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Studies on the interaction effect of tillage, organics and nitrogen on root length, root volume and yield of sorghum in subsoil hard pan soils

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Abstract: A field experiment was carried out with sorghum (CO 26) in an Alfisol having hard pan at shallow depth to study the interaction effect of tillage practices, organics and nitrogen on grain yield and root volume of sorghum. Remarkable influence of chiseling on the root length and root volume of the sorghum crop was evidenced from the better proliferation of roots in to the deeper layers. Root length increased with increasing levels of N, while organics had no effect on root length. Chiseling significantly increased the grain yield of sorghum. Among the organics, the composted coir pith registered the highest grain yield of sorghum. The grain yield of sorghum due to chiseling and 75 per cent of the recommended N was on par with the mould board or country ploughing with 100 per cent recommended N indicating the scope of saving 25 per cent fertiliser N.

Key words: Tillage, Organics, Nitrogen levels, Root volume, Sorghum grain yield.

Introduction

Soils with sub soil hard pan reduce the growth and yield of crop by restricting the root growth, movement of water and nutrients, aeration, drainage etc. The reduction in yield levels varies depending upon the depth of hard pan, which determines the volume of soil available for root exhaustion. Yield reduction in sorghum and maize were reported in red sandy soils, where the sub soil hard pan exists (Gupta and Satyendra Kumar, 1994). Deep tillage in coarse textured soils induces prolific and deeper root system (Chambers *et al.* 1990) and thus, increases the water supply. Poor root growth accentuates the water stress effects. Adequate root growth is dependent on soil physical and chemical environments such as soil compaction, soil strength, amount of water and nutrient supply, soil temperature and depth of water table (Das *et al.* 1995). The current study, therefore, was undertaken to evaluate the extent of effect of tillage, organics and N levels on root volume and yield of sorghum crop.

Materials and Methods

A field experiment was conducted for two seasons in succession during 1996-97, to study the effect of tillage and organics on sandy clay loam (Pichanur series - Typic Haplustalf), reddish brown soil having sub soil hard pan at shallow depth (at 15 cm) in the farmer's field at Nachipalayam village of Madukkarai block of Coimbatore district on sorghum crop. The analysis of initial soil samples showed that the bulk density was 1.45 Mg m^{-3} in surface layer, whereas the bulk density was much higher in 15 - 30 cm (1.81 Mg m^{-3}) and 30 - 45 cm (1.84 Mg m^{-3}) depths. Contrary to this, the hydraulic conductivity was very high in surface layer (2.38 cm h^{-1}) compared to other two depths (0.30 and 0.38 cm h^{-1}). The infiltration rate was found to be 0.62 cm h^{-1}. The soil was tested to be neutral in reaction (pH : 7.1) with a EC value of 0.42 dSm^{-1}. The organic carbon content was 2.1 g kg^{-1} and $KMnO_4$ oxidisable - N, Olsen - P and NH_4OAC - K status of the soil were 142, 7.3 and 112 kg ha^{-1} respectively. The iron and alumunium oxides were found to be high. The mechanical analysis of the initial soil revealed that it contained 23.42 % clay, 12.28 % silt, 9.78% fine sand and 52.68% coarse sand. The following treatments were imposed in a split plot design and the 27 treatment combinations were replicated thrice. The main plot treatments were (type of tillage) *viz.* T_1 - Country ploughing twice; T_2 - Mould board ploughing twice ; T_3 - Chisel ploughing once + couintry ploughing twice ;

Table 1. Effect of tillage, organics and levels of N on root length (cm) at different stages (sorghum)

Treat-ments	M_1				M_2				M_3				
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	Grand mean
T1S1	8.35	9.10	9.30	8.92	8.60	9.25	8.35	8.73	8.65	8.70	8.30	8.55	8.73
T1S2	15.20	15.90	15.95	15.86	16.35	15.65	16.95	16.32	16.95	16.30	16.10	16.45	16.15
T1S3	20.90	21.80	21.40	21.37	20.55	23.00	23.70	22.42	21.30	22.75	23.35	22.47	22.08
T1S4	26.75	27.30	28.25	27.43	26.75	27.35	28.35	27.48	25.95	27.30	22.60	25.28	26.73
T1S5	28.85	28.65	29.00	28.83	28.60	28.80	29.15	28.85	27.30	28.85	28.90	28.35	28.68
T1S6	29.45	30.05	30.00	29.83	30.65	29.70	30.20	30.18	30.20	29.95	29.20	29.78	29.93
T1S7	29.85	30.35	30.20	30.13	31.55	29.95	30.85	30.78	31.35	30.35	31.05	30.97	30.62
T1S8	30.05	30.05	30.10	30.07	30.55	30.75	30.35	30.55	31.35	30.95	31.55	31.28	30.63
Mean	23.67	24.15	24.27	24.03	24.20	24.31	24.74	24.41	24.13	24.39	23.88	24.17	24.19
T2S1	8.65	8.520	8.95	8.70	8.15	8.40	8.05	8.20	8.30	8.20	8.45	8.32	8.40
T2S2	18.10	19.10	18.05	18.42	18.75	19.30	19.25	19.10	18.45	18.80	23.10	20.12	19.21
T2S3	24.70	25.05	25.60	25.12	23.35	24.20	24.45	24.00	23.30	24.45	24.35	24.03	24.38
T2S4	31.20	31.00	32.05	31.42	31.40	31.60	32.80	31.93	31.10	30.95	32.05	31.37	31.57
T2S5	32.00	32.00	32.40	32.13	33.55	32.40	34.10	33.35	33.20	32.80	31.90	32.63	32.70
T2S6	32.15	32.70	32.30	32.38	33.90	33.20	34.40	33.83	33.65	33.15	33.90	33.57	33.26
T2S7	32.35	33.20	33.60	33.05	34.25	33.45	33.95	33.88	34.65	33.40	34.25	34.10	33.67
T2S8	31.25	33.15	34.25	32.88	34.95	33.50	33.80	34.08	34.25	34.55	34.60	34.47	33.81
Mean	26.3	26.84	27.09	26.76	27.28	27.00	27.60	27.30	27.11	27.04	27.82	27.33	27.13
T3S1	8.40	8.45	8.25	8.37	8.90	8.55	8.80	8.75	9.20	8.95	9.00	9.05	8.72
T3S2	22.75	23.90	24.15	23.60	22.90	22.95	23.15	23.00	23.80	23.80	23.45	23.68	23.43
T3S3	32.90	34.55	33.20	33.55	31.75	33.70	33.95	33.13	31.90	32.35	33.35	32.53	33.07
T3S4	42.45	42.20	43.70	42.78	41.90	41.40	42.00	41.77	41.80	42.70	41.40	41.97	42.17
T3S5	47.20	47.80	47.65	47.55	48.30	49.10	49.45	48.95	49.05	48.70	48.40	48.72	48.41
T3S6	44.10	50.80	51.00	50.30	50.20	50.95	50.90	50.68	49.85	51.65	51.10	50.87	50.62
T3S7	49.90	52.10	50.65	50.88	51.30	51.20	53.70	52.07	53.10	52.05	52.05	52.40	51.78
T3S8	51.00	52.05	51.25	51.43	50.9	51.45	51.30	51.22	53.30	52.25	52.55	52.70	51.78
Mean	37.96	38.98	38.73	38.55	38.26	38.66	38.16	38.70	39.0	39.06	38.20	38.99	38.75
Grand Mean	29.31	29.99	30.03	29.78	29.92	29.99	30.50	30.14	30.08	30.16	29.97	30.15	

	T	M	N	S	T on S	S on
SEd	0.21	-	0.17	0.27	0.47	0.47
CD (P=0.05)	0.48	NS	0.33	0.54	0.93	0.93

and source of organics *viz.* ; M_1 - No organics ; M_2 - Farm yard manure @ 12.5 t ha^{-1} ; M_3 - Composted coir pith @ 12.5 t ha^{-1}. The sub plot treatmetns were N_1 - No Nitrogen ; N_2 - 75 % of the recommended N ; N_3 - 100 % of the rcommended N. There were eight stages of sampling *viz.* S_1 - 15 DAS ; S_2 - 30 DAS ; S_3 - 45 DAS ; S_4 - 60 DAS ; S_5 - 75 DAS ; S_6 - 90 DAS ; S_7 - 105 DAS ; S_8 - At harvest.

Tillage treatments were done as contemplated in the experiment. At the time of seeding, 50% of N, full dose of P and K in the form of urea, single super phosphate and muriate of potash, respectively were applied basally. The remaining half dose of N was top dressed at 45 days after sowing. The farm yard manure and composted coir pith were applied basally and incorporated thoroughly in the top soil @ 12.5 t ha^{-1} as per the treatment schedule, 15 days before sowing.

Root samples were collected at 15 days interval, by removing the soil around the selected

Table 2. Effect of tillage, organics and levels of N on root volume (cm^{-3}) at different stages (sorghum)

	M_1				M_2				M_3				
Treat-ments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	Grand mean
T1S1	1.81	1.81	1.90	1.84	1.85	1.93	2.04	1.94	1.78	1.86	1.87	1.84	1.87
T1S2	2.59	2.54	2.61	2.58	2.53	2.58	2.58	2.56	2.52	2.64	2.54	2.57	2.57
T1S3	6.20	6.16	6.02	6.13	6.69	5.95	6.22	6.29	5.95	6.24	6.03	6.07	6.16
T1S4	11.15	10.78	12.07	11.33	10.15	11.07	11.74	10.99	10.91	12.47	12.57	11.98	11.43
T1S5	11.18	11.66	12.13	11.65	11.16	11.11	11.67	11.31	10.75	12.64	12.59	11.99	11.65
T1S6	9.85	9.40	9.74	9.66	9.39	9.62	9.46	9.49	9.24	9.13	9.41	9.26	9.47
T1S7	9.45	9.03	9.37	9.28	8.82	9.19	9.24	9.08	9.17	8.14	8.74	8.68	9.01
T1S8	8.48	8.57	8.65	8.87	8.64	8.57	8.29	8.50	8.19	8.02	8.97	8.39	8.48
Mean	7.59	7.49	7.81	7.63	7.40	7.18	7.65	7.52	7.31	7.14	6.27	7.59	7.58
T2S1	1.88	1.90	2.05	1.94	1.95	1.92	2.04	1.97	1.98	1.89	1.99	1.95	1.95
T2S2	2.91	2.90	3.01	2.94	2.93	2.86	2.87	2.89	2.91	2.85	2.95	2.90	2.91
T2S3	7.11	7.13	7.10	7.11	7.09	7.20	7.03	7.11	7.21	7.17	7.15	7.18	7.13
T2S4	11.75	12.46	14.08	12.76	11.55	12.66	13.33	12.51	11.42	12.28	12.87	12.19	12.49
T2S5	13.06	13.55	12.62	13.08	12.78	13.24	13.42	13.15	11.59	12.60	13.50	12.56	12.93
T2S6	10.19	10.44	10.05	10.23	10.12	11.22	11.13	10.82	9.87	10.54	10.12	10.18	10.41
T2S7	9.83	9.96	9.73	9.84	9.44	10.19	10.18	9.94	9.13	9.55	9.11	9.26	9.68
T2S8	9.12	9.78	9.17	9.36	9.50	9.19	9.03	9.24	9.09	9.20	9.12	9.14	9.25
Mean	8.23	8.52	8.48	8.41	8.17	8.56	8.63	8.45	7.90	8.26	8.35	8.17	8.34
T3S1	1.92	1.97	1.92	1.94	1.82	1.98	1.93	1.91	1.83	1.81	1.96	1.87	1.91
T3S2	4.01	4.06	4.07	4.04	3.96	4.15	4.12	4.08	3.99	4.11	4.03	4.04	4.07
T3S3	9.70	9.94	10.29	9.98	9.87	10.15	11.12	10.38	10.12	11.35	11.47	10.98	10.45
T3S4	18.10	18.45	19.60	18.72	17.30	19.90	20.85	19.35	10.12	11.35	11.47	10.98	10.45
T3S5	19.46	21.62	20.48	20.52	18.16	20.29	21.12	19.86	17.91	21.48	21.72	20.37	20.25
T3S6	15.71	16.10	16.97	16.26	16.25	16.97	17.12	16.78	15.12	14.95	17.09	15.85	16.29
T3S7	14.71	15.65	15.67	15.34	14.70	15.72	15.47	15.30	13.96	14.23	15.59	14.59	15.08
T3S8	14.06	13.80	14.74	14.20	13.05	14.09	14.41	13.85	12.66	13.81	14.65	13.71	13.92
Mean	12.20	12.69	12.96	12.63	11.89	12.91	13.26	12.68	11.48	12.69	13.41	12.54	12.62
Grand mean	9.34	9.57	9.75	9.56	9.15	9.55	9.85	9.55	8.90	9.36	9.34	9.43	

	T	M	N	S	T on S	S on T	T on S	S on T	NxS
SEd	0.08	-	0.08	0.13	0.14	0.14	0.22	0.23	0.23
CD (P=0.05)	0.19	NS	.26	0.30	0.28	0.47	0.47	0.46	0.46

plants using spade to the required depth. Then the plants with the mass of soil were put in a drum of water to remove the soil. After washing, the root samples were dried under shade and used for measuring its length and volume. The volume of the root was measured by the method of displacement, when the root bunches were immersed in water contained in a measuring cylinder (Jene *et al.* 1980). All the plants of the test crop from the net plot were harvested and the treatment wise yield of grain and straw in sorghum were recorded and the data were subjected to statistical scrutiny (Panse and Sukhatme, 1978).

Results and Discussion

Root Length

The data on root length measured at different stages indicated that chiseling the field had a significant positive influence on root length (Table 1). It has registered the highest value of 38.75 cm followed by mould board

Table 3. Effect of tillage, organics and levels on N on grain yield of sorghum (kg ha^{-1})

	T_1				T_2				T_3				
Treatments	M_1	M_2	M_3	TxN Mean	M_1	M_2	M_3	TxN Mean	M_1	M_2	M_3	TxN Mean	N Mean
N_1	2578	2803	3053	2811	2700	2905	3160	2922	2903	3738	3853	3498	3077
N_2	3538	3738	3903	3726	3603	3865	3968	3812	3925	4085	4210	4073	3870
N_3	3898	3953	4093	3981	3758	3990	4105	3951	4165	4258	4398	4273	4068
TxM Mean	3338	3498	3683	3506	3354	3527	3654	3562	3664	4117	4154	3948	

	T	M	N	TxM	T on N	N on T	M on N	N on M
SEd	18	18	19	31	32	33	32	33
CD (P=0.05)	41	41	40	71	68	69	68	69

Table 4. Effect of tillage, organics and levels of N on straw yield of sorghum (kg ha^{-1})

	T_1				T_2				T_3				
Treatments	M_1	M_2	M_3	TxN Mean	M_1	M_2	M_3	TxN Mean	M_1	M_2	M_3	TxN Mean	N Mean
N_1	11335	11960	12205	11833	11990	11905	11515	11803	12195	12475	12460	12377	12004
N_2	13630	13955	13795	13793	13490	13150	13595	13412	12710	13890	13970	13523	13576
N_3	14140	14385	14585	14370	14030	14513	13675	14072	13955	14389	14970	14437	14293
TxM Mean	13035	13433	13528	13332	13170	13188	12928	13096	12953	13583	13800	13446	

	T	M	N	T on N	N on T
SEd	-	-	-	244	145
CD (P=0.05)	NS	NS	NS	551	304

ploughing treatment (27.13 cm) and the lowest root length of 24.19 cm was registered under country ploughing treatment. Among the levels of N, application of 100 per cent recommended dose (N_3) registered the highest value but was comparable with 75 per cent recommended dose (N_2). The N_2 level was inturn comparable with control (N_1). The last stage (S_8) was found to record the highest value but on par with the preceding stage (S_7). The root length increased along with the stages. The manurial treatment did not influence the length of the roots. The interaction effect of T x S indicated that irrespective of tillage treatments, the highest value was registered at harvest. However, in chiseling, upto seventh stage the root lengths were significantly superior over the preceding stages; the stages S_7 and S_8 were comparable, whereas in other two tillage treatments, the root lengths were significantly higher upto the first five stages than the preceding stages, and thereafter they were on par with each other. In first stage (S_1), the different tillage treatments did not influence the root length. Aftermath, the chiseling was found to influence the root length significantly upto last stage followed by mouldboard ploughing. The lowest values were registered under country ploughing treatment in all stages.

Root Volume

The results pertaining to the root volume of sorghum crop (Table 2) indicated a similar trend as that of the results of root length with regard to main effects and also the interaction effect of T x S. The T x N interaction revealed that irrespective of tillage treatments, N_3 level increased the root volume. In chiseled plots, the N_3 level was significantly superior over other levels, whereas in mouldboard ploughing and country ploughing treatments, N_3 and N_2 levels were on par with each other but significantly higher than control (N_1). In all the three N levels, chiseling was found to be significantly superior followed by mouldboard ploughing which inturn superior to country ploughing. The S x N interaction revealed that irrespective of the N levels, the root volume increased with advancement in stages. In almost all the stages, 100 per cent recommended N (N_3) registered numerically higher values followed by N_2 and N_1 levels. All the three levels were comparable among themselves.

The rooting pattern *viz.* length, volume and distribution is a function of resistance offered by the soil to the growing roots. The resistance of the soil is governed by texture and structure which influences the various physical parameters of the soil. A compacted layer not only results in the decrease of pore space, but also reduces the size of pores and thus offers increased resistance to the penetration of roots (Bodman and Constantin, 1965). The rooting pattern was also influenced by soil strength which was found to increase with increase in bulk density and soil moisture tension (Taylor *et al.* 1966).

In general, roots grow in macropores (Hatano *et al.* 1988). The soils having hardpan did not have optimum ratio of macro and micro pores. This might be due to the higher bulk density resulting in reduced non capillary porosity which hampered the root proliferation culminating in lower grain yield. In the present experiment, the root length and root volume of sorghum crop was monitored at 15 days interval to substantiate the above conclusions. The results clearly indicated the positive influence of chiseling as compared to other tillage practices in increasing the root length and root volume irrespective of stages (Sundara Sarma *et al.* 1978). The root length increased with increasing level of nitrogen application. The root volume increased linearly with increasing levels of N possibly due to higher N availability. Further, this effect of nitrogen application was perceptible only in chiseled plots, which might be due to the favourable environment created for the efficient utilisation of applied N in comparison with other tillage treatments (Sarkar *et al.* 1989).

Grain Yield

The grain yield data revealed that among the tillage treatments, chiseling registered significantly higher grain yield of 3948 kg ha^{-1} followed by mouldboard ploughing (356[illegible] kg ha^{-1}) while the lowest yield of 3506 kg ha^{-1} was recorded under country ploughing treatment (Table 3). Among the different manures tried, composted coir pith registered the highest yield of 3860 kg ha^{-1} which was significantly superior over the other two treatments. The control registered the significantly lower yield of 3452 kg ha^{-1} as compared to farm yard manure treatment (3527 kg ha^{-1}). The perceptible influence of increasing N levels on the grain yield has been clearly found with increasing yield. The N_3 level registered the highest grain yield of 4068 kg ha^{-1} followed by N_2 level (3870 kg ha^{-1}). The lowest yield of 3077 kg ha^{-1} was registered in control treatment (N_1). The interaction effect of T x M showed that irrespective of tillage treatments, composted coir pith recorded significantly superior yield followed by farm yard manure. Control recorded the lowest grain yield. In all the organic manure treatments, chiseling registered markedly higher grain yield compared to other tillage treatments. Mould board ploughing and country ploughing treatments were found to be on par with each other. The interaction effect of T x N indicated that irrespective of tillage treatments, N application had a significant positive influence. The N_3 treatment recorded markedly higher yield followed by N_2 and N_1 treatments. Irrespective of N levels, chisel ploughing influenced the grain yield significantly than other two tillage treatments. The M x N interaction revealed that irrespective of organic manures, N application at higher dose recorded significantly higher grain yield than the lower levels. Irrespective of N levels, composted coir pith increased the sorghum grain yield significantly followed by farm yard manure. The lowest yield of grain was rgistered under control treatment.

Straw Yield

The results of the straw yield of sorghum showed that neither the various tillage treatments nor the organics treatments influenced the straw yield. However, the N levels had a significant effect (Table 4). Among the N levels, 100 per cent recommended dose (N_3) registered the highest straw yield of 14,293 kg ha^{-1} followed by N_2 treatment (13,576 kg ha^{-1}). The lowest straw yield of 12,004 kg ha^{-1} was recorded in control treatment (N_1). The interaction effect of T x N showed that irrespective of tillage treatments, higher level of N application (N_3) registered significantly higher straw yield followed by lower levels (N_2 and N_1). The N_1 recorded the significantly lowest value than N_2 level. Under each level of N application, all the tillage treatments behaved similarly.

Providing favourable condition for the better growth of crops by way of deep tillage practices, addition of organics and adequate nutrient supply improves the yield levels of crops. In the present study, chiseling the soil resulted in spectacular increase in grain yield of sorghum (3948 kg ha^{-1}) which might be due to the favourable physical environment provided for the crop growth. The works of Gupta and Abrol (1993) and Gupta and Satyendra Kumar (1994) also confirmed the above finding. Besides, chiseling also improved the nutrient and water movement thereby increasing the nutrient uptake by the crop. The increased grain yield (3830 kg ha^{-1}) registered in the plots that received composted coir pith might be due to its manurial value under the favourable physical environment. As could be expected, increased N availability with increased levels of N influenced the grain yield significantly. It is interesting to note that chiseling along with 75 per cent recommended N registered the yield on par with the treatment receiving 100 per cent recommended N along with mouldboard or country ploughing, and adoption of this technology can help in the saving of 25 per cent of fertiliser N. This might be due to the chiseling, that would have created a favourable physical environment for the increased mineralisation and mobility of fertiliser N resulting in higher uptake and enhanced grain yield.

The organic manures applied at the rate of 12.5 t ha^{-1} also increased the grain yield, which might be due to the favourable physical environment created due to application. In the present study, remarkable effect of chiseling on the root length and root volume of the sorghum crop is well evidenced from the better proliferation of roots.

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