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Effect of tillage and soil amendments on soil quality and yield of clusterbean (*Cyamopsis tetragonoloba*) in shallow hardpan soils of arid Gujarat

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The arid zone of India covers about 12% of the country's geographical area and occupies over 31.7 m ha of hot desert and about 7 m ha under cold desert. In Gujarat, 6.22 m ha area is under arid zone. Kachchhis the largest district (45652 sq km) in the state of Gujarat and the entire region is under arid zone(Shamsudheen *et al.* 2009). Soil related constraints like low organic matter status, inherently low soil fertility in terms of macro and micro nutrients, crusting, and the presence of hard pan at variable depth or shallow soil depths, pose severe limitation to crop production in this region. The compact subsurface especially with shallow soils does not allow proper development of root systems in several crops and leads to decline in the yield (Dayal *et al.* 2009, Kar *et al.* 2009). Tillage is an age old practice to prepare the seed bed during cultivation. Deep tilling the sandy soils once in every 3-4 years is a common practice among farmers in arid region of India as a measure to reduce clod formation at the surface (Faroda 1998). Papendic and Parr (1997) recommended reduced tillage in the sandy soils of arid regions due to the risks of hard pan development and loss of soil structure consequent to tillage. In soils with inherent hard pan at shallow depths, root penetration and water movement down through the soil profile is a problem. In such situations a deep tillage may be beneficial once in few years. Therefore, the present investigation was carried out to find out the management options for improving soil productivity and quality in shallow hard pan soils in arid Gujarat.

A field experiment was carried out at the research farm of Central Arid Zone Research Institute, Regional Research Station, Kukma, Bhuj, Gujarat during rainy (*kharif*) season of 2009. The climate of the region is arid with average rainfall of 315 mm (average of last 15 years). A total of 496 mm rainfall was received in 11 rainy days during the cropping period of current experiment. The soil at the experimental site was sandy loam with average clay content of 16.3%, silt 7.5% and sand 76.2%. The soil is alkaline in reaction (pH 8.3), non-saline (EC 0.3 dS/m), low in organic carbon (0.43 %), available N (100.4 kg/ha) and P (6.0 kg/ha) and medium in K (145 kg/ha). Average bulk density of soil was 1.45 Mg/m^3.The land selected for experiment was under perennial grasses for the preceding 15 years. The field experiment was laid out with four tillage practices (Deep: tillage to 0.25 to 0.30 m depth with a tractor drawn mould board plough, followed by one pass of cultivator and levelling by harrow, Shallow: tillage to 0.12-0.15 m depth by tractor drawn cultivator passing twice followed by levelling with harrow, Minimum: by one time surface passing of cultivator and Control: with direct seeding) as the main treatments and were split into four soil amendments (gypsum at 5 Mg/ha, farmyard manure (FYM) at 5 Mg/ha and both gypsum and FYM at 5 Mg/ha each and control) as sub treatments. The experiment was laid out in a split plot design with three replications. The average N, P and K contents in FYM used in the experiment was 0.54, 0.21 and 0.72% respectively and the calcium content of gypsum used in the experiment was 12.2% with 1.2% magnesium. Clusterbean (*Cyamopsis tetragonoloba* L. Taub) cv *Maru guar* was sown on 18 July 2009. All the agronomic practices were followed as recommended for the region. The total rainfall received during the crop periods was 432.2 mm in 6 rainy days. The crop was harvested on 24 October 2009. Grain yield, straw yield and yield attributes were recorded at harvest. Soil samples were collected from two depths 0-0.15 and 0.15-0.30 m after harvest of the crop. Bulk density was measured from 0-0.15 and 0.15-0.30 m depths on undisturbed soil cores after the crop harvest. The soil organic carbon stock was computed as per standard methods (Batjes 1996). The activity of various enzymes, viz. acid phosphatase and alkaline phosphatase in soils were assayed by the methods proposed by (Tabatabai 1982). The statistical software package Genstat (v. 14) was used for data analysis. The economic indicators were calculated based on the

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existing price of the inputs and outputs.

Tillage practices significantly (P <0.05) influenced the plant height of clusterbean and the highest plant height was recorded under deep tillage (46.3 cm) and lowest under no-tillage (35.4 cm). The yield attributing characteristics such as no. of pods/plant, no. of grains/pod and 1000 grain weight were also significantly influenced by the tillage practices with maximum values under deep tillage followed by shallow tillage and least in no-tillage treatments (Table 1).

Tillage practices significantly influenced the grain and straw yields of clusterbean. The deep tillage increased the grain yield by 63 % over control (123 kg/ha), 36.2 % over minimum tillage and 15.6 % over shallow tillage.The trend in straw yield was also similar to that of grain yield in all the tillage treatments. The increase in straw yield under deep tillage over control, minimum tillage and shallow tillage was 38.1, 28.7 and 16.9%, respectively. The higher grain and straw yields in deep tillage as compared to other tillage practices could be attributed to better soil physical environment provided by the deep tillage in this previously untilled grassland. Introduction of tillage might have helped improving the root penetration in this soil underlined by hard pan apart from improving physical and hydrological properties. Although no-till farming was suggested as the best management of the soil in arid ecosystem by some workers (Papendic and Parr 1997) some other group of workers reported a limited tillage after the first monsoon showers as ideal in the desert regions (Gupta *et al.* 1997). Machado *et al.* (2007) reported a yield reduction of 21 and 15% in wheat and barley respectively over six years, in zero tilled soils compared with conventionally tilled soils. Reduced cereal yields under short term conservation tillage practices were also reported by Kankanen *et al.* (2011). The yield levels of clusterbean obtained in this experiment was in general low, which is attributed to erratic and low rainfall pattern during the growing season and shallow soil conditions.

Application of amendments such as gypsum and FYM caused significant effect on height of the plants, 1000 grain weight, straw and grain yields. Application of gypsum along with farm yard manure (at 5 tonnes/ha each) resulted in significantly higher grain yield of 277 kg/ha over the application of FYM (258 kg/ha) and gypsum (219 kg/ha) alone and control (199 kg/ha). Combined application of gypsum and FYM resulted in an increase of 21.1% in straw yield over control, 10.1% increase in straw yield over application of gypsum at 5 tonnes/ha and 5.3% over application of FYM. The increased yields with application of gypsum and FYM were attributed to improved soil properties and water and nutrient availability which were also reported for sesame-clusterbean intercropping in the same region by Meena *et al.* (2009). The effects of soil

Table 1 Effect of tillage and soil amendments on growth, yield attributes, yields and economic benefits of clusterbean

Treatment	Plant height (cm)	No. of pods/plant	No. of grains/pod	1000 grain weight	Grain yield (kg/ha)	Straw yield (kg/ha)	Net returns (₹/ha)	B:C ratio
No-tillage								
No-amendment	34	5.6	6.7	24.65	96.85	447.04	–661	0.88
Gypsum @ 5 Mg/ha	35	6.1	6.7	28.05	97.50	508.35	–1 214	0.80
FYM @ 5 Mg/ha	36	6.3	7.2	28.1	133.22	514.45	–415	0.93
Gypsum + FYM @ 5 Mg/ha	37	6.6	6.9	29.82	166.08	581.81	–132	0.98
Minimum tillage								
No-amendment	36	6.4	7.1	29.16	210.59	520.82	2 900	1.58
Gypsum @ 5 Mg/ha	42	6.8	7.2	30.47	209.74	586.78	2 334	1.40
FYM @ 5 Mg/ha	38	7.2	7.5	29.95	212.93	606.92	2 389	1.40
Gypsum + FYM @ 5 Mg/ha	42	8.8	7.1	29.80	218.67	647.59	1 861	1.27
Shallow tillage								
No-amendment	34	8.4	7.1	28.40	218.07	521.99	2 593	1.48
Gypsum @ 5 Mg/ha	43	10.7	7.6	29.94	235.12	650.59	2 788	1.44
FYM @ 5 Mg/ha	39	11.2	7.0	30.52	345.41	793.60	6 135	1.93
Gypsum + FYM @ 5 Mg/ha	43	12.1	7.5	30.66	328.01	790.72	4 810	1.66
Deep tillage								
No-amendment	39	10.3	7.4	29.59	270.39	787.03	10 695	1.87
Gypsum @ 5 Mg/ha	48	10.4	7.6	29.85	331.78	845.24	12 521	1.90
FYM @ 5 Mg/ha	49	12.7	8.2	30.72	338.68	817.51	12 555	1.87
Gypsum + FYM @ 5 Mg/ha	48	17.4	8.1	30.84	394.78	865.83	14 199	1.87
F Tillage	4.65**	5.61**	8.92***	4.10*	28.59***	16.59***	133.25***	26.34***
Amendments	2.52*	NS	NS	3.02*	4.37*	3.76*	NS	NS
Tillage × amendments	NS	NS	NS	NS	NS	NS	NS	NS

$^*P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$

amendments on other properties such as number of pods/ plant, number of grains/pod and net returns were not significant. The interaction of tillage and amendments were also not significant (Table 1).

The tillage practices significantly altered the soil organic carbon stock. At harvest the soil organic carbon stock in the surface layers (0 to 15 cm) were higher by 37.3% in control plots, 34.5% in minimum tillage and 24.5% in shallow tillage compared to the deep tillage practices. The same trend was observed in sub surface layers also. It was earlier reported that single mould board ploughing of long-term no-tillage fields can potentially alter the previous carbon gain (Kettler *et al.* 2000, Yang *et al.* 2008). The effect of various soil amendments on soil organic carbon stock was non-significant. The increased organic carbon stock under no-tillage plots were mainly attributable to the increased organic carbon content and bulk density of the soil.

The tillage practices significantly lowered the enzyme activities in soil. The activity of alkaline phosphatase at the surface (0 to 15 cm) was greater by 48.7%, in control plots compared to deep tillage and by 40.8%, compared to shallow tillage. The surface layers exhibited higher enzymatic activity in all the tillage treatments except deep tillage. Tillage influenced the acid phosphatase activities in soil also (Table 2) with reduced enzyme activities under various levels of soil tillage. Application of amendments improved the soil enzymes, but the effect was statistically not significant.

The economic analysis of the adoption of tillage and amendments showed that significantly improved net returns were attainable with deep tillage over all other tillage types (Table 2). Net returns was negative in case of no-tillage indicating that adoption of no-tillage in hard pan soils are not economical especially in the initial year of conversion. However there is a need to test the effect of no-tillage and residue retention in such soil over the years as it is reported that the economic yield could be realised under no-tillage when the system stabilise sustainability. The effect of adoption of periodic tillage (deep tillage once after many years of no-tillage) may also need to be explored to take advantage of no-tillage on improvement in soil quality and at the same time to enhance the crop yield by breaking the hard pan. The effect of amendments on net returns was statistically not significant.

SUMMARY

A field experiment was conducted at CAZRI, Regional Research Station, Kukma-Bhuj during *kharif* 2009 to find out the management options for improving soil productivity and quality in shallow hard pan soils in arid Gujarat. There

Table 2 Effect of tillage and soil amendments on soil organic carbon stock (OCS), acid and alkaline phosphatase (Acid-P and Alk-P) in surface (0-15 cm) and subsurface soils (15-30 cm)

Treatment	OCS-surface (Mg/ha)	OCS-Sub surface (Mg/ha)	Acid–P: surface (mg PNP/kg/h)	Acid-P: subsurface (mg PNP/kg/h)	Alk-P: surface (mg PNP/ kg/h)	Alk-P surface (mg PNP/kg/h)
No-tillage						
No-amendment	11.09	11.45	17.52	16.80	28.43	25.62
Gypsum @ 5 Mg/ha	11.02	11.20	16.30	15.50	30.28	26.40
FYM @ 5 Mg/ha	10.74	11.11	16.51	16.04	31.72	28.11
Gypsum + FYM @ 5 Mg/ha	10.64	11.16	17.89	15.20	33.38	2641
Minimum tillage						
No-amendment	10.55	10.87	17.12	15.62	21.37	18.75
Gypsum @ 5 Mg/ha	10.32	10.40	17.00	15.17	22.19	19.40
FYM @ 5 Mg/ha	10.40	10.52	16.82	14.13	22.88	20.00
Gypsum + FYM @ 5 Mg/ha	10.35	10.60	17.54	15.31	24.56	21.79
Shallow tillage						
No-amendment	8.92	9.43	15.11	13.14	17.73	16.57
Gypsum @ 5 Mg/ha	8.79	9.04	15.57	13.06	17.42	15.93
FYM @ 5 Mg/ha	8.91	8.75	16.01	14.27	18.80	16.89
Gypsum + FYM @ 5 Mg/ha	9.50	8.85	16.41	14.83	19.35	18.47
Deep tillage						
No-amendment	6.87	6.69	15.78	11.61	14.58	17.52
Gypsum @ 5 Mg/ha	6.88	7.08	15.20	12.12	15.54	15.23
FYM @ 5 Mg/ha	6.81	7.35	15.43	13.55	15.81	17.24
Gypsum + FYM @ 5 Mg/ha	6.70	7.17	15.51	13.29	17.63	17.59
F Tillage	39.27***	32.00***	15.70***	34.80***	43.95***	51.36***
Amendments	NS	NS	NS	NS	NS	NS
Tillage × amendments	NS	NS	NS	3.07**	NS	NS

*P<0.05, ** P<0.01, *** P<0.001

were four tillage treatments, viz no-tillage, minimum tillage, shallow tillage and deep tillage in main plots and four amendments (gypsum at 5 Mg/ha, farmyard manure (FYM) at 5 Mg/ha and both gypsum and FYM at 5 Mg/ha each and control) in sub plots. The results of the experiment showed that deep tillage along with the application of gypsum and FYM at 5 Mg/ha produced maximum yield and maximum net returns. The study found a decreased yield and negative net returns under no-tillage in these shallow hard pan soils. However soil biological and physical properties were better under no-tillage. Long term studies may be necessary to find out the applicability of no-tillage in these soils from a yield perspective.

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