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Interactive Effect of Tillage and Phosphate Fertilization in Conjunction with FYM to Sorghum+Greengram Intercropping System on Physico-chemical Properties of the Soil

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Abstract: Tillage operations, particularly disc and chisel ploughing, on medium textured soils for two consecutive years (*kharif*, 1989 and 1990) significantly lowered the bulk density and increased soil porosity, water holding capacity, hydraulic conductivity and basic infiltration rate of the soil. Incorporation of farm yard manure and phosphate fertilization improved the physical conditions of the soil and the stored soil moisture profile.

Key words: Tillage, phosphate, sorghum, greengram, intercropping.

Legumes intercropped with sorghum may help in stabilizing yields and return over space and time, apart from stepping up the pulse production in the country. Excessive tillage not only deteriorates the soil environment, but also increases the cost of production. On the other hand, zero tillage seriously affects the growth and establishment of plant through increased weed competition and poor soil physical conditions. Reduced tillage has been found highly useful in improving soil physical environment and the yield of crop without adverse effect on the environment (Gupta and Aggarwal, 1992). In dryland soils where crop depend only upon conserved soil moisture, there is an essential need to enhance profile water storage. Thus, tillage practices play an important role in dry farming/rainfed agriculture, however, proper choice of implements, timely operations and the methods of their use have to be specified for different agroclimatic zones. Hard setting soil, and those having root restricting layers, need some form of mechanical loosening through deep tillage to conserve soil and water and facilitate crop growth (Lal, 1989). Incorporation of FYM not only improves the soil physical and chemical characteristics, but also the utilization efficiency of nutrients by crops (Gaikwad and Khuspe, 1976; Aggarwal and Kumar, 1996) through enhanced soil biological activity. Furthermore, adequate fertilization of surface soil and proper management are important in promoting deeper, vigorous and extensive rooting system (Tisdale *et al.*, 1993). In view of the above facts, a field experiment was conducted to elucidate the interactive effect of tillage, FYM and phosphate fertilization to sorghum+greengram interactive system on physico-chemical properties of the soil, a key factor governing the crop productivity.

Materials and Methods

The field experiment was conducted during *kharif*, 1989 and 1990. The mean annual rainfall of the region is 637±7 mm, most of which is received during the last week of June to mid September. The soil of the experimental field was sandy loam in texture, non-saline (EC, 0.31 dS m^{-1}) having pH of 7.4 and was low in N (250.2 kg ha^{-1}), medium in P (34.5 kg P_2O_5 ha^{-1}) and high in K (412 kg K_2O ha^{-1}).

The experiment was conducted in the split plot design with main plot treatment being five tillage operations (conventional tillage, disc ploughing, chisel ploughing, minimum tillage and zero tillage) and the sub-plot treatment being two levels of FYM (0 and 10 t ha^{-1}) and three levels of phosphorus (0, 30 and 60 kg ha^{-1}) making in all, 30 treatments. These treatment combinations were replicated four times in a net plot size of 21.0 sq. m. The same set of treatments was repeated in the second year. The tillage treatments were imposed during seed bed preparation in strips of 30x6 m (main plot). Conventional tillage had twice (cross) 7.5 cm deep ploughing with a country plough. Disc ploughing had one 25 cm deep ploughing with a cross cultivation. Chisel ploughing had one 40 cm deep ploughing at 52.5 cm spacing, followed by a cross cultivation. In minimum tillage, one 12.5 cm deep disc harrowing was undertaken. No tillage operation was undertaken in zero tillage treatment.

Sorghum (var. CSH-6) and greengram (var. K-851) were used as test crops and were grown in an intercropping system on the same site under rainfed conditions for two consecutive years. At the end of two years of experimentation, soils from each treatment plot were analyzed for physical (bulk density, soil porosity, water holding capacity, basic infiltration rate and hydraulic conductivity), and chemical (EC, organic carbon and available P_2O_5 and K_2O) constants using standard methods of analysis. For determining the bulk density and hydraulic conductivity, undisturbed soil cores were drawn with the help of core sampler from two depths, 0-15 and 15-30 cm (Arnold, 1986). Hydraulic conductivity was determined using constant head technique over the soil column. The water holding capacity was determined in the disturbed core of soil samples collected from each plot to a depth of 30 cm using Keen Raczkowsi boxes (Piper, 1950). The infiltration rate was determined in the field for each plot using double ring infiltrometer (Singh, 1980). Profile soil moisture was computed from soil moisture determined gravimetrically from three consecutive soil depths, 0-15, 15-30 and 30-45 cm. Test of significance (F test) was used for estimating the treatment differences.

Results and Discussion

Physical parameters

When compared with the values of physical constants determined prior to the experimentation, various tillage operations resulted in improvement of the soil physical conditions (Table 1).

Bulk density and porosity: It is apparent from the data that various tillage treatments significantly decreased the bulk density and increased the soil porosity in both 0-15 and 15-30 cm soil layers, as compared to zero tillage treatments. Disc ploughing was found to be more effective and minimum values of bulk density of 1.37 and 1.46 Mg m^{-3} were recorded as against 1.43 and 1.50 Mg m^{-3} under conventional, and 1.46 and 1.52 Mg m^{-3} under zero tillage treatment in surface (0-15 cm) and sub-

Table 1. Initial physico-chemical characteristics of experimental field

Characteristics	Content
Physical	
Mechanical separates (%)	
Sand	59.71
Silt	22.09
Clay	17.29
Textural class	Sandy loam
Bulk density (Mg m^{-3})	
0-15 cm	1.47
15-30 cm	1.52
30-45 cm	1.59
Particle density (g/cc)	2.65
Total porosity (%)	
0-15 cm	44.53
15-30 cm	42.64
30-45 cm	40.00
Hydraulic conductivity (cm hr^{-1})	
0-15 cm	0.76
15-30 cm	0.56
Basic infiltration rate (cm hr^{-1})	0.71
Water holding capacity (%)	33.84
Moisture retention (%)	
Field capacity	18.2
Permanent wilting point	8.9
Chemical	
pH	7.40
EC2 (dS m^{-1})	0.31
Organic carbon (%)	0.37
Available N (kg ha^{-1})	250.20
Available P_2O_5 (kg ha^{-1})	34.35
Available K_2O (kg ha^{-1})	482.40

surface (15-30 cm) layers of soil, respectively.

Decrease in bulk density and increase in soil porosity to a greater degree, as a consequence of disk ploughing (deep tillage), is attributed to the change brought in pore geometry. Bhusan *et al.* (1973) have also reported that deep ploughing results into more stirring (loosening and mixing) of soil decreasing the large size aggregates (2 to 5 mm), but improved the granulation of smaller aggregates (1 to 0.1 mm) (Batra *et al.*, 1972) and thereby increased the total pore spacing of the soil, and consequently decreased the bulk density in both surface and sub-surface soil layers, as a consequence of enhanced and proliferated root growth (Nitant and Singh, 1995). The extent of decrease in bulk density due to application of FYM and phosphorus treatment were, 5.52 and 3.47, and 4.57 and 0.67% in both surface and sub-surface layers, respectively.

Water holding capacity: All tillage operations, except conventional tillage, significantly increased the water holding capacity of soil over the treatment receiving zero tillage. Among the different tillage treatments, disk ploughing was found to be the best, where the value recorded was 37.89% as against 34.47% and 35.34% recorded under zero and conventional tillage, respectively. Further, incorporation of FYM increased the WHC (36.78%) of soil over no FYM treatment (34.89%), however, application of phosphatic fertilizers did not affect this physical parameter.

Basic infiltration rate and hydraulic conductivity of soil: Tillage treatments had significantly increased the basic infiltration of soil over that in zero tillage. The magnitude of increase, due to disc and chisel ploughing, was to the tune of 79 and 62% over zero tillage, and 52 and 38% over conventional tillage treatment, respectively. Disc ploughing was also found to be the best, where a maximum value of hydraulic

Table 2. Effect of tillage, FYM and levels of phosphorus on soil physical parameters

Treatment	Bulk density (mg m^{-3}) Soil depth (cm)		Soil porosity (%) Soil depth (cm)		Maximum water holding capacity (%)	Basic infiltration rate (mm hr^{-1})	Hydraulic conductivity (cm hr^{-1}) Soil depth (cm)	
	0-15	15-30	0-15	15-30			0-15	15-30
Initial values	1.47	1.52	44.53	42.64	33.84	7.10	0.76	0.56
Tillage								
Conventional	1.43	1.50	46.15	43.35	35.33	9.90	1.30	1.06
Disk	1.37	1.46	48.17	45.00	37.89	15.10	1.92	1.18
Chisel	1.40	1.49	47.25	43.58	36.02	13.69	1.64	1.57
Minimum	1.41	1.50	46.92	43.52	35.47	9.09	1.51	1.29
Zero	1.46	1.52	44.98	42.47	34.47	8.44	1.07	0.87
S.Em±	0.003	0.005	0.121	0.177	0.313	0.004	0.011	0.008
CD at 5%	0.010	0.014	0.372	0.546	0.963	0.012	0.035	0.027
FYM (t ha^{-1})								
F_0	1.45	1.53	45.29	42.16	34.89	9.29	1.43	1.26
F_{10}	1.37	1.46	48.09	45.01	36.78	13.20	1.54	1.38
S.Em±	0.004	0.003	0.111	0.101	0.302	0.007	0.006	0.008
CD at 5%	0.008	0.008	0.312	0.285	0.850	0.020	0.018	0.021
Phosphorus (P_2O_5 kg ha^{-1})								
P_0	1.44	1.50	45.81	43.22	35.45	11.17	1.40	1.23
P_{30}	1.42	1.49	46.57	43.72	36.14	11.25	1.50	1.35
P_{60}	1.39	1.49	47.69	43.82	35.91	11.32	1.56	1.38
S.Em±	0.004	0.003	0.136	0.124	0.369	0.009	0.009	0.009
CD at 5%	0.010	0.009	0.382	0.349	NS	0.025	0.022	0.026

conductivity, 1.92 cm hr^{-1} was recorded as against 1.30 and 1.07 cm hr^{-1} for the treatment receiving conventional and zero tillage. Like tillage treatment, FYM and phosphate fertilization had also significantly increased the basic infiltration rate and hydraulic conductivity of the soil under study. The magnitude of increase in basic infiltration rate was 42.1% due to FYM treatment. Pelegrin *et al.* (1988 and 1990) have also reported that the difference in infiltration rate by disc ploughing, chisel ploughing and other tillage implements could be caused by a different structure pattern with a different pore system being created by them due to influence of plough pan. An improvement in basic infiltration rate and hydraulic conductivity of the soil due to disc, and chiesel ploughing over zero tillage is attributed to a significant change in the soil pore geometry and enhanced root growth in the surface soil layer, which is also evident by decreased bulk density and increased porosity under these treatments (Subramanian *et al.*, 1975; Jorge *et al.*, 1984).

Table 3. Effect of tillage, FYM and levels of phosphorus on per cent soil moisture content (volume basis)

Treatment	At sowing Depth (cm)						At harvest Depth (cm)					
	0-15		15-30		30-45		0-15		15-30		30-45	
	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990
Tillage												
Convent.	18.43	19.30	20.49	25.22	16.20	28.48	10.11	16.46	12.84	19.01	17.39	21.71
Disc	18.92	20.39	21.20	26.40	16.58	29.57	11.58	18.82	14.12	20.37	18.20	23.05
Chisel	18.62	19.20	21.01	26.11	16.30	29.73	10.80	18.39	13.45	20.14	18.89	22.86
Minimum	18.51	18.92	21.23	25.70	16.19	28.59	10.44	18.01	12.34	19.94	16.62	21.94
Zero	18.15	18.20	20.46	23.48	15.79	26.14	9.48	16.29	10.70	17.94	15.71	20.83
S.Em±	0.107	0.082	0.084	0.084	0.067	0.183	0.068	0.165	0.070	0.143	0.234	0.159
C.D. 5%	0.331	0.253	0.257	0.257	0.205	0.564	0.209	0.507	0.216	0.438	0.719	0.488
FYM (t ha^{-1})												
F_0	18.14	18.54	20.43	24.68	15.90	27.78	9.70	16.80	11.75	18.81	16.63	21.35
F_{10}	18.90	19.86	21.32	26.08	16.52	29.22	11.26	18.39	13.63	20.15	18.09	22.80
S.Em±	0.060	0.073	0.059	0.076	0.048	0.165	0.076	0.137	0.076	0.160	0.124	0.172
C.D. 5%	0.228	0.207	0.167	0.214	0.133	0.466	0.215	0.387	0.214	0.451	0.348	0.485
Phosphorus levels (kg P ha^{-1})												
P_0	18.48	18.61	20.82	24.76	16.23	27.86	10.16	17.27	12.26	18.89	16.70	21.43
P_{13}	18.55	19.17	20.90	25.35	16.16	28.46	10.51	17.65	12.73	19.39	17.34	22.05
P_{28}	18.54	19.81	20.90	26.04	16.25	29.19	10.78	17.86	13.08	20.16	18.04	22.76
S.Em±	0.073	0.090	0.073	0.093	0.081	0.202	0.093	0.167	0.009	0.196	0.151	0.211
C.D. 5%	NS	0.253	NS	0.263	NS	0.569	0.263	0.473	0.263	0.552	0.428	0.595

Soil moisture: Various tillage treatments, as compared to zero tillage, recorded significantly higher moisture content in all the three soil layers examined during both the years of investigation (Table 2). The soil profile moisture as a whole, at sowing and after harvest of the crop, was higher in the disc and chisel ploughing treatments. Likewise, an increase in the soil moisture content was also evident as a consequence of FYM during both the years and phosphate fertilization in the second year of experimentation. An improvement in soil physical parameters, in turn, resulted in an increased soil moisture content in different soil layer of the profile, has also been reported by Heilman *et al.* (1991).

Chemical parameters: Different tillage treatments, though did not influence the pH, electrical conductivity and available K status of the soil, but have significantly altered the organic carbon and available P status of the soil (Table 3). Significantly highest values of organic carbon was observed in plot receiving zero tillage (0.42%), while the soil available phosphorus was the highest (47.74 kg P_2O_5 ha^{-1}) from the plot receiving disc ploughing treatment. Incorporation of FYM and P-fertilization have also significantly improved the organic carbon, and available P_2O_5 and K_2O status of the soil. An improvement in the level of available P in the soil under deep tillage has also been reported by Gaikwad and Khuspe (1976). The favorable effect of deep tillage, FYM and phosphate fertilization in improving these soil parameters, is an outcome of increased proliferation of roots and microbial activity, which in turn have released the organic acids lowering down the pH of the soil (Maurya and Gosh, 1972) and releasing the native phosphorus and potassium from the soil, apart from reduction in fixation of applied phosphorus (Khaini and More, 1984). Higher value of organic carbon in the plot receiving zero tillage is attributed to lesser degree of decomposition of organic matter in the soil (Carter *et al.*,1988). Wruke and Arnold (1985) have also reported that direct drilling of seed caused changes in soil macro aggregates, reduced the evaporation rate and increased the microbial biomass, C and N, total organic carbon and N and extractable ions, at the surface when compared with the treatment receiving deep tillage.

The results indicated that deep tillage treatments (Disc and Chisel ploughing) were superior to shallow tillage treatments (conventional tillage, minimum tillage and zero tillage) in improving the physical conditions of the soil along with chemical parameters and greater profile water storage, which in turn resulted in deeper rooting system for efficient use of water from lower soil depth during dry spell and better supply of nutrients to crop. Thus, deep tillage is especially desirable for enhancing downward movement of water in the profile for higher crop yields under dryland condition.

References

Aggarwal, R.K. and Kumar, P. 1996. Integrated use of farmyard manure and fertilizer N for sustained yield of pearl millet (*Pennisetum glaucum*) in an arid region. *Annals of Arid Zone* 35: 29-35.

Arnold, K. 1986. *Methods of Soil Analysis*. Agronomy Monograph 9 (Part 1). ASA-SSSA, Madison, Wisconsin, USA.

Batra, M.L., Jagan Nath and Agarwal, R.P. 1972. Soil physical properties and crop yield as influenced by tillage practices. *Indian Journal of Agriculture Research* 6: 205-208.

Bhusan, L.S., Varade, S.B. and Gupta, C.P. 1973. Influence of tillage practices on clod size, porosity and water retention. *Indian Journal of Agriculture Science* 43: 466-471.

Carter, L.S., Johnson, H.W. and Kimpinski, J. 1988. Direct drilling and soil loosening for spring cereals on a fine sandy loam in Atlankik, Canada. *Soil Tillage Research* 5(1): 5-17.

Gaikwad, C.B. and Khuspe, V.S. 1976. Long term effect of tillage and manuring on some physical and chemical properties in black soils under rainfed cropping. *Journal of Maharashtra Agricultural University* 1: 145-147.

Gupta, J.P. and Aggarwal, R.K. 1992. Integrated resource management for sustained crop production in arid region. *Proceedings of the National Seminar on Natural Farming*, pp. 59-67. Udaipur.

Heilman, M.D., Hickman, M.V. and M.J. Taylor, 1991. A comparison of wingchisel tillage with conventional tillage on crop yield, resource conservation and economics. *Journal of Soil and Water Conservation* 46: 78-80.

Jorge, J.A., Libardi, P.L., Foloni, L.L., Almeida, J.O.C., Reichardt,K. and Gamero, C.A. 1984. Effect of subsoiling and disking on soil and hydraulic conductivity. Ravista. *Brasileira-de-Ciencia-de-Solo* 8: 1-6.

Khaini, K.N. and More, D.A. 1984. Long term effect of tillage operations and farmyard manure applications in soil properties and crop yield in vertisol. *Journal of Indian Society of Soil Science* 32: 392-393.

Lal, R. 1989. Conservation tillage for sustainable agriculture: Tropic versus temperate environments. *Advances in Agronomy* 42: 86-197.

Maurya, P.R. and Gosh, A.B. 1972. Effect of long term manuring and rotational cropping on fertility status of alluvial calcareous soil. *Journal of Indian Society for Soil Science* 20: 31-43.

Nitant, H.C. and Singh, P. 1995. Effects of deep tillage on dryland production of redgram (*Cajanus cajan* L.) in central India. *Soil Tillage Research* 34: 17-26.

Pelegrin, F., Campus, M., Moreno, F. and Loper, J. 1988. Respuesta de diferentia sistemas de laboreode infiltracion de ague enel suelo, apical de mediante simuladoved Iluvia. *Proceeding of 20th International Conference on Agricultural Mechanization*, Zaragoza 1:101-109.

Pelegrin, F., Moreno, F., Martin-Arauda, J. and Camps, M. 1990. The influence of tillage method on soil physical properties and water balance for a typical crop rotation in SW Spain. *Soil Tillage Research* 16: 345-358.

Piper, C.S. 1950. *Soil and Plant Analysis*. University of Adelaide, Adelaide, Australia.

Singh, R.A. 1980. *Soil Physical Analysis*. Kalyani Publisher, Ludhiana.

Subramanian, S., Loghanathan, S., Ravi Kumar, V. and Krishnamoorthy, K.K. 1975. Effect of tillage and organic amendments on the physical properties of soil and yield of bajra. *Madras Agriculture Journal* 29: 106-109.

Tisdale, S.L., Melson, W.L., Beaton, J.D. and Havlin, J.L. 1993. *Soil Fertility and Fertilizers*. Printice Hall of India Pvt. Ltd., New Delhi.

Wruke, M.A. and Arnold, W.E. 1985. The effect of three tillage systems on soil properties and corn and soybean growth. *Proceedings of South Dakota Academy Science* 64: 197-207.