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Effect of mechanical soil management through subsoiling and preparatory tillage on growth and nutrients uptake of sugarcane (*Saccharum* complex hybrid) plant and ratoon crop

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ABSTRACT

A field experiment was conducted during 2008-2010 at G B Pant University of Agriculture and Technology, Pantnagar to study the response of sugarcane plant and ratoon crops to subsoiling and preparatory tillage. The experiment consisting of five subsoiling treatments in plant crop (No subsoiling, subsoiling at 1.0 m, subsoiling at 1.5 m, cross-subsoiling at 1.0 m and cross-subsoiling at 1.5 m distance) and three preparatory tillage practices (two harrowing, four harrowing and one rotavator) was laid out in strip plot design with three replications. The ratoon crop was managed mechanically with a newly developed Sugarcane Ratoon Manager in all the subsoiling treatments. The root and shoot growth, nutrients uptake, and yield of plant and ratoon crops increased with the intensity of subsoiling. The most intense subsoiling, i.e. cross-subsoiling at 1.0 m in plant crop resulted significantly more root biomass (70.1 g/m^3), shoot dry matter (40.9 tonnes/ha), nutrient uptake (220.9 kg N, 26.6 kg P and 307.6 kg K/ha), cane weight (883.8 g), millable canes (100.2 thousand/ha) and cane yield (75.8 tonnes/ha). Subsoiling practices coupled with mechanized management of ratoon exhibited significant improvement in root biomass (73.6 %), shoot dry matter (31.7 %), NPK uptake (29.3, 34.9 and 34.3 %, respectively), cane weight (13.6%), millable canes (21.9%) and cane yield (26.6%) over manual operations (control). All the preparatory tillage practices were at par with respect to the parameters studied, however, root biomass increased significantly with increase in number of tillage practices being maximum in four harrowing treatment.

Key words: Deep fertilizer placement, Deep tillage, Nutrient uptake, Ratoon, Subsoiling, Sugarcane

Tillage is one of the fundamental agro-technical operations in agriculture because of its influence on soil properties and crop growth. It is important to adopt appropriate tillage practices that avoid the degradation of soil structure, maintain crop yield as well as ecosystem stability. Sugarcane being a deep rooted crop requires tillage which ensures effective exploitation of soil from deeper layers. Preparatory tillage operations are usually carried out with disc harrow and rotavator but the depth of tillage is confined to 10-15 cm. Repeated operations by plough confining to a constant depth over a long period result in formation of hard pan or plough sole. Surface compaction can be alleviated by annual tillage but subsoil compaction is complex and expensive to alleviate. The presence of hard layer in subsoil leads to restricted water infiltration and vertical root growth, which subsequently reduces nutrients and water uptake by the crop.

Subsoil compaction also restricts the movement of nutrients as the application of fertilizers is usually accomplished by broadcasting and mixing in upper 2-5 cm soil layer (Chichester *et al*. 1985). Hence, there is a need to break this sub surface compact layer and ameliorate aeration in subsoil for better root zone environment. Alleviation of subsoil compaction would be possible through special tillage techniques like subsoiling (Thakur and Kumar 1999). Subsoiling is a well established practice in agriculture which enhances or re-establishes the soil profile structure, thus allowing rapid infiltration. Chisel plough and subsoiler improve soil structure by establishing a system of deep cracks and fissures in the subsoil, facilitating the downward movement of water, air and roots (Raper *et al.* 1998). Both subsoiling-cum-deep fertilizer placement and subsoiling-cum-differential rate fertilizer placement methods were found equally effective in increasing the yield of sugarcane crop substantially (Mandal 2007, Mandal and Thakur 2010a). Traditionally, for management of sugarcane ratoon the fertilizer is broadcast and mixed in the top 10-12 cm soil with the help of cultivator or disc harrow, thus resulting in very poor nutrient use efficiency. An improved technology

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for deep tillage, off-barring, deep fertilizer placement and simultaneous soil pulverization and consolidation to conserve moisture by developing a device known as 'Sugarcane Ratoon Manager' was introduced during 2007-2008 in *Tarai* region of Uttarakhand (Manoj Kumar 2010, Thakur 2011). The results of several on-farm and farmers participatory research trials have indicated substantial increase in ratoon yield (25-30%) with the use of developed technology (Thakur *et al*. 2010). Hence, the present study was conducted to asses the influence of mechanical soil management through subsoiling and preparatory tillage on plant growth, NPK uptake and productivity in sugarcane plant-ratoon cropping system.

MATERIALS AND METHODS

The field experiment was conducted during 2008-2009 and 2009-2010 at the N E Borlaug Crop Research Centre (29° N and 79.5° E, 243.8 m above msl), G B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The treatments consisting of five subsoiling along with fertilizer placement treatments, i.e. no subsoiling (S_1), subsoiling at 1.0 m distance (S_2), subsoiling at 1.5 m distance (S_3), cross subsoiling at 1.0 m distance (S_4) and cross subsoiling at 1.5 m distance (S_5); and three preparatory tillage practices, i.e. two harrowing (2H), four harrowing (4H) and one rotavator (1R) were laid out in strip plot design with three replications. The $N:P_2O_5:K_2O$ doses were applied @ 120:60:40 kg/ha, respectively, in plant crop and 150:60:40 kg/ha in ratoon crop. Soil of the experimental plot was silty clay loam having pH 7.4, organic carbon 1.1%, available nitrogen 196.2 kg/ ha, phosphorus 21.4 kg/ ha and potassium 202.2 kg/ ha. The initial soil bulk density was 1.44 and 1.61 Mg/m^3 at 0-30 and 30-60 cm depths, respectively. Subsoiling was done up to a depth of 40 cm by Pant-ICAR Subsoiler-cum-Differential Rate Fertilizer Applicator which has been designed and developed under the ICAR National Professor scheme (Mandal and Thakur 2010 b, Thakur 2010). This machine can perform two operations simultaneously, viz. subsoiling up to 50 cm depth and fertilizer application in the subsoil which ultimately saves fuel and time. In the present study half of the nitrogen and full amount of phosphorus and potassium were applied as basal dose through subsoiler-cum-differential rate fertilizer applicator with 80 per cent dose at the depth of 20 cm and remaining 20 per cent at 40 cm. In cross-subsoiling operation, fertilizers were adjusted to half in each pass for equal distribution. In no subsoiling treatment, the fertilizers were applied manually in the furrows at about 15 cm depth. The rest of the nitrogen was top dressed in two equal splits on 16 May and 10 June. After subsoiling operation preparatory tillage treatments were carried out to break the clods and the field was levelled. Sugarcane (variety CoS 97264) was planted at 75 cm row spacing on March 29, 2008 and harvested on February16, 2009.

The ratoon crop management was carried out in the first week of March, 2009. The ratoon management of plant crop in control (no subsoiling) treatment was done manually with spade and mixing of fertilizers after broadcasting, whereas in all other treatments, the ratoon was managed with a newly developed machine known as Pant-ICAR Deep Soil Volume loosener-cum-Fertilizer Applicator or Sugarcane Ratoon Manager. The ratoon crop was harvested on January 02, 2010. For root study, at maximum tillering stage (July) of plant and ratoon crops (June), the plants were randomly selected in first row from each treatment and cut from the ground surface. A pit of 75 cm × 75 cm × 45 cm was dug out keeping plant row in the middle. All the soil excavated from the pit was taken out carefully. Roots were separated from soil by repeated washing using sieve. The roots were dried in a hot air oven at 70±1°C till the constant weight was obtained. Oven dry weight of roots was multiplied by a costant 4.444 to express as g/m^3. Soil organic carbon, available N, available P and available K were determined at harvest by using modified Walkley and Black method (Jackson 1973), alkaline potassium permanaganate method (Subbiah and Asija 1956), spectro-photometry method (Jackson 1973) and Flame photometric method (Jackson 1973), respectively. Uptake of nitrogen, phosphorous and potassium were determined in canes, green leaves and trash at harvest stage by multiplying dry matter yield with their respective nutrient concentration. Nitrogen, phosphorous and potassium content in different plant parts were determined by following micro Kjeldahl's method (Jackson 1973), Vanadomolybdo phosphoric yellow colour method (Jackson 1973) and neutral ammonium acetate method (Jackson 1973), respectively.

RESULTS AND DICUSSION

Root biomass

Root dry weight of both plant and ratoon crops increased significantly due to subsoiling treatments and mechanized management of ratoon (Table 1). Dry weight of roots enhanced with increase in intensity of subsoiling in both

Table 1 Root biomass as affected by subsoiling-cum-deep fertilizer placement and preparatory tillage in plant and mechanized management in ratoon crops

Treatment	Root dry weight (g/ m^3)	
	Plant crop	Ratoon crop
Subsoiling		
S_1 : No subsoiling	46.1	41.0
S_2 :Subsoiling at 1.0 m	62.9	67.1
S_3 :Subsoiling at 1.5 m	57.0	58.8
S_4 :Cross subsoiling at 1.0 m	70.1	85.7
S_5 : Cross subsoiling at 1.5 m	67.0	73.2
SEm±	1.5	2.0
CD (P = 0.05)	5.0	6.6
Preparatory tillage		
2H : Two harrowing	51.2	61.6
4H : Four harrowing	70.1	70.0
1R : Once rotavator	60.5	63.8
SEm±	3.1	1.9
CD (P = 0.05)	12.1	4.7

Table 2 Interaction effect of subsoiling-cum-deep fertilizer placement and preparatory tillage practices on root biomass (g/ m^3) in plant crop

Treatment	Two harrowing	Four harrowing	Once rotavator
S_1 : No Subsoiling	36.5	56.3	45.3
S_2 : Subsoiling at 1.0 m	53.1	73.3	62.2
S_3 : Subsoiling at 1.5 m	48.1	65.2	57.6
S_4 : Cross-subsoiling at 1.0 m	61.2	79.4	69.7
S_4 : Cross-subsoiling at 1.5 m	57.1	76.0	67.8
SEm±		3.1	
CD (P = 0.05)		9.2	

the crops. Cross-subsoiling at 1.0 m distance resulted in significantly higher root dry weight being 70.1 and 85.7 g/ m^3 in plant and ratoon crops, respectively than other treatments except cross-subsoiling at 1.5 m distance in ratoon crop. Significantly lowest dry weight of roots as 46.1 and 40.0 g/m^3, respectively for plant and ratoon crops were obtained in no subsoiling treatment (control).

Though under no subsoiling treatment the plant crop exhibited more root biomass than ratoon, in all the subsoiling treatments ratoon performed better than plant crop. About 52.0 per cent increase in root dry weight of plant crop was observed in cross-subsoiling at 1.0 m distance over no subsoiling while in ratoon crop, the improvement was over 109 per cent. It reflects the pronounced effect of subsoiling and ratoon management operations along with deep placement of fertilizers on root growth of ratoon crop.

In general, the root dry weight increased with increase in number of preparatory tillage practices. The root dry weight under four harrowing was significantly higher in the order of 70.1 and 70.0 g/m^3 in plant and ratoon crops, respectively than the remaining preparatory tillage practices. Between four harrowing and two harrowing tillage practices, root dry weight did not vary significantly in both plant and ratoon crops. The interaction effect between subsoiling and preparatory tillage operations on root dry weight was non-significant in ratoon crop but was significant in plant crop (Table 2). Rotavator once in combination with no subsoiling exhibited statistically at par with subsoiling at 1.0 or 1.5 m distance and two harrowing combination. Cross-subsoiling at 1.0 m distance along with four harrowing recorded significantly higher root biomass (79.4 g/m^3) as compared to other treatment combinations. However, it was at par with cross-subsoiling at 1.5 m distance and four harrowing (76.0 g/m^3), subsoiling at 1.0 m and four harrowing (73.3 g/ m^3) combinations. All the combinations of subsoiling and preparatory tillage, recorded significantly higher root biomass than two harrowing and no subsoiling (36.5 g/m^3) treatment.

In ratoon crop, mechanized management with Sugarcane Ratoon Manager recorded 73.6 % increase in root dry weight over manual operations. The cutting of old roots, loosening of soil between rows and placement of fertilizers in the root zone by the machine created congenial environment for vigorous root growth. The higher root biomass of plant crop under subsoiling treatments might be attributed to differential rate application of fertilizers at different depths which promoted vigorous growth of roots. The overall better soil condition owing to subsoiling and its fortification with P and K fertilizers could be reasoned for increased root biomass production.

Shoot dry matter

Subsoiling operations significantly increased the shoot dry matter yield of plant and ratoon crops (Table 2). The most intense subsoiling, i.e. cross-subsoiling at 1.0 m distance produced significantly highest cane of 27.0 and 26.5 tonnes/ha and total dry matter yield of 40.9 and 40.2 tonnes/ha in plant and ratoon crops, respectively. Green tops and trash yield of plant crop were also significantly more under cross-subsoiling at 1.0 m but remained at par with subsoiling at 1.0 m and cross-subsoiling at 1.5 m. Same trend was also observed in ratoon crop except that cross-subsoiling at 1.0 m was at par with only cross-subsoiling at 1.5 m for green tops. In both plant and ratoon crops, significantly lowest cane, green tops, trash and total dry matter yield were found in no subsoiling treatment. However, this treatment showed significantly equal green tops dry matter yield with subsoiling at 1.0 and 1.5 m in ratoon crop. The per cent increase in cane, green tops, trash and total dry matter yield under cross-subsoiling at 1.0 m was 34.3, 25.0, 41.1 and 34.5 over no subsoiling in plant crop, respectively, whereas in ratoon crop corresponding values were 48.0, 60.5, 41.5 and 48.9 per cent. The mechanized ratoon management registered 31.7 % increase in shoot dry matter accumulation over manual operations (control).

Preparatory tillage practices failed to show significant variations in dry matter yield in both the crops except in plant crop where four harrowing being at par with one rotavator accumulated significantly more dry matter in trash than two harrowing.

The increase in shoot growth with subsoiling practices could be ascribed to more root biomass production which facilitated nutrients and water absorption particularly from deeper layers of soil. The deep placement of fertilizers, proper aeration, better moisture regime etc. would also enhance plant growth in agreement with Mandal and Thakur (2010a) who observed more cane growth under subsoiling and deep fertilizer placement operations.

Nutrient uptake

The NPK uptake improved with subsoiling operations and showed increasing trend with the intensity of subsoiling. The highest intense subsoiling, i.e. cross-subsoiling at 1.0 m resulted in significantly more NPK uptake (Table 3). Crop raised without subsoiling exhibited significantly lowest uptake. The differences among preparatory tillage were non-significant, however, the total uptake was maximum with four harrowing.

Nitrogen uptake by plant and ratoon crops increased

Table 3 Shoot dry matter of sugarcane plant and ratoon crops under subsoiling-cum-deep fertilizer placement and preparatory tillage practices

Treatment	Shoot dry matter (tonnes/ha)							
	Plant crop				Ratoon crop			
	Cane	Green tops	Trash	Total	Cane	Green tops	Trash	Total
Subsoiling								
S_1 : No subsoiling	20.1	4.8	5.6	30.4	17.9	3.8	5.3	27.0
S_2 :Subsoiling at 1.0 m	23.0	5.7	7.3	36.0	22.2	4.7	6.8	33.7
S_3 :Subsoiling at 1.5 m	22.8	5.2	7.1	35.1	20.7	4.3	6.3	31.3
S_4 :Cross subsoiling at 1.0 m	27.0	6.0	7.9	40.9	26.5	6.1	7.5	40.2
S_5 : Cross subsoiling at 1.5 m	25.1	5.8	7.2	38.1	24.4	5.5	7.2	37.0
SEm±	0.5	0.2	0.3	0.6	0.6	0.3	0.3	0.7
S_1 : No subsoiling	1.8	0.6	0.8	1.8	1.9	1.0	1.1	2.3
Preparatory tillage								
2H : Two harrowing	22.9	4.3	6.4	33.6	21.3	3.8	6.3	31.3
4H : Four harrowing	24.1	6.7	7.8	38.5	23.3	6.0	7.4	36.6
1R : Once rotavator	23.8	5.5	6.9	36.2	22.5	4.8	6.6	33.9
SEm±	0.6	0.6	0.4	1.3	1.1	0.4	0.6	1.9
CD (P = 0.05)	NS	NS	1.4	NS	NS	NS	NS	NS

significantly with subsoiling operations. Cross-subsoiling at 1.0 m being at par with cross-subsoiling at 1.5 m resulted in significantly more N uptake in plant (220.9 kg/ha) and ratoon (211.2 kg/ha) than rest of the treatments in both the crops. Crop grown without subsoiling removed significantly lowest amount of total N. Under cross-subsoiling at 1.0 m, N uptake was higher by 38.9 and 66.1 kg/ha than no subsoiling in plant and ratoon crops, respectively.

In both the crops, significantly highest and lowest total P uptake by cane was under cross-subsoiling at 1.0 m and no subsoiling, respectively.

Subsoiling practices resulted in more K uptake. The crop grown with cross-subsoiling at 1.0 m removed significantly highest total K in both the crops, whereas significantly lowest uptake was in no subsoiling.

The ratoon crop responded better to subsoiling than plant crop in terms of nutrient uptake as per cent increase in N, P and K removal by ratoon under cross-subsoiling at 1.0 m over no subsoiling was 45.6, 54.2 and 53.7 against 30.8, 37.8 and 36.4 in plant crop, respectively. The mechanized operations in ratoon also helped in nutrient absorption through favourable soil manipulation and proper fertilizer placement in root zone. Compared to manual operations in ratoon crop, an increase of 29.3 % in N, 34.9% in P and 34.3% in K uptake was noticed due to mechanized management.

The nutrient uptake is the function of dry matter and nutrient content. Subsoiling resulted in higher dry matter production which led to more nutrients uptake by plants. Moreover, higher root biomass under subsoiling operations helped in nutrient absorption. These results are in conformation with the findings of Singh (2008).

Yield attributes and yield

Yield attributes and cane yield increased significantly in both the crops due to subsoiling in plant crop and mechanized operations in ratoon crop (Table 4). Cross-subsoiling at 1.0 m being at par with cross-subsoiling at 1.5 m produced significantly higher number of millable cane (100.2 and 118.2 thousand/ha), cane length (225.8 and 221.6 cm) and cane weight (883.8 and 752.2 g) than that of no subsoiling and subsoiling at 1.5 m distance in plant crop and ratoon crops, respectively. In plant crop, cross-subsoiling at 1.0 m produced significantly higher cane girth (7.8 cm) than no subsoiling and subsoiling at 1.5 m distance treatments, but was at par with remaining treatments. In ratoon crop, the differences in cane girth were not significant. The higher value of cane length and girth in subsoiling treatments might be due to better moisture and nutrient availability by way of enhanced root and shoot growth which in turn increased the individual cane weight. An increase in cane yield was observed with increasing intensity of subsoiling. Cross-subsoiling at 1.0 m distance produced the maximum cane yield of 75.8 and 74.9 tonnes/ha in plant and ratoon crops which were significantly higher than rest of the treatments but remained at par with cross-subsoiling at 1.5 m in both the crops, respectively. The increase in cane yield under cross-subsoiling at 1.0 m was 28.0 and 37.9, 22.8 and 37.2, 41.5 and 35.9, 28.3 and 37.3 per cent than no subsoiling in plant and ratoon crops, respectively. The mechanized management of ratoon resulted in 26.6 % increase in cane yield over manual operations. Increase in cane yield was due to higher individual cane weight and number of millable canes. Plant and ratoon crops grown under cross-subsoiling at 1.0 m distance treatment had 21.0 and 29.5 per cent more millable canes and 16.9 and 15.2 per cent heavier cane weight than that of no subsoiling, respectively. The ratoon crop managed by Sugarcane Ratoon Manager attained 13.6 % more cane weight and 21.9 % higher millable canes than that of manually managed crop

Table 4 Nutrient uptake in sugarcane plant and ratoon crops as influenced by subsoiling-cum- deep fertilizer placement and preparatory tillage

Treatment	Nutrient uptake (kg/ha)					
	Plant crop			Ratoon crop		
	N	P	K	N	P	K
Subsoiling						
S_1 : No subsoiling	168.8	19.3	225.4	145.1	17.5	199.7
S_2 :Subsoiling at 1.0 m	199.3	23.4	268.9	179.6	22.3	252.5
S_3 :Subsoiling at 1.5 m	191.3	22.6	260.7	163.6	20.4	233.7
S_4 :Cross subsoiling at 1.0 m	220.9	26.6	307.6	211.2	27.0	307.0
S_5 : Cross subsoiling at 1.5 m	208.7	24.7	285.4	196.0	24.7	279.8
SEm±	2.9	0.3	3.4	4.3	0.4	6.6
CD (P = 0.05)	9.4	1.0	11.2	13.8	1.3	21.4
Preparatory tillage						
2H : Two harrowing	181.1	21.5	248.1	163.8	20.4	232.6
4H : Four harrowing	213.9	25.0	289.4	195.1	24.4	278.0
1R : Once rotavator	198.3	23.4	271.5	178.4	22.3	253.1
SEm±	8.9	0.9	9.7	11.3	1.6	23.0
CD (P = 0.05)	NS	NS	NS	NS	NS	NS

(control). Higher cane yields under subsoiling treatments owing to increased individual cane weight coupled with number of millable canes in the experiments carried out on the same soil type in the vicinity of the present experiment were obtained by a number of researchers at Pantnagar (Mandal 2007, Singh 2008, and Mandal and Thakur 2010b). The low cane yield under no subsoiling may be imputed to less number of yield attributes. Jagpat *et al.* (1995) and Mandal (2007) also noted less number of millable canes, individual cane weight and over all cane growth under no subsoiling operation. The preparatory tillage practices did not significantly improve cane yield and yield attributes in both the crops except number of millable canes and cane length in the ratoon crop. Four harrowing operation being at par with one rotavator treatment resulted in significantly higher number of millable canes (114.8 thousand/ha) and cane length (212.1 cm) than that of two harrowing treatment in ratoon crop.

Economics of plant-ratoon system

Cross subsoiling at 1.0 m distance exhibited significantly higher gross return, cost of cultivation, net return and benefit: cost ratio than other treatments in sugarcane plant-ratoon cropping system (Table 5). Compared to no subsoiling, cost of cultivation under cross subsoiling at 1.0 m was higher by ₹ 3 801/ha but this treatment gave ₹ 65 511 and ₹ 61 709/ha more gross and net return, respectively. Among preparatory tillage, cost of cultivation

Table 5 Yield attributes and yields of sugarcane plant and ratoon crops as influenced by subsoiling-cum- deep fertilizer placement and preparatory tillage

Treatment	Cane length (cm)		Cane girth (cm)		Cane weight (g)		NMC ('000/ ha)		Cane yield (t/ha)	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
Subsoiling										
S_1	204.3	185.9	7.1	6.6	755.8	652.9	82.8	91.3	59.2	54.3
S_2	218.1	208.1	7.5	6.9	852.6	691.8	93.5	107.1	68.2	66.8
S_3	210.4	199.6	7.2	6.7	827.2	669.6	89.1	105.5	67.6	63.6
S_4	225.8	221.6	7.8	7.1	883.8	752.2	100.2	118.2	75.8	74.9
S_5	222.2	212.3	7.5	7.0	872.2	700.1	95.2	114.3	70.6	69.7
SEm±	3.6	2.1	0.1	0.4	20.1	11.6	2.7	2.7	2.1	1.7
CD (P = 0.05)	11.9	7.0	0.4	NS	65.5	37.7	8.9	8.7	6.7	5.5
Preparatory tillage										
2H	214.3	199.4	7.1	6.7	770.3	644.1	89.6	100.2	66.8	63.1
4H	218.2	212.1	7.7	7.0	924.1	741.7	94.0	114.8	69.2	68.3
1R	216.0	205.0	7.4	6.8	820.7	694.3	92.7	106.9	68.8	66.2
SEm±	3.4	2.4	0.2	0.3	36.8	36.7	3.3	2.7	2.5	1.8
CD(P = 0.05)	NS	9.4	NS	NS	NS	NS	NS	10.8	NS	NS

Table 6 Economics analysis under different treatments in sugarcane plant–ratoon cropping system

Treatment	Gross return (₹/ha)	Cost of cultivation (₹/ha)	Net return (₹/ha)	B:C ratio
Subsoiling				
S_1 : No subsoiling	196 259	72 794	123 466	1.69
S_2 :Subsoiling at 1.0 m	234 744	73 548	161 196	2.19
S_3 :Subsoiling at 1.5 m distance	227 052	72 916	154 136	2.11
S_4 :Cross subsoiling at 1.0 m	261 770	76 595	185 175	2.42
S_5 : Cross subsoiling at 1.5 m	244 076	75 235	168 841	2.24
SEm±	4 152	90	4 063	0.05
CD (P = 0.05)	13 541	294	13 250	0.17
Preparatory tillage				
2H : Two harrowing	223 450	73 403	150 047	2.04
4H : Four harrowing	240 701	75 168	165 533	2.20
1R : Once rotavator	234 190	74 081	160 108	2.16
SEm±	7 355	147	7 209	0.09
CD (P = 0.05)	NS	581	NS	NS

was significantly higher under four harrowing (₹ 75 168/ha) than two harrowing (₹ 73 403/ha) and one rotavator (₹ 74 081/ha). Gross return, net return and benefit: cost ratio were the highest under four harrowing (₹ 240 701, 165 533/ha and 2.20) and the lowest with two harrowing (₹ 223 450, 150 047/ha and 2.04), respectively. The highest gross return, net return and benefit: cost ratio under cross subsoiling at 1.0 m distance may be due to the maximum yield obtained in this treatment. The highest cost of cultivation under cross subsoiling at 1.0 m distance and four harrowing was due to additional cost of closer subsoiling and more harrowing operation.

The present study clearly indicated that mechanical soil manipulation through subsoiling along with deep and differential rate fertilizer application in sugarcane is helpful in increasing the root and shoot growth, nutrients uptake, millable canes and cane weight which ultimately contributed to substantial increase in cane yields of both the crops in sugarcane plant-ratoon cropping system.

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