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RESEARCH ARTICLE

EFFECTS OF SUBSOILING ON SUGARCANE PRODUCTIVITY AND SOIL PROPERTIES

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Abstract

Field experiments were conducted during 2008-2011 at Punjab Agricultural University Regional Station, Faridkot (30^0 40'N and 74^0 44'E), Punjab, India, to study the effect of subsoiling on sugarcane productivity and soil properties. The treatments comprised two preparatory tillage (4 harrowing and 2 harrowing) and five subsoiling treatments (no subsoiling, subsoiling at 1.0 m distance, subsoiling at 1.5 m, cross subsoiling at 1.0 m x 1.0 m and cross subsoiling at 1.5 m x 1.5 m). Sugarcane variety CoJ 88 was planted in furrows at 75 cm row spacing. Recommended agronomic and plant protection practices were followed for all the treatments. There was no significant effect of preparatory tillage on yield and quality of sugarcane. Subsoiling treatments influenced sugarcane yield and quality during all the years. The highest cane yields of 68.7, 67.4 and 81.8 t/ha during 2008-09, 2009-10 and 2010-11 respectively were recorded under cross subsoiling at 1.0 m x 1.0 m which was significantly higher than no subsoiling. The average yield enhancement in subsoiling at 1.0 m x 1.0 m was 19.4% over that in control. Subsoiling also reduced the bulk density and increased the infiltration rate of soil.

Key words : *Sugarcane, subsoiling, productivity, soil bulk density, infiltration rate*

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Introduction

Sugarcane is an important agro-industrial crop of India cultivated in 4.2 M ha with an annual production of 277.8 Mt in 2009-10 (Anonymous 2011). It has also been estimated that by 2025 AD, sugar production should increase to a level of 37 Mt which cannot be achieved by area expansion alone because of enormous pressure to grow cereals and other crops for food security of the country (Thakur 2012). For obtaining these targets, development of improved technologies holds the key. However, soil management technologies especially subsoil has not received much attention. Soil compaction below tillage depths (>20-25 cm) is of greater concern than the surface compaction because it is a difficult problem to solve (Thakur 2012). Subsoil compaction can cause serious root restriction (Tardieu 1994; Westermann and Sojka 1996) and the loss of both transmission and water storage pores. Naseri et al. (2007) indicated that the soils susceptible to compaction and harvesting traffic make them compacted. The maximum compaction occurred in the first layer (0-20 cm depth) and minimum or no compaction happened in the layer beyond 60 cm depth. Subsoiling is a process by which the hard pan layer or compacted layer of the soil is broken without turning over the infertile subsoil to the top. This process is usually done with a tractor drawn subsoiler to a depth of at least 50 cm. Subsoiling breaks the hard pan layer of the soil, facilitates downward movement of water, enhances drainage and thereby induces deep penetration of the roots. In many sugarcane growing countries of the world, deep tillage (achieved by ploughing, subsoiling or chiseling) is believed to be necessary to produce high crop yields (Yang and Quintero 1995). The subsoilers, which are generally attached to the planting unit, fracture the tillage pan directly under the row and permit root growth into the subsoil area. In untilled soils, they also fracture and loosen a 6-12 inch strip of surface soil. Whiteley and Dexter (1982) suggested the possibility that positive yield responses to in-row subsoilers are due as much from fracturing the surface soil as from fracturing the tillage pan. According to Reeder et al. (1993) controlled traffic is essential to obtain long term benefits from subsoiling. Annual subsoiling was found effective in reducing bulk density by 4.9% compared with no-till treatments on the silty loam soils (Jin et al. 2007). Subsoiling operation can increase soil porosity and decrease the compacted soil bulk density by up to 3-4% (Soltanabadi et al. 2008; Solhjou and Niazi Ardekani 2001). Infiltration rate in subsoiled land is significantly higher than that of unsubsoiled land (Soltanabadi et al. 2008). In India, not much work on subsoiling of sugarcane soils was done. The present study was an attempt to study the effect of different subsoiling treatments on sugarcane yield and quality and soil properties.

Materials and methods

Field experiments were conducted during 2008-09, 2009-10 and 2010-11 at Punjab Agricultural University, Regional Station, Faridkot, (30^0 40'N and 74^0 44'E) Punjab, India, which typically represents Zone IV (South-Western Zone) of Punjab situated at 200 m above MSL. The soil of the experimental field was sandy loam in texture with pH (8.2, 8.3 and 8.0) and electrical conductivity (0.55, 0.34 and 0.25 dS/m) in the normal range, low in organic carbon (0.43, 0.39 and 0.40%), low in available phosphorus (6.5, 5.5 and 6.8 kg/ha) and high in available potassium (372, 520 and 690 kg/ha) during the three experimental years, respectively. The minimum temperature ranged 3.8 - 30.1, 7.8 - 28.3 and 6.0 - 29.3^{o}C; the mean temperature ranged 18.3 - 28.1, 19.4 - 30.4 and 19.7 - 29.8^{o}C; the mean RH ranged 51.3 - 78.2, 45.1 - 72.6 and 46.2 - 76.1%; total rainfall of 561.1, 475.5 and 432.8 mm during 2008-09 and 2009-10 and 2010-11 crop seasons, respectively.

A mid-maturing sugarcane variety (CoJ 88) was planted on February 02, 2008, March 25, 2009 and March 08, 2010 using 8 t/ha seed for the experiments conducted in strip plot design with three replications. The treatments comprised different combinations of two preparatory tillage practices, i.e. 4 harrowing and 2 harrowing and five subsoiling treatments (S1 to S5), namely no subsoiling (S1), subsoiling at 1.0 m distance (S2), subsoiling at 1.5 m distance (S3), cross subsoiling at 1.0 m x 1.0 m (S4) and cross subsoiling at 1.5 m x 1.5 m (S5). After implementing the subsoiling treatments, sugarcane was planted in

Table 1. Effect of subsoiling on growth parameters of sugarcane

Treatment	Germination (%)			Tillers (000/ha)			NMC (000/ha)			Single cane wt. (g)		
	2008-09	2009-10	2010-11	2008-09	2009-10	2010-11	2008-09	2009-10	2010-11	2008-09	2009-10	2010-11
Preparatory tillage												
4H	32.7	33.8	33.6	136.4	138.8	191.6	94.1	90.0	92.3	841	1046	786
2H	34.3	32.9	35.3	132.3	138.5	196.8	91.6	92.9	94.2	806	1075	887
LSD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Subsoiling												
S1	32.5	31.9	34.7	123.1	129.3	172.3	87.1	82.0	82.8	815	914	658
S2	34.4	33.5	35.3	140.3	139.6	201.8	95.6	93.2	96.4	835	1114	815
S3	32.8	34.8	32.6	130.6	137.1	197.3	93.5	90.4	94.5	808	1024	805
S4	34.5	34.8	35.5	144.8	146.3	201.0	95.8	97.4	95.3	821	1152	820
S5	33.6	32.1	34.4	132.9	141.2	198.6	92.4	94.3	97.2	838	1096	833
LSD (5%)	NS	NS	NS	13.4	7.5	18.2	5.5	NS	8.6	NS	136	65

4H = 4 harrowing, 2H = 2 harrowing
S_1 = No subsoiling, S_2= Subsoiling at 1.0 m, S_3= Subsoiling at 1.5 m, S_4= Cross subsoiling at 1.0 m
S_5 = Cross subsoiling at 1.5 m

furrows at 75 cm spacing between rows. Lindane 20 EC @ 5 litre/ha was applied after placing the setts which were then covered with light planking. Nitrogen was applied at 150 kg/ha in two equal splits, i.e. half dose at first irrigation and the remaining half in the month of May. Observations of germination, number of shoots and millable canes (NMC), single cane weight, cane yield and juice quality were recorded. Commercial cane sugar per cent (CCS) was calculated by using the formula of Sastry and Chari (1960). Per cent CCS was multiplied with cane yield to get sugar yield. Infiltration rate was measured *in situ* using double ring infiltrometer in the field (Bouwer 1986) and bulk density of the soil was measured using core method (Black and Hartage, 1986).

Results and discussion

The results of the experiments (Table 1) indicated that preparatory tillage did not significantly influence the growth of sugarcane. However, number of tillers, millable canes and single cane weight of sugarcane exhibited significant differences among various subsoiling methods (Table 1). Increased cane weight and number of millable canes with subsoiling as compared to conventional ploughing was also reported by Mandal and Thakur (2010). The highest number of tillers was recorded with cross subsoiling at 1.0 m (S4), which was significantly higher than no subsoiling (S1) and was at par with all other subsoiling treatments. This increase in tillers over no subsoiling was 17.6, 13.1and 16.6 %, respectively during 2008-09, 2009-10 and 2010-11 years of study. Lower bulk density (Fig. 1) and better aeration below soil in S4 treatment was responsible for root development, thereby producing higher number of tillers. Similarly, significantly higher number of millable canes and single cane weight were recorded in S4 treatment than in S1.

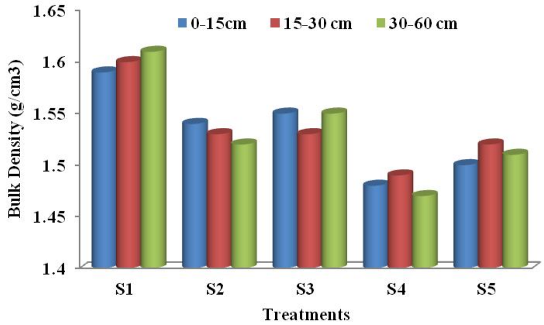

Fig. 1. Effect of subsoiling treatments on bulk density

There was no significant effect of preparatory tillage on yield and quality of sugarcane (Table 2 & 3) whereas these parameters were significantly

Table 2. Effect of subsoiling on cane and sugar yield

Treatment	Cane yield (t/ha) 2008-09	Cane yield (t/ha) 2009-10	Cane yield (t/ha) 2010-11	Pooled Mean	CCS (t/ha) 2008-09	CCS (t/ha) 2009-10	CCS (t/ha) 2010-11	Pooled Mean
Preparatory tillage								
4H	65.9	79.2	61.6	67.9	8.25	10.34	7.88	8.70
2H	64.5	76.0	58.7	67.3	8.14	10.11	7.51	8.71
LSD (5%)	NS	NS	NS		NS	NS	NS	
Subsoiling								
S1	61.6	69.2	51.7	60.8 (0.0)*	7.69	9.21	6.43	7.77 (0.0)*
S2	66.2	79.9	58.2	68.1 (12.0)	8.34	10.56	7.43	8.77 (12.8)
S3	63.9	77.8	59.8	67.1 (10.3)	8.08	10.12	7.45	8.55 (10.0)
S4	68.7	81.8	67.4	72.6 (19.4)	8.63	10.83	8.65	9.37 (20.5)
S5	65.7	79.2	63.6	69.5 (14.3)	8.24	10.40	8.63	9.09 (16.9)
LSD (5%)	3.5	8.1	9.6	3.7	0.4	0.82	1.36	0.49

* Values in parentheses are percentage increase in cane and sugar yield over S1
4H = 4 harrowing, 2H = 2 harrowing
S_1 = No subsoiling, S_2= Subsoiling at 1.0 m, S_3= Subsoiling at 1.5 m,
S_4= Cross subsoiling at 1.0 m, S_5 = Cross subsoiling at 1.5 m

Table 3. Effect of subsoiling on sugarcane quality parameters

Treatment	Sucrose (%)			CCS (%)		
	2008-09	2009-10	2010-11	2008-09	2009-10	2010-11
Preparatory tillage						
4H	17.75	18.98	18.36	12.51	13.07	12.79
2H	17.95	18.08	18.08	12.62	13.30	12.60
LSD (5%)	NS	NS	NS	NS	NS	NS
Subsoiling						
S1	17.74	19.01	17.88	12.48	13.28	12.45
S2	17.97	18.83	18.35	12.61	13.20	12.78
S3	17.91	18.67	17.97	12.64	13.04	12.51
S4	17.86	18.93	18.43	12.57	13.22	12.85
S5	17.77	18.74	18.50	12.53	13.17	12.90
LSD (5%)	NS	NS	NS	NS	NS	NS

4H = 4 harrowing, 2H = 2 harrowing, S_1 = No subsoiling, S_2= Subsoiling at 1.0 m, S_3= Subsoiling at 1.5 m, S_4= Cross subsoiling at 1.0 m, S_5 = Cross subsoiling at 1.5 m

affected by subsoiling treatments in all the three experiments. The yield (68.7, 81.8 and 67.4 t/ha in 2008-09, 2009-10 and 2010-11) recorded under cross subsoiling at 1.0 m was the highest among all the subsoiling treatments while it was significantly superior to control. On the basis of pooled analysis of cane and sugar yield it can be concluded that all the subsoiling treatments were significantly better than no subsoiling. Among the subsoiling treatments, cross subsoiling performed better than subsoiling in one direction at 1.0 m and 1.5 m spacing. It was observed that the cane yield under cross subsoiling at 1.0 m was 19.4% higher than no subsoiling. Mandal and Thakur (2010) also recorded that subsoiling increased the cane yield by 15.9% compared to conventional ploughing. According to Touchton and Johnson (1982), no-tillage soybean production without in-row subsoiling reduced wheat grain yield as compared to chiseling and moldboard ploughing. The increase in sugarcane yields with deep ploughing and subsoiling was also reported by Saveson et al. (1966). Cheng (1968) found that subsoiling to a depth of 45 cm increased cane yield by 20-30% compared with shallow tillage of 30 cm. Hammad and Dawelbeit (2001) observed that 20 and 30 cm deep ploughing before disc harrowing, significantly increased cane and sugar yields. Recaud (1977) found that subsoiling resulted in 19- 40% increase in cane yield. Deep tillage also increased soybean and corn yields (Reeder et al.1993). Significant improvement in commercial cane sugar was observed with cross subsoiling at 1.0 m as compared to no subsoiling while it was on par with the rest of the subsoiling treatments.

The results given in Fig. 1 revealed that the bulk density of the soil decreased with subsoiling. The lower values of bulk density were found in cross subsoiling treatments. With increased level of subsoiling there was increase in infiltration rate of the soil (Fig. 2). This decreased bulk density and increased infiltration rate in response to subsoiling had positive effects on sugarcane root growth and biomass production.

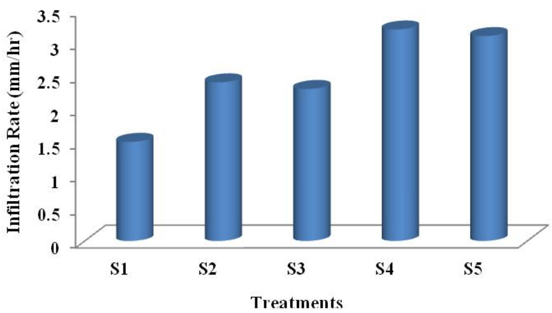

Fig. 2. Effect of subsoiling treatments on infiltration rate of the soil

From the above results it can be concluded that there is need for soil health management not only for top soil but also for subsoil to break the stagnant yield barriers of sugarcane. The results clearly indicated the positive effect of subsoiling over conventional method of land preparation. Cross subsoiling at 1.0

m x1.0 m spacing has given significantly higher yield than no subsoiling. This can be attributed to subsoil disturbance in closer spacing which resulted in lower bulk density and higher infiltration rate which ultimately produced higher root proliferation. Thus subsoiling is recommended for higher productivity and soil health improvement in sugarcane.

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