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Nutrient Uptake, Tuber Yield and Soil Physico-chemical Properties as Influenced by Tillage and Nutrition for Tannia (*Xanthosoma sagittifolium* (L.) Schott) in the Red Soils of Southern Kerala

Atul Jayapal[1], O.K. Swadija[2] and Vijayaraghavakumar[3]
[1]Onattukara Regional Agricultural Research Station, Kerala Agricultural University, Kayamkulam 690 502, Kerala, India
[2,3]College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram 695 522, Kerala, India
Corresponding author: Atul Jayapal, email: atul.j@kau.in

Abstract

A study was undertaken at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during 2014-2016 to identify an ideal tillage system and plant nutrition for tannia for improving the nutrient uptake and tuber yield of tannia and also to evaluate their effects on the physico-chemical properties of soil. The design used was split plot and was replicated four times. The main plot treatments were conventional tillage followed by pit system, conventional tillage followed by mound system, deep tillage followed by pit system and deep tillage followed by mound system. The sub plot treatments were combinations of soil conditioners (control, coir pith, rice husk) and nutrient management systems (integrated nutrient management (INM) and organic nutrition). The results revealed that deep tillage to a depth of 30 cm followed by pit or mound system of planting, application of coir pith as soil conditioner (@ 500 g plant^{-1}) and organic nutrition (FYM @ 37.5 t ha^{-1} + wood ash @ 2 t ha^{-1}) is ideal for enhancing nutrient uptake and tuber uptake of tannia without depletion of soil nutrient status.

Key words: Bulk density, Organic carbon, Nutrient Uptake, Porosity, Water holding capacity.

Introduction

Tannia (*Xanthosoma sagittifolium* (L.) Schott) belonging to the family Araceae is mainly grown for its tubers which are considered more nutritious than taro and potato. The tubers are used as vegetable and possess good keeping quality compared to other vegetables. In India, tannia is grown in Kerala, parts of Tamil Nadu, Andhra Pradesh, Maharashtra, Odisha, West Bengal and in North East India. In Kerala, tannia is usually raised as an intercrop in coconut and banana since it is one of the most shade tolerant food crops.Although tannia can be grown in a wide variety of soil, significant variation in yield has been observed when it is grown in different soil types. It is understood that the physico-chemical properties of the soil can be improved by tillage which will be reflected in the growth and yield of tannia. Utilization of crop residues is a viable preposition for retention of soil moisture and maintenance of soil fertility. Hence, appropriate quantity of crop residues can be applied in a cost-effective manner to enhance crop productivity. Coir pith, which is an under - utilized crop residue and which may otherwise cause environmental pollution can be used as a soil conditioner for growing tuber crops. Coir pith has high water holding capacity which can serve for longer retention of soil moisture when used as soil conditioner. When grown in soil conditioned with coir pith, increase in tuber yield of sweet potato, elephant foot yam and taro has been reported (Mukherjee, 2001). The use of rice husk as a soil conditioner is followed among traditional tannia farmers and has found to result in better tuber yield. Tannia has great potential for organic production and prefer organic production practices. Considering all these factors, a two-year experiment was undertaken to identify an ideal tillage system, use of a soil conditioner and nutrient management system for improving the nutrient uptake and tuber yield of tannia and also to evaluate their effects on the physico-chemical properties of soil.

Materials and Methods

The experiment was undertaken at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during August 2014 to May 2015 and from May 2015 to February 2016. The soil of the experimental site was sandy loam with moderately acidic pH. Organic carbon content and available P was high in soil, available N was low and available K was medium (Table 1). The design used was split plot design and these treatments were replicated four times. The main plot treatments were conventional tillage followed by pit system, conventional tillage followed by mound system, deep tillage followed by pit system and deep tillage followed by mound system. The sub plot treatments were combinations of soil conditioners (control, coir pith and rice husk) and nutrient management systems (integrated nutrient management (INM) and organic nutrition). The soil conditioners were applied @ 500 g per plant. The integrated management system involved application of farmyard manure (FYM) @ 25 t ha^{-1} along with fertilizer dosage of 80:50:150 kg NPK ha^{-1} as chemical fertilizers. Half FYM and full P were given as basal and the remaining half FYM along with N and K were given in three splits at 2, 4 and 6 months after planting (MAP). In organic nutrition, FYM @37.5 t ha^{-1} along with wood ash @ 2 t ha^{-1} was given. Two-third FYM was given as basal and the remaining FYM and wood ash were given in three equal splits at 2, 4 and 6 months after planting. Dolomite @ 1 t ha^{-1} was given uniformly to all treatments at the time of land preparation.

A local land race obtained from farmers' field was used for the study. The land was prepared as per the treatments and corm pieces weighing 80g were used for planting. A

Table 1. Physico-chemical properties of the soil of the experimental sites

Sl. No.	Parameter	Experimental area I		Experimental area II		Materials and Methods
A.	Mechanical composition					
1.	Coarse sand (%)	18.50		19.25		International pipette method (Piper, 1966)
2.	Fine sand (%)	32.50		30.35		
3.	Silt (%)	27.35		25.50		
4.	Clay (%)	21.65		24.90		
	Texture - Sandy clay loam					
B.	Physical properties					
		0-15cm depth	15-30cm depth	0-15cm depth	15-30cm depth	
1.	Bulk density (Mg m^{-3})	1.59	1.70	1.67	1.73	Core method (Gupta and Dakshinamoorthi, 1980)
2.	Particle density (Mg m^{-3})	2.41	2.50	2.45	2.48	
3.	Porosity (%)	34.02	32.00	31.84	30.24	
4.	Water holding capacity (%)	23.00	21.20	21.11	20.40	
C.	Chemical properties					
		0-15cm depth	15-30cm depth	0-15cm depth	15-30cm depth	
1.	Soil reaction (pH)	5.65	5.26	5.58	5.25	pH meter with glass electrode (Jackson, 1973)
2.	Organic carbon(%)	1.12	0.99	1.38	1.20	Walkley and Black's rapid titration method (Jackson, 1973)
3.	Available N (kg ha^{-1})	212.50	204.88	225.79	200.70	Alkaline $KMnO_4$method (Subbiah and Asija, 1956)
4.	Available P (kg ha^{-1})	149.63	136.51	177.17	169.68	Bray colorimetric method (Jackson, 1973)
5.	Available K (kg ha^{-1})	197.08	185.36	229.65	212.07	Ammonium acetate method (Jackson, 1973)

spacing of 0.75 m x 0.75 m was adopted. Mulching was given with green leaves. Intercultural operations and earthing up were done along with top dressing at 2, 4 and 6 months after planting. The crop was raised as rainfed crop and a total of 179.09 cm and 173.8 cm rainfall were received during first and second year respectively. The crop was harvested at 9 MAP when the leaves started to dry up. The observational plants uprooted were separated into cormels, corm, blade and petiole and the sub samples were taken and oven dried at 65 ± 5°C. The plant samples were then ground to pass through a 0.5 mm sieve and digested for the analysis of NPK content. The N content in each plant part was estimated by the modified micro kjeldahl method (Jackson, 1973). The P content in plant sample was determined by Vanadomolybdo phosphoric yellow colour method and read in a spectrophotometer. The K content in plant sample was determined by flame photometer method (Piper, 1966). Total crop uptake of N, P and K were calculated by multiplying N/P/K content of each plant part with their respective dry weight and summing up the values.

The plants were uprooted carefully from each net plot and were separated into corms and cormels and the yield was expressed in t ha^{-1}(Fig.1 and Fig. 2). Soil samples were taken from experimental plots before and after the experiment from two depths, 0 to 15 cm and 15 to 30 cm. These were air dried, powdered and passed through a 2 mm sieve and analysed for mechanical composition and physico - chemical properties except organic carbon status as outlined in Table 1. The soil samples passed through 0.2 mm sieve were used for organic carbon estimation. Post the experiment, after each harvest, the composite samples were collected from each plot, processed and analysed for physico-chemical properties using the standard procedures as indicated in Table 1.

Results and Discussion

Uptake of nutrients

N uptake

Perusal of the data in Table 2 clearly indicated that uptake of N was significantly influenced by the main effects of treatments. Among tillage systems, deep tillage followed by pit system resulted in significantly higher uptake of N (68.64 and 73.17 kg ha^{-1} during I and II year respectively) followed by deep tillage and mound system during both the years. Coirpith as soil conditioner resulted in significantly higher uptake of N during both the years

Table 2. Effect of tillage systems, soil conditioners and nutrient management on nutrient uptake (kg ha^{-1})

Treatments	N uptake		P uptake		K uptake	
	I year	II year	I year	II year	I year	II year
Tillage systems (L)						
Conventional tillage- pit system	51.30	61.36	9.16	11.05	87.11	126.80
Conventional tillage-mound system	44.05	55.93	8.00	10.04	76.67	120.77
Deep tillage-pit system	68.64	73.17	13.77	15.54	138.99	173.94
Deep tillage-mound system	57.57	63.10	10.89	12.67	110.26	143.78
SEm±	0.359	0.427	0.107	0.135	0.688	1.248
CD (0.05)	1.329	1.582	0.397	0.500	2.549	4.624
Soil conditioners (S)						
Control	47.70	57.93	9.14	11.45	90.49	133.89
Coir pith	62.01	67.77	11.61	13.03	115.10	147.45
Rice husk	56.46	64.47	10.62	12.49	104.19	142.63
SEm±	0.515	0.582	0.120	0.141	0.980	1.331
CD (0.05)	1.457	1.647	0.340	0.398	2.771	3.764
Nutrient management (N)						
INM	50.12	59.37	9.30	11.36	93.63	133.27
Organic nutrition	60.66	67.40	11.61	13.29	112.89	149.38
SEm±	0.421	0.475	0.098	0.115	0.800	1.086
CD (0.05)	1.190	1.345	0.278	0.325	2.263	3.073

Table 3. Interaction effect of tillage systems, soil conditioners and nutrient management on nutrient uptake (kg ha^{-1})

Treatments	N uptake		P uptake		K uptake	
	I year	II year	I year	II year	I year	II year
L x S interaction						
l_1s_1	43.19	55.32	7.93	10.23	75.53	120.05
l_1s_2	56.60	65.14	10.21	11.84	97.15	132.51
l_1s_3	54.12	63.61	9.33	11.08	88.65	127.84
l_2s_1	37.10	50.60	6.84	9.32	66.39	115.73
l_2s_2	51.38	61.58	9.25	10.77	87.42	126.37
l_2s_3	43.66	55.60	7.93	10.05	76.20	120.21
l_3s_1	61.09	67.56	12.29	14.34	123.73	161.88
l_3s_2	74.86	76.27	14.92	16.09	152.83	181.05
l_3s_3	69.98	75.68	14.11	16.18	140.41	178.88
l_4s_1	49.44	58.22	9.51	11.93	96.30	137.90
l_4s_2	65.22	68.07	12.05	13.42	122.98	149.87
l_4s_3	58.06	63.00	11.12	12.67	111.51	143.58
SEm±	1.030	1.164	0.241	0.281	1.959	2.661
CD (0.05)	NS	NS	NS	NS	NS	NS
L x N interaction						
l_1n_1	46.64	56.34	8.23	10.05	79.18	119.78
l_1n_2	55.96	66.38	10.09	12.05	95.03	133.82
l_2n_1	41.57	54.03	7.32	9.29	71.01	113.33
l_2n_2	46.53	57.83	8.69	10.79	82.33	128.21
l_3n_1	60.26	67.85	11.96	14.29	123.91	162.87
l_3n_2	77.02	78.49	15.58	16.78	154.07	185.00
l_4n_1	52.00	59.27	9.69	11.80	100.41	137.09
l_4n_2	63.15	66.92	12.10	13.53	120.11	150.47
SEm±	0.841	0.951	0.196	0.230	1.600	2.173
CD (0.05)	2.379	2.689	0.555	NS	4.525	NS
S x N interaction						
s_1n_1	43.73	55.36	8.22	10.69	82.50	128.25
s_1n_2	51.68	60.49	10.06	12.22	98.47	139.53
s_2n_1	56.35	63.04	10.24	11.88	104.09	138.18
s_2n_2	67.67	72.49	12.97	14.17	126.11	156.71
s_3n_1	50.27	59.71	9.43	11.51	94.31	133.37
s_3n_2	62.64	69.23	11.81	13.48	114.08	151.88
SEm±	0.728	0.823	0.170	0.199	1.385	1.882
CD (0.05)	2.060	2.328	0.481	NS	NS	NS

NS- Not significant

(62.01 and 67.77 kg ha^{-1}) proving its superiority over control and rice husk. Uptake of N was significantly higher under organic nutrition during both the years (60.66 and 67.40 kg ha^{-1} during I and II year respectively) than under INM. As shown in Table 3, the interactions L x N and S x N had significant effects on the uptake of N during both the years. Considering L x N interaction, the treatment combination of deep tillage with pit system of planting and organic nutrition had registered significantly higher uptake of N during both the years (77.02 and 78.49 kg ha^{-1} during I and II year respectively) which was followed by the treatment combination of deep tillage with mound system of planting and organic nutrition in I year and the same treatment with INM during the II year.

The significant effect of S x N interaction was evident during both the years and the treatment combination of coirpith as a soil conditioner with organic nutrition in tannia registered significantly higher uptake of N (67.67 and 72.49 kg ha^{-1} during I and II year respectively) and was followed by rice husk under organic nutrition. The data presented in Table 4 indicated no significant effect of L x S x N interaction on N uptake.

P uptake

The significant effects of the treatments on the uptake of P during both the years are depicted in Table 2. Deep tillage followed by pit system registered significantly higher P uptake during both the years (13.77 and 15.54 kg ha^{-1} during I and II year respectively) followed by deep tillage and mound system. Soil conditioners had significant effect on P uptake. Among the soil conditioners, coirpith as soil conditioner produced significantly higher uptake of P during both the years (11.61 and 13.03 kg ha^{-1} during I and II year respectively) which was closely followed by rice husk. Organic nutrition registered significantly higher uptake of P during both the years (11.61 and 13.29 kg ha^{-1} during I and II year respectively). Among interactions (Table 3), the interactions L x N and S x N had significant effects on P uptake only during I year. The treatment combination of deep tillage followed by pit system of planting with organic nutrition resulted in higher uptake of P during both the years. Similarly, the treatment combination of coir pith as a soil conditioner with organic nutrition had registered significantly higher uptake of P during both the years. No significant variation in P uptake was noticed due to L x S x N interaction (Table 4) during both the years.

K uptake

The significant effect of treatments on K uptake is evident from Table 2. As in the case of uptake of N and P, deep tillage followed by pit system resulted in significantly higher uptake of K (138.99 and 173.94 kg ha^{-1} during I and II year respectively). Deep tillage followed by pit or mound system resulted in higher K uptake than conventional tillage followed by pit or mound system. Application of soil conditioner profoundly influenced K uptake and coirpith was found superior to rice husk during both the years (115.1 and 147.45 kg ha^{-1} during I and II year respectively). Organic nutrition showed its superiority in enhancing K uptake (from 93.63 under INM to 112.89 kg ha^{-1} during I year and from 133.27 under INM to 149.38 kg ha^{-1} during II year). As shown in Table 3, only the interaction L x N had significant effect on K uptake that too only during I year. The treatment combination of deep tillage with pit system of planting and organic nutrition resulted in significantly higher uptake of K (154.07 kg ha^{-1}) and the highest uptake of K during II year though was not significant. The interaction L x S x N had no significant effect on K uptake during both the years (Table 4).

Though the effect of the treatment combinations of tillage system, soil conditioner and nutrient management (L x S x N) did not appreciably influence the nutrient uptake, the highest uptake of N, P and K were recorded by deep tillage and pit system with coirpith as soil conditioner under organic nutrition during both the years. Improvement in soil physical and chemical properties due to deep tillage, application of soil conditioner and organic manures might have culminated in higher uptake of nutrients resulting in higher tuber yield.

Corm and cormel yield

The treatments had significant effects on tuber yield in terms of cormel and corm yield during both the years (Fig. 1 and Fig. 2). Deep tillage followed by pit system resulted in the highest cormel yield (4.36 t ha^{-1} during I year and 5.94 t ha^{-1} during II year) and corm yield (6.96 and 8.5 t ha^{-1} during I and II year respectively). Conventional tillage followed by mound system resulted in the lowest cormel and corm yields during both the years. Ramesh *et al*. (2007) also reported that ploughing to a depth of 20-40 cm can improve the growth and yield of tannia. Application of soil conditioner had significant effect during both the years. Coirpith was found superior to rice husk for higher cormel yield (3.95 t ha^{-1} during I year and 5.08 t ha^{-1} during II year) and corm yield (6.32 t ha^{-1} during I year and 7.68 t ha^{-1} during II year). Significant increase in tuber yield due to amendment of soil with coirpith has also been reported by Mukherjee (2001) in other tuber crops like sweet potato, taro and elephant foot yam. During both the years, organic nutrition resulted in significantly higher cormel yield (3.9 t ha^{-1} during I year and 5.13 t ha^{-1} during II year) and corm yield (6.36 t ha^{-1} during I year and 7.79 t ha^{-1} during II year) than under INM. Suja *et al*. (2009) also reported superior tuber yield of tannia due to organic nutrition.

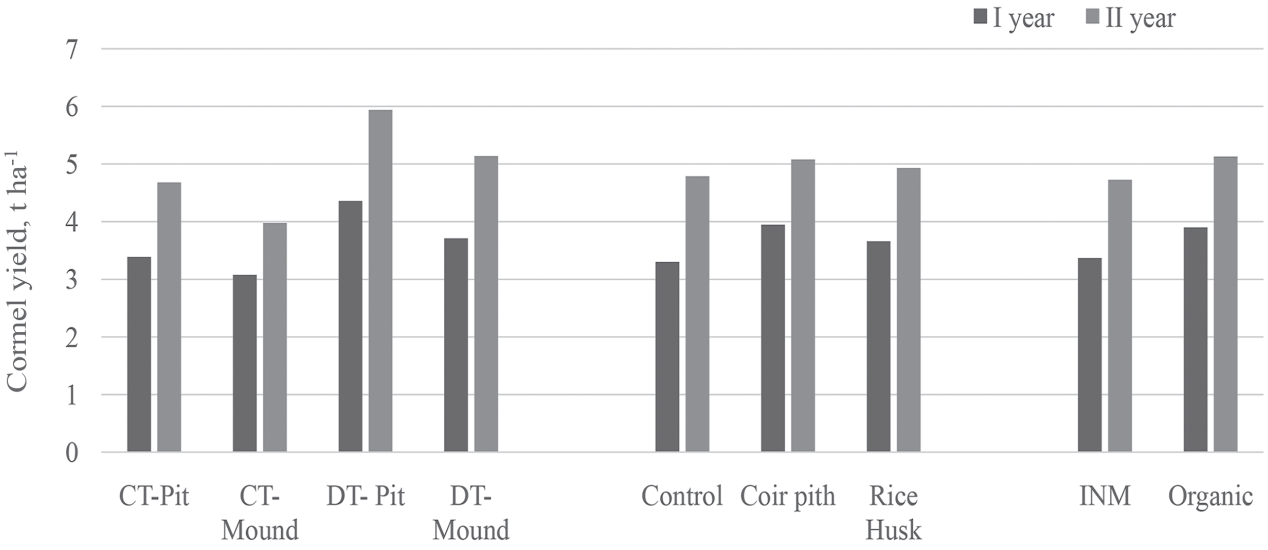

Fig. 1. Effect of tillage systems, soil conditioners and nutrient management on cormel yield of tannia

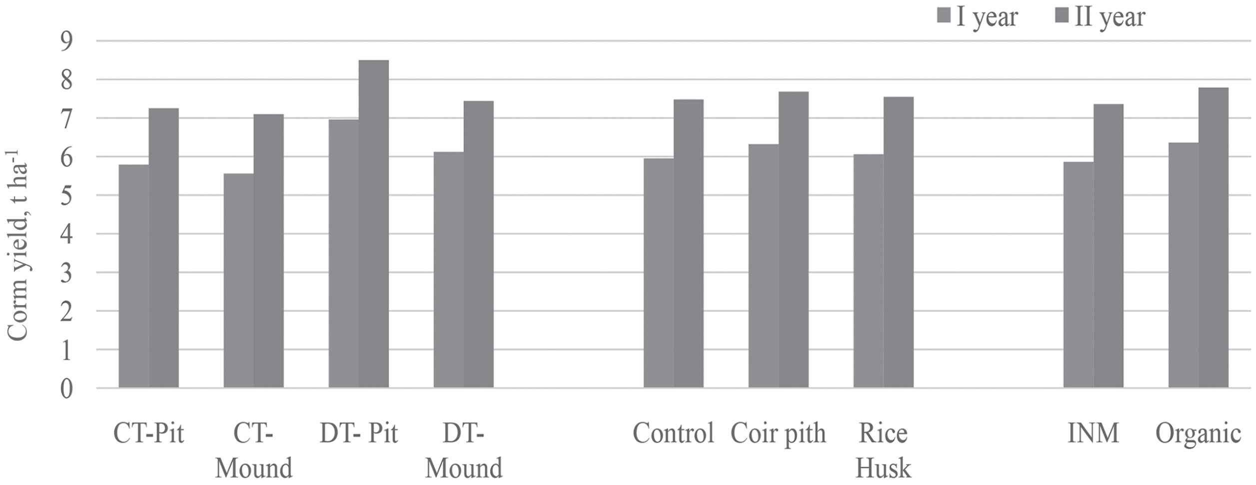

Fig. 2. Effect of tillage systems, soil conditioners and nutrient management on corm yield

The effect of treatments on nutrient uptake was reflected in corm and cormel yield. Deep tillage, application of coir pith as soil conditioner and organic nutrition resulted in higher nutrient uptake leading to higher tuber yield with these treatments. Correlation analysis also revealed significant and positive correlation of cormel and corm yields with N, P and K uptake during both years (Table 5). Higher uptake and efficient utilization of nutrients might have led to higher cormel and corm yields.

Soil physical properties

Among the physical properties of soil, the bulk density was generally higher in lower soil layers prior to the experiment (Table 1) which might be due to lower concentration of organic matter, lesser aggregation, lesser root penetration and compaction caused by the weight of overlying layers (Agbede, 2006). Compared to initial level, the bulk density values were lower after the experiment (Table 6). This could be attributed to the effect of tillage on loosening the soil as reported by Agbede (2008). It can be seen from Table 1 that initially, the surface soil (0 to 15 cm depth) was more porous with high water holding capacity than subsoil (15 to 30 cm depth). After the experiment, porosity and water holding capacity of the soil increased over the respective initial values during both the years in 0 to 15 cm and 15 to 30 cm depth of soil

Table 4. Effect of L x S x N interaction on nutrient uptake (kg ha^{-1})

Treatments	N uptake		P uptake		K uptake	
	I year	II year	I year	II year	I year	II year
$l_1s_1n_1$	41.05	52.28	7.26	9.30	69.38	114.64
$l_1s_1n_2$	45.33	58.36	8.61	11.15	81.68	125.46
$l_1s_2n_1$	51.68	59.22	9.16	10.74	88.40	125.18
$l_1s_2n_2$	61.51	71.07	11.27	12.94	105.90	139.83
$l_1s_3n_1$	47.20	57.51	8.27	10.11	79.77	119.51
$l_1s_3n_2$	61.04	69.71	10.39	12.06	97.53	136.16
$l_2s_1n_1$	34.96	49.20	6.19	8.58	60.82	109.05
$l_2s_1n_2$	39.23	52.01	7.49	10.06	71.96	122.41
$l_2s_2n_1$	47.91	59.60	8.19	10.04	79.88	119.77
$l_2s_2n_2$	54.85	63.56	10.30	11.50	94.97	132.98
$l_2s_3n_1$	41.83	53.28	7.57	9.27	72.34	111.19
$l_2s_3n_2$	45.50	57.91	8.28	10.83	80.07	129.24
$l_3s_1n_1$	54.96	64.65	11.01	13.54	112.70	156.30
$l_3s_1n_2$	67.23	70.47	13.58	15.15	134.76	167.47
$l_3s_2n_1$	65.69	69.49	12.79	14.49	134.63	165.98
$l_3s_2n_2$	84.03	83.04	17.05	17.68	171.03	196.11
$l_3s_3n_1$	60.14	69.41	12.09	14.85	124.41	166.32
$l_3s_3n_2$	79.82	81.96	16.12	17.52	156.42	191.43
$l_4s_1n_1$	43.96	55.31	8.44	11.34	87.09	133.02
$l_4s_1n_2$	54.92	61.14	10.57	12.52	105.51	142.78
$l_4s_2n_1$	60.13	63.85	10.81	12.25	113.44	141.80
$l_4s_2n_2$	70.31	72.29	13.28	14.58	132.52	157.94
$l_4s_3n_1$	51.91	58.66	9.80	11.83	100.71	136.46
$l_4s_3n_2$	64.21	67.34	12.44	13.50	122.31	150.71
SEm±	1.457	1.646	0.340	0.398	2.771	3.763
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- Not significant

irrespective of treatments (Table 6). Another notable finding is that appreciable decrease in bulk density and increase in porosity and water holding capacity were found generally in 0 to 15 cm depth of soil after the experiment. This might be due to the fact that the soil conditioners and organic manures were applied and incorporated in the surface soil (0-15 cm depth).

The physical properties of the soil were greatly influenced by tillage systems, soil conditioners and nutrient management (Table 6). Deep tillage followed by pit or mound system resulted in lower bulk density and higher porosity and water holding capacity in both soil depths during both the years than conventional tillage followed by pit or mound system. This might be due to the increased loosening effect of soil up to 30 cm depth in deep tillage and only up to 15 cm depth in conventional tillage. According to Burwell and Larson (1969), lowering of bulk density was found to increase soil water retention.

Table 5. Correlation of yield versus nutrient uptake

Variables correlated	Correlation coefficients (r)	
	I year	II year
Cormel yield x N uptake	0.992**	0.921**
Cormel yield x P uptake	0.992**	0.953**
Cormel yield x K uptake	0.978**	0.949**
Corm yield x N uptake	0.930**	0.823**
Corm yield x P uptake	0.946**	0.850**
Corm yield x K uptake	0.932**	0.843**

** Significant at 1% level *Significant at 5% level

Table 6. Effect of tillage systems, soil conditioners and nutrient management on soil physical properties after the experiment

Treatments	Bulk density (Mg m^{-3})				Porosity (%)				Water holding capacity (%)			
	I year		II year		I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
Tillage systems (L)												
Conventional tillage- pit system	1.47	1.62	1.50	1.70	36.42	34.28	36.39	31.12	26.94	23.45	27.05	22.30
Conventional tillage-mound system	1.49	1.67	1.52	1.69	36.28	32.86	36.17	31.64	27.14	22.57	27.30	23.93
Deep tillage-pit system	1.40	1.55	1.44	1.56	37.54	34.63	37.24	36.12	27.67	25.62	29.91	25.54
Deep tillage-mound system	1.41	1.55	1.46	1.55	37.58	35.21	36.89	36.34	27.96	24.34	30.12	24.45
SEm±	0.003	0.005	0.004	0.003	0.092	0.255	0.155	0.150	0.066	0.047	0.101	0.075
CD (0.05)	0.012	0.017	0.014	0.013	0.341	0.946	0.574	0.556	0.243	0.175	0.375	0.277
Soil conditioners (S)												
Control	1.46	1.61	1.49	1.64	36.33	34.00	36.48	33.60	27.16	23.33	28.06	23.48
Coir pith	1.44	1.60	1.48	1.63	37.02	34.20	36.67	33.92	27.73	24.56	29.10	24.65
Rice husk	1.42	1.59	1.47	1.62	37.51	34.54	36.86	33.90	27.39	24.09	28.63	24.04
SEm±	0.001	0.004	0.001	0.003	0.059	0.188	0.054	0.143	0.020	0.045	0.063	0.076
CD (0.05)	0.004	0.012	0.003	0.009	0.168	NS	0.153	NS	0.056	0.126	0.180	0.214
Nutrient management (N)												
INM	1.45	1.61	1.49	1.63	36.67	34.03	36.63	33.61	27.25	23.74	27.95	23.81
Organic nutrition	1.43	1.59	1.48	1.62	37.23	34.46	36.72	34.01	27.60	24.25	29.24	24.30
SEm±	0.001	0.003	0.001	0.003	0.049	0.154	0.044	0.117	0.016	0.036	0.052	0.062
CD (0.05)	0.003	0.010	0.003	0.007	0.137	NS	NS	0.331	0.046	0.103	0.147	0.175

NS- Not significant

Choudhary *et al*. (1985) also observed reduced bulk density in 10 to 30 cm soil depth by deep ploughing (45 cm) than conventional ploughing to 10 cm depth. Application of soil conditioner showed favourable influence on soil physical properties during both the years. Rice husk as soil conditioner was superior to coir pith in lowering bulk density and increasing porosity while coir pith was found to increase water holding capacity of the soil. Increase in water holding capacity of the soil due to coir pith application has been reported by Bhowmic and Debnath (1985) and Cresswell (1992). The water holding capacity of coir pith has been reported to be above 500 per cent by Das (1992) and 400 to 600 per cent by Savithri and Khan (1994). Logmadevi (1997) also opined that application of coir pith reduced bulk density and increased water holding capacity of soil. Bulk density of the soil was lowered and porosity and water holding capacity of the soil increased due to organic nutrition compared to INM. The results are in agreement with the findings of Gerhardt (1997) and Kumar *et al*. (2015).

Higher tuber yield in terms of cormel and corm yields was also obtained due to deep tillage followed by pit system of planting, application of coir pith as soil conditioner and organic nutrition during both years of experimentation (Fig. 1 and Fig. 2). Significant but negative correlation of corm yield with bulk density and positive correlation of yield with porosity and water holding capacity were noticed in both depths of soil during both the years (Table 7). Agbede (2008) also obtained significant but negative correlation of yield of tannia with soil bulk density. Adekiya *et al*. (2011) also observed differences in bulk density dictated the differences in the growth and yield of cocoyam. It is evident the present study that higher tuber yield (Fig. 1 and Fig. 2) and improvement in soil physical properties (Table 1 and Table 6) could be achieved due to deep tillage followed by pit system of planting, application of coir pith as soil conditioner and organic nutrition.

Soil reaction

The data presented in Table 1 revealed that the surface soil (0 to15 cm depth) was less acidic than subsoil (15 to 30 cm depth) before the start of the experiment. After the experiment also, the same trend has been observed (Table 8). Higher soil pH in surface soil (0 to 15 cm depth) than in sub soil (15-30 cm depth) as observed in the present study has been earlier reported by Obatalu and Ibiremo (1999) and Agbede (2010). The reason might be higher concentration of organic matter in surface soil than in the subsoil coupled with the presence of acid causing ions like Al^{3+}.

After the experiment soil acidity increased or decreased from the initial status depending upon the treatments (Table 8). In general, soil became more acidic after deep tillage and pit system of planting. This might be due to more porosity of the soil due to deep tillage which resulted in more leaching of bases. However, application of soil conditioners like coir pith and rice husk lowered the soil acidity in both depths of soil during both the years which might be due to improvement in physico-chemical properties of soil due to application of crop residues. By virtue of high cation exchange capacity, coir pith is able to retain large amounts of nutrients and the adsorption complex has high contents of exchangeable K, Na, Ca and Mg as reported by Verhagen and Papadopoulos (1997) and Prabhu and Thomas (2002). Due to alkaline nature of rice husk, pH increased over control in rice husk applied plots. Organic nutrition also lowered soil acidity than INM in both depths of soil during both years as wood ash, which is alkaline in nature, was a component in organic nutrition. Although deep tillage followed by pit system of planting increased soil acidity after the experiment, this effect could be counteracted by application of soil conditioner and organic nutrition. These treatments also resulted in higher cormel and corm yields (Fig.1 and Fig.2).

Soil nutrient status

Organic Carbon

As shown in Table 1, initially, the surface soil had higher content of organic carbon (1.12% and 1.38% during I and II year respectively) than subsoil (0.99% and 1.2% during I and II year respectively). This might be due to high concentration of organic matter in the surface soil.

Table 7. Correlation analysis of tuber yield versus soil physical properties

Variables correlated	Correlation coefficients (r)	
	I year	II year
Cormel yield x bulk density (0-15 cm depth)	-0.824**	-0.922**
Cormel yield x bulk density (15-30 cm depth)	-0.746**	-0.791**
Cormel yield x porosity (0-15 cm depth)	0.751**	0.866**
Cormel yield x porosity (15-30 cm depth)	0.577**	0.786**
Cormel yield x water holding capacity (0-15 cm depth)	0.637**	0.816**
Cormel yield x water holding capacity (15-30 cm depth)	0.921**	0.643**
Corm yield x bulk density (0-15 cm depth)	-0.755**	-0.705**
Corm yield x bulk density (15-30 cm depth)	-0.701**	-0.563**
Corm yield x porosity (0-15 cm depth)	0.650**	0.691**
Corm yield x porosity (15-30 cm depth)	0.490*	0.575**
Corm yield x water holding capacity (0-15 cm depth)	0.513*	0.635**
Corm yield x water holding capacity (15-30 cm depth)	0.856**	0.657**

** Significant at 1% level *Significant at 5% level

The findings of Obatolu and Ibiremo (1999) and Agbede (2010) are in agreement with the result. Organic carbon status of the surface soil increased after the experiment whereas it declined in the sub soil (Table 8). Even after crop removal, improvement of organic carbon in the surface soil might be due to application of organic manures and soil conditioners in the surface soil and addition of leaf litter of the crop. This is evident from the fact that even in the surface soil, the plots which were treated with soil conditioners and organic nutrition registered comparatively higher status of organic carbon than the plots which received no soil conditioners but organic nutrition (Table 8).

Tillage system influenced the organic carbon status in the surface soil only, during both the years (Table 8). Conventional tillage resulted in higher status of organic carbon than deep tillage though higher tuber yield was recorded for deep tilled plots (Fig. 1 and Fig. 2). Due to more loosening of the soil under deep tillage, there might have been more oxidation of organic carbon resulting in lower content under deep tillage. Organic carbon status improved in both soil depths due to application of soil conditioners. Coir pith was found superior to rice husk in producing higher tuber yield as well as improving the organic carbon status which might be due to the rapid decomposition of coir pith compared to rice husk. At harvest, the remnants of rice husk could be seen in rice husk applied plots while coir pith has been completely decomposed and mixed with soil. Compared to INM, organic nutrition invariably improved the tuber production as well as the organic carbon status of the soil during both the years which might be due to higher carbon content of organic manures. Srivastava (1985), More (1994), Kaswala *et al*. (2013) and Radhakrishnan *et al*. (2013) also observed increase in soil organic carbon status due to organic nutrition.

Available N

Initially available N was higher in 0 to 15 cm depth of soil than in 15 to 30 cm depth (Table 1). In general, available N status after the experiment was higher in 15

Table 8. Effect of tillage systems, soil conditioners and nutrient management on soil chemical properties after the experiment

Treatments	pH				Organic carbon (%)			
	I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Tillage systems (L)								
Conventional tillage- pit system	5.78	5.37	5.31	5.13	1.25	0.85	1.43	1.10
Conventional tillage-mound system	5.81	5.46	5.35	5.18	1.23	0.86	1.42	1.08
Deep tillage-pit system	5.61	5.25	5.16	4.91	1.22	0.85	1.46	1.08
Deep tillage-mound system	5.64	5.37	5.23	5.03	1.20	0.84	1.41	1.10
SEm±	0.010	0.005	0.007	0.003	0.007	0.003	0.008	0.005
CD (0.05)	0.037	0.018	0.027	0.010	0.025	NS	0.029	NS
Soil conditioners (S)								
Control	5.62	5.24	5.16	4.92	1.20	0.85	1.40	1.07
Coir pith	5.86	5.52	5.39	5.21	1.25	0.87	1.46	1.10
Rice husk	5.65	5.32	5.24	5.06	1.22	0.85	1.42	1.08
SEm±	0.009	0.008	0.009	0.007	0.006	0.002	0.009	0.007
CD (0.05)	0.025	0.022	0.025	0.019	0.018	0.007	0.026	0.018
Nutrient management (N)								
INM	5.61	5.27	5.21	4.99	1.19	0.84	1.42	1.07
Organic nutrition	5.81	5.45	5.32	5.13	1.26	0.87	1.44	1.10
SEm±	0.007	0.006	0.007	0.006	0.005	0.002	0.007	0.005
CD (0.05)	0.020	0.018	0.020	0.016	0.014	0.005	0.021	0.015

NS- Not significant

to 30 cm depth of soil than in 0 to 15 cm depth of soil which might be due to crop removal and leaching loss of N from the surface layer. This is evident from the depletion of available N status in the surface soil and improvement in the sub soil than the initial status after the experiment (Table 9).

Conventional tillage followed by pit/ mound system (l_1 and l_2) resulted in higher status of available N in two soil depths compared to deep tillage followed by pit or mound system (l_3 and l_4) during both the years. Higher uptake of N by the crop raised by deep tillage might have resulted in lower status of available N after the experiment from such plots than conventionally tilled plots. Available N status was found to be higher in plots which did not receive any soil conditioner in both depths of soil compared to plots which received soil conditioner. In plots treated with soil conditioner, there was increased porosity and water holding capacity (Table 6) and hence better root penetration which might have helped the plants to take up more of the available N. Organic nutrition was found superior to INM during both years in registering higher status of available N in the soil. Slow decomposition and slow release of nutrients from organic manures might have contributed to higher status of available N in the soil. Corroboratory results have been reported by Srivastava (1985), More (1994) and Suja *et al*. (2012).

Available P

There was build-up of available P in both depths of soil after the experiment (Table 9) especially in the

Table 9. Effect of tillage systems, soil conditioners and nutrient management on soil nutrient status after the experiment (kg ha^{-1})

Treatments	Available N				Available P				Available K			
	I year		II year		I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
Tillage systems (L)												
Conventional tillage- pit system	182.93	190.25	205.93	219.52	157.47	160.28	218.48	202.41	301.17	109.48	373.62	321.90
Conventional tillage-mound system	187.12	234.16	217.43	227.88	148.04	170.17	191.25	181.58	325.17	126.20	399.76	296.39
Deep tillage-pit system	178.23	165.16	169.32	194.43	142.46	183.95	176.15	250.43	180.88	107.54	246.90	265.03
Deep tillage-mound system	180.32	177.71	184.50	206.98	127.58	209.80	168.19	306.48	253.12	105.46	312.79	249.34
SEm±	3.072	1.474	4.062	0.371	1.064	1.077	1.917	2.617	0.958	1.037	1.594	1.716
CD (0.05)	11.381	5.462	15.050	1.374	3.944	3.992	7.104	9.696	3.550	3.844	5.908	6.357
Soil conditioners (S)												
Control	199.92	211.68	207.74	225.79	156.28	183.73	204.39	255.85	255.85	97.07	319.87	249.61
Coir pith	164.64	174.05	185.02	200.70	131.49	175.66	172.32	213.20	274.91	128.22	346.16	314.51
Rice husk	181.89	189.73	190.12	210.11	143.89	183.76	188.83	236.63	264.49	111.22	333.77	285.37
SEm±	1.201	0.935	0.969	2.091	1.571	0.964	1.879	1.567	1.099	0.333	1.501	1.513
CD (0.05)	3.396	2.645	2.742	5.914	4.443	2.726	5.316	4.433	3.110	0.943	4.245	4.279
Nutrient management (N)												
INM	172.48	178.75	187.38	204.89	136.85	173.83	182.16	221.30	259.96	105.27	327.20	255.77
Organic nutrition	191.82	204.89	201.21	219.52	150.92	188.27	194.88	249.15	270.21	119.07	339.34	310.56
SEm±	0.980	0.763	0.792	1.707	1.283	0.787	1.534	1.280	0.898	0.272	1.225	1.235
CD (0.05)	2.773	2.160	2.239	4.829	3.628	2.226	4.340	3.619	2.539	0.770	3.466	3.494

sub soil (15 to 30 cm depth) compared to initial status (Table 1). Higher status of available P in surface soil (0 to 15 cm depth) was recorded by conventional tillage followed by pit or mound system and by deep tillage followed by pit or mound system in sub soil (15 to 30 cm depth) during both the years. Plots without soil conditioner registered appreciably higher status of available P in both depths of soil in both years. Coir pith as soil conditioner recorded the lower status of available P compared to rice husk. Higher tuber yield and high uptake of P recorded in plots conditioned with coir pith might have led to lower status of available P in such plots compared to high P status in plots with no soil conditioner or rice husk as soil conditioner. Organic nutrition resulted in higher status of available P compared to INM which is in agreement with the findings of Srivastava (1985), More (1994) and Suja *et al*. (2012). It is well known that organic matter reduces P fixation and enhances P availability. Also, organic acids produced during the decomposition of organic matter might have increased the solubility of native P (Singh *et al*., 2008).

Available K

After the experiment, build-up of available K was noticed (Table 9) compared to initial values (Table 1). Available K status was found to be higher at 0 to 15 cm depth than in 15 to 30 cm depth.

Conventional tillage followed by mound registered appreciably higher status of available K in both depths of soil except in 15 to 30 cm depth during II year when conventional tillage followed by pit system dominated other tillage systems. Higher uptake of K from deep tilled plots and higher tuber yield might have resulted in lower status of available K after the experiment. A marked increase in available K status in both depths of soil during both the years was observed due to application of coir pith as soil conditioner compared to rice husk and control. Higher K content of coir pith and release of K in available form to the crop through its gradual decomposition might have increased the status of available K in the soil. Available K was appreciably higher in plots with organic nutrition. Slow decomposition of organic manures, reduction of K fixation and leaching loss, solubilisation and release of K might be the reasons for the higher status of available K in plots given organic nutrition. Similar findings have been earlier reported by Srivastava (1985), More (1994) and Suja *et al*. (2008).

Conclusion

Higher uptake of N, P and K and tuber yield resulted in treatments that were given deep tillage followed by pit system of planting. Enhanced nutrient uptake and superior tuber yield were recorded when coirpith was applied as soil conditioner (@500 g plant^{-1}). Organic nutrition (FYM @ 37.5 t ha^{-1} + wood ash @ 2 t ha^{-1}) improved the nutrient uptake and tuber yield. Significant and positive correlation of cormel and corm yield with N, P and K uptake were observed. Deep tillage followed by pit or mound system registered lower bulk density and higher porosity and water holding capacity in both depths of soil during both years. Rice husk as soil conditioner was superior to coir pith in lowering bulk density and increasing porosity while coir pith was found to increase water holding capacity of the soil. Compared to INM, organic nutrition lowered bulk density and increased porosity and water holding capacity of the soil. Correlation study revealed significant and negative correlation of tuber yield with bulk density and significant and positive correlation with porosity and water holding capacity of the soil. In general, application of soil conditioners and organic nutrition lowered soil acidity in both depths of soil during both the years. After the experiment, the organic carbon status of the surface soil increased whereas it decreased in the sub soil and an increasing trend was observed in the case of available N status. Improvement in available P and K status were noticed in both depths of soil. Conventional tillage favoured higher status of organic carbon and available N, P and K in the soil. Applying coir pith as soil conditioner improved the status of organic carbon and available K in both depths of the soil. Compared to INM, organic nutrition resulted in higher status of organic carbon and available N, P and K in both depths of the soil during both the years.

The results of the study indicated that deep tillage to a depth of 30 cm followed by pit or mound system of planting, application of coir pith (@ 500 g plant^{-1}) and organic nutrition (FYM @ 37.5 t ha^{-1} + wood ash @ 2 t ha^{-1}) is ideal for enhancing nutrient uptake and tuber uptake of tannia and for improving the physico-chemical properties of the soil without depletion of soil nutrient status.

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