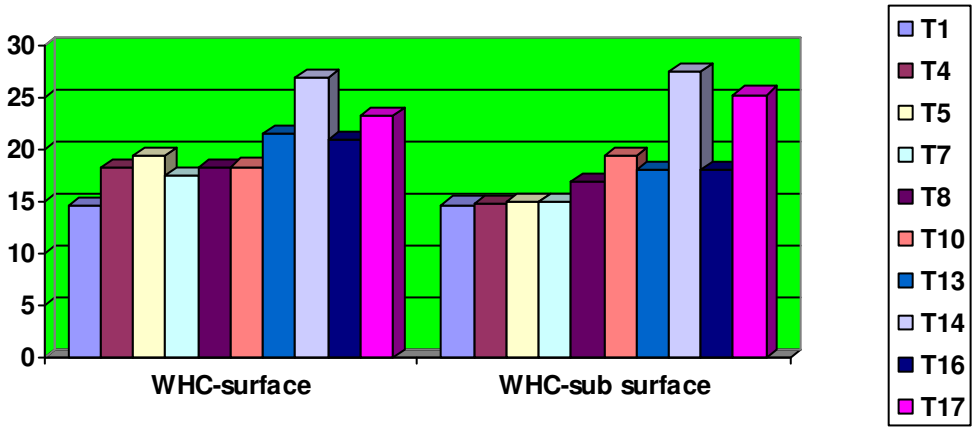


Figure 4. Effect of soil compaction, coir pith, and FYM on hydraulic conductivity (cm hr^{-1})

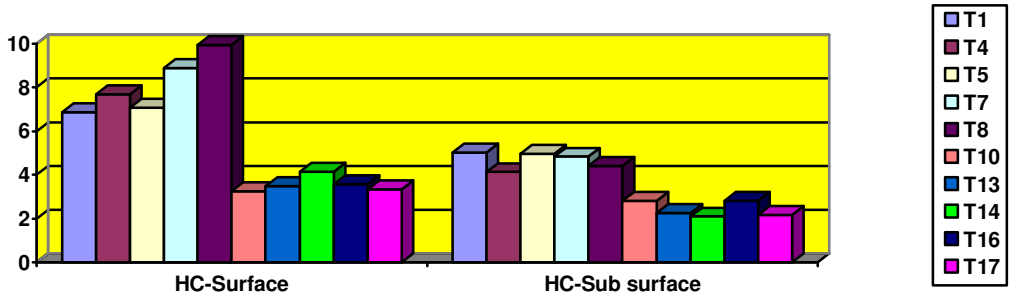


Table 4.Effect of soil compaction on yield and uptake of nutrients by Sesame

Treatment	Seed Yield (kg ha^{-1})	Haulm Yield (kg ha^{-1})	N-uptake (kg ha^{-1})	P-uptake (kg ha^{-1})	K-uptake (kg ha^{-1})
T_1	307.79	2534.14	12.00	2.46	25.59
T_2	317.95	2646.90	14.20	2.69	38.32
T_3	338.57	3190.75	17.80	2.80	33.45
T_4	328.31	3159.98	14.92	2.61	33.83
T_5	328.31	2944.51	12.17	3.40	36.18
T_6	369.35	3211.28	14.48	3.37	33.30
T_7	348.83	3262.57	14.29	3.43	35.52
T_8	400.12	3149.72	20.67	3.39	35.60
T_9	400.12	3775.56	18.86	3.95	34.64
T_{10}	430.91	3201.02	20.29	3.77	51.17
T_{11}	451.43	3447.25	20.28	4.00	50.93
T_{12}	420.65	4093.61	21.41	3.47	52.49
T_{13}	461.70	4165.42	16.88	4.73	56.24
T_{14}	543.69	4298.89	20.53	4.13	55.54
T_{15}	492.94	4391.14	21.75	4.63	51.41
T_{16}	512.98	4206.45	23.69	4.10	53.73
T_{17}	554.02	4256.67	25.77	5.56	52.27
T_{18}	461.70	4104.14	25.14	4.30	57.65
C.D	NS	NS	2.80	NS	4.21

For Sesame also, the highest uptake of nutrients and yield is been observed in the T_{17} treatment. The compaction effect persisted even after third crop.

Compaction of coarse textured soils using 400 kg roller passing 4 times along with 5t ha^{-1} FYM and 5 t ha^{-1} coir pith improved the soil physical properties, nutrient uptake and in turn, yield of crops under rice based cropping system.

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