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Effect of Subsoiling and Preparatory Tillage Practices on Juice Quality and Economics of Sugarcane (*Saccharum officinarum* L.) under South Gujarat Condition

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ABSTRACT

The experiment consisting of five subsoiling treatments (S_0 to S_4), namely no subsoiling (S_0), subsoiling at 1.5 m distance (S_1), subsoiling at 2.0 m distance (S_2), cross subsoiling at 1.5 m x 1.5 m (S_3) and cross subsoiling at 2.0 m x 2.0 m (S_4) and two preparatory tillage practices, i.e., 2 harrowing and 4 harrowing was laid in split plot design with four replications. Various subsoiling treatments did not differ significantly on juice quality (brix, pol (sucrose) content in juice (percentage), pol (sucrose) content in cane (percentage), purity percentage, C.C.S. percentage and fibre percentage) during both the years of investigation and in pooled analysis except C.C.S. percentage during 2016-17. Crop grown under cross subsoiling at 1.5 m distance (S_3) recorded significantly higher commercial cane sugar (18.2, 18.6 and 18.4 t ha^{-1}), respectively during individual year of study and in pooled analysis. Preparatory tillage practices did not affect significantly the quality parameters. The highest gross return, net return and benefit: cost ratio under cross subsoiling at 1.5 m distance may be due to the maximum yield obtained in this treatment. The cost of cultivation was highest with cross subsoiling and more harrowing operation.

***Key words:** Tillage, Sugarcane, Subsoiling, Quality, Economics, Brix*

INTRODUCTION

Sugarcane is the second most important industrial crop of India with the highest production of sugar after Brazil. The area occupying in the country is 5.06 million ha which is 3 per cent of the total cultivated area with the production and productivity of 361.04 million tonnes and 71.6 t ha^{-1}, respectively[2]. About 4 million growers are involved in the cultivation of sugarcane in India. 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[14]. Sugar industry contributes significantly to the rural economy as the sugar mills are mostly located in the rural areas and provide large scale employment for nearly 4 per cent of the rural population.

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Sugarcane is an important cash crop of Gujarat which is most popular among the farmers. The area, production and yield of sugarcane in Gujarat is 2.02 lac ha, 127.50 lac tonnes and 63.1 t ha^{-1}, respectively[2]. Heavy rainfall, perennial canal irrigation facility and good infrastructure of sugar factories enhanced the sugarcane cultivation in south Gujarat. But tremendous increase in various industries in this region resulted in scarcity of labourers making all the operations difficult to carry out at proper time. Moreover, labourers do also not prefer to work in agriculture because of attractive wages and other benefits offered by the industrialists. In these circumstances, the farmers of this region are always in search of that option which is less human labourers oriented. Owing to sound economic background, the farmers of this area can afford costly agro techniques based on mechanization or any other concepts which require lesser human labourers but suitable in all respect. The steep rise in cost of production, non-availability of labourers in adequate numbers at the time of harvesting and high cost of inputs is eroding the profits, thus making sugarcane cultivation less sustainable.

Among various reasons for the low productivity of sugarcane, soil compaction is the major factor. Soil compaction is emerging as a serious problem affecting the yield of field crops leading to soil degradation worldwide. Compaction-induced soil degradation affects about 68 million hectares and 11 per cent of land globally[1,3].

Nowadays, mechanization in sugarcane farming is becoming more important due to the ever-increasing demand for sugarcane together with the problem of a labour shortage. Along with preparatory tillage practices also increase crop yield. Chisel ploughing and subsoiling have resulted a significant yield increase in sugarcane crop[15].

MATERIAL AND METHODS

The field experiment was conducted at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari during 2015-16 and 2016-17. Navsari Agricultural University campus is geographically located at 20º57' N latitude and 72º54' E longitude at an altitude of 10 meters above the mean sea level.

Data on soil analysis revealed that soil of experimental plot was clay in texture. The soil of the both plots (on an average of both years) was medium, medium and fairly rich in available nitrogen(269.85 kg ha^{-1}), phosphorus (27.7 kg ha^{-1}) and potassium (372.65 kg ha^{-1}), respectively and slightly alkaline in reaction (8.01). The annual average rainfall received during 2015-16 and 2016-17 were 1474.0 and 1358.6 mm, respectively. The annual mean relative humidity ranged from 18.8 to 103.7 and 21.3 to 98.6 per cent during the investigation period. The mean sunshine hours ranged between 0.4 to 10.5 and 0.1 to 10.6 hours during the period of experimentation, respectively.

Sugarcane (*var*. CoN 05071) was planted on December 02, 2015 and December 10, 2016 using 50,000 two eye budded setts ha^{-1} seed for the experiments conducted in split plot design with four replications.

The treatments comprised of different combinations of five subsoiling treatments (S_0 to S_4), namely no subsoiling (S_0), subsoiling at 1.5 m distance (S_1), subsoiling at 2.0 m distance (S_2), cross subsoiling at 1.5 m x 1.5 m (S_3) and cross subsoiling at 2.0 m x 2.0 m (S_4) and two preparatory tillage practices, *i.e.,* 2 harrowing and 4 harrowing. After implementing the subsoiling treatments, sugarcane was planted in furrows at 100 cm spacing between rows.

A common dose of 125 kg ha^{-1} for each P_2O_5 and K_2O in the form of single super phosphate and muriate of potash, respectively, were applied uniformly to all the experimental plots prior to planting and it was mixed with the soil. Nitrogen was applied @ 250 kg ha^{-1} in the form of urea in all treatments in four splits, *i.e.*, 15 per cent at the time of planting, 30 per cent at 45 days after planting, 20 per cent at 90 days after planting and 35 per cent before final earthing-up, *i.e.*, 150 days after planting.

The juice parameters were obtained by referring the table for the polarimeter reading[4].

The sucrose per cent cane was calculated by using the following equation:

Pol (%) cane = Pol (%) juice x (0.9-Fibre (%)/100)

The commercial cane sugar percentage (C.C.S. %) was calculated as below:

C.C.S. % = [B x 1.02 - S x 0.29]

Where,

B = Juice brix

S = Sucrose (%) juice

The commercial cane sugar (C.C.S.) yield (t ha-1) was calculated using the cane yield value (t ha-1) and C.C.S. (%) as under:

$$\text{CCS (t ha}^{-1}\text{)} = \frac{\text{Cane yield (t ha}^{-1}\text{) x CCS (\%)}}{100}$$

The fiber (%) was calculated as below:

$$\text{CCS (t ha}^{-1}\text{)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \text{ x } 100$$

The economics of planting sugarcane were worked out by considering the prevailing market rates for different inputs and produces.

RESULTS AND DISCUSSION

Quality studies

The observations on brix, pol (sucrose) content in juice (percentage), pol (sucrose) content in cane (percentage), purity percentage, C.C.S. percentage, fibre percentage and commercial cane sugar (C.C.S.) yield (t ha^{-1}) in sugarcane crop recorded at harvest during both the years of study and the data are presented in Table 1, 2 and 3.

The sugarcane quality (Table 1, 2 and 3) in terms of brix, pol percentage (sucrose) content in juice, pol percentage (sucrose) content in cane, purity percentage and fibre percentage were not influenced significantly by different subsoiling practices during both the years and in pooled analysis.

Cross sub soiling at 1.5 m distance treatment observed maximum brix, pol (sucrose) content in juice (percentage), pol (sucrose) content in cane (percentage), purity percentage, C.C.S. percentage and fibre percentage and minimum with no subsoiling, respectively during first year, second year of experimentation and in pooled analysis. During 2016-17, cross subsoiling at 1.5 m distance (S_3) observed significantly higher commercial cane sugar (%) and treatment S_4, S_1, and S_2 were at par with S_3 treatment.

The data given in Table no 3 revealed that differences in commercial cane sugar yield (t ha^{-1}) due to subsoiling operations were significant during both the years and in combined analysis. Crop grown under cross subsoiling at 1.5 m distance (S_3) recorded significantly higher commercial cane sugar (18.2, 18.6 and 18.4 t ha^{-1}), respectively during individual year of study and in pooled analysis. S_3 treatment was at par with S_4 during 2015-16, 2016-17 and in pooled analysis, respectively. Although subsoiling practices did not affect the juice quality significantly, but better juice quality may be explained through the logic that subsoiling by way of disturbing soil up to deeper layer, enable the roots to explore larger volume of soil, thus facilitate more availability of nutrients, including the micro-nutrients.

The better juice quality obtained under cross subsoiling at 1.5 m distance was possibly due to overall good plant growth enabling plants to accumulate more photosynthates for synthesis of juice sucrose.

Commercial cane sugar yield is a function of cane yield and CCS per cent, both of which were significantly increased by cross subsoiling at 1.5 m distance practice during both the years. Crop grown with cross subsoiling at 1.5 m distance operation produced 18.2, 18.6 and 18.4 t ha^{-1} commercial cane sugar yield, which was 21.9, 20.9 and 21.7 per cent higher than no subsoiling treatment in both the years and in pooled analysis, respectively. Such increase in commercial cane sugar yield may be attributed primarily to increased cane yield and to some extent to improved juice quality. These findings are in close conformity with those of Jagtap *et al*.[6], Kumar and Thakur[8] and Hashemi and Shokuhfar[5].

The variations in (Table 1, 2 and 3) brix, pol (sucrose) content in juice (percentage), pol (sucrose) content in cane (percentage), purity percentage, C.C.S. percentage and fibre percentage due to preparatory tillage practices were not significant in both the years of study and combined analysis. However, at harvest, the maximum brix, pol (sucrose) content in juice (percentage), pol (sucrose) content in cane (percentage), purity percentage, C.C.S. percentage and fibre percentage was obtained with four harrowing and lowest with two harrowing, respectively during 2015-16, 2016-17 and in pooled analysis.

The preparatory tillage operations (Table 3) failed to cause significant effect on commercial cane sugar during both the years of experimentation as well as in combined analysis. However, four harrowing resulted in the highest commercial cane sugar (16.3, 16.9 and 16.6 t ha^{-1}) and lowest with two harrowing (15.4, 15.8 and 15.6 t ha^{-1}), respectively during individual years of investigation and on pooled analysis.

Preparatory tillage practices did not affect significantly the quality parameters include brix, pol per cent cane, pol per cent juice, purity per cent, CCS (%) and Commercial cane sugar (t ha^{-1}) in the both the years and pooled result. Non significant effect of preparatory tillage on juice quality suggests that, such operations favour the initial establishment and growth of the crop, but not the compositions. The result could be supported by studies of Jiu Hao *et al*.[7], Singh *et al*.[12] and Surendran *et al*.[13] in sugarcane.

The interaction between subsoiling and preparatory tillage practices with respect to brix, pol (sucrose) content in juice (percentage), pol (sucrose) content in cane (percentage), purity percentage, C.C.S. percentage, fibre percentage and commercial cane sugar (C.C.S.) yield (t ha^{-1}) were not significant in both the years and in combined analysis.

Economics

The data on economics of sugarcane crop as influenced by subsoiling and preparatory tillage operation are furnished in Table 4. The gross as well as net realization and benefit cost ratio for individual treatments were worked out on the basis of pooled cane yield considering prevailing market prices.

Gross return was influenced by subsoiling practices. The maximum gross return was obtained from cross subsoiling at 1.5 m distance (₹450780 ha^{-1}). The gross return with cross subsoiling at 1.5 m distance over no subsoiling increased by ₹88086 ha^{-1} in pooled analysis.

The maximum gross return was recorded under four harrowing (₹ 411411/ha) and the lowest with two harrowing (₹392447/ha) in pooled analysis.

All the treatments had higher cost of cultivation than no subsoiling. Cost of cultivation tended to increase with the increasing the intensity of tillage. Significantly higher cost of cultivation (₹141468 ha^{-1}, respectively) was calculated under cross subsoiling at 1.5 m distance than other remaining treatments in combined analysis. Four harrowing resulted higher cost (₹137148 ha^{-1}) of cultivation than two harrowing treatment.

Net return was influenced by subsoiling treatments. Highest net return was achieved under cross subsoiling at 1.5 m distance (₹309312ha^{-1}) than that of no subsoiling (₹76086 ha^{-1}) in pooled analysis. The increase in net return under cross subsoiling at 1.5 m distance than no subsoiling by margin of 24.59%, respectively in pooled analysis.

The highest net return was achieved with four harrowing (₹274263ha^{-1}) and the lowest with two harrowing (₹257699ha^{-1}) in pooled analysis. Benefit: Cost ratio was influenced by subsoiling practices. The maximum benefit: cost ratio was received with cross subsoiling at 1.5 m distance (3.19).

The maximum benefit: cost ratio was recorded under four harrowing (3.00). The lowest benefit: cost ratio accrued with two harrowing (2.91) in pooled analysis.

Among all the treatments no subsoiling exhibited significantly lower cost of cultivation, gross return, net return and benefit: cost ratio than that of subsoiling treatments. The highest gross return, net return and benefit: cost ratio under cross subsoiling at 1.5 m distance may be due to the maximum yield obtained in this treatment. The cost of cultivation was highest with cross subsoiling and more harrowing operation.

Considering the economics in subsoiling treatments, maximum net realization and BCR ratio were obtained in cross subsoiling at 1.5 m distance (₹ 3, 09, 312 ha^{-1} and 3.19, respectively) followed by cross subsoiling at 2.0 m distance (₹ 2, 74, 214 ha^{-1} and 2.97, respectively), subsoiling at 1.5 m distance (₹ 2, 63, 143 ha^{-1} and 2.94, respectively), subsoiling at 2.0 m distance (₹ 2, 50, 011 ha^{-1} and 2.86, respectively) and no subsoiling (₹ 2, 33, 226 ha^{-1} and 2.80, respectively). The maximum net realization and BCR in preparatory tillage practices with four harrowing (₹2, 74, 263 ha^{-1} with BCR 3.00). These results are in partially accordance with those of Kumar ***et** al*.[9], Singh *et al*.[11] and Malagi *et al*.[10].

Table 1: Effect of subsoiling and preparatory tillage operation on brix (%), pol (%) juice and pol (%) cane

Treatments	Brix (%)			Pol (%) juice			Pol (%) cane		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Subsoiling (S)									
S-0: No subsoiling	18.7	18.7	18.7	18.5	18.2	18.3	14.3	14.1	14.2
S-1: SS at 1.5 m distance	19.0	19.0	19.0	18.9	19.1	19.0	14.5	14.7	14.6
S-2: SS at 2.0 m distance	18.9	19.0	18.9	18.7	18.7	18.7	14.4	14.4	14.4
S-3: CSS at 1.5 m distance	19.5	19.6	19.5	19.4	19.6	19.5	14.9	15.0	14.9
S-4: CSS at 2.0 m distance	19.2	19.3	19.3	19.0	19.3	19.1	14.6	14.9	14.7
SEm±	0.21	0.19	0.20	0.35	0.30	0.31	0.24	0.21	0.21
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V. %	3.05	2.81	2.93	5.22	4.52	4.62	4.70	4.01	4.07
Preparatory tillage (H)									
H-1: 2 harrowing	19.0	19.1	19.0	18.8	18.9	18.8	14.5	14.5	14.5
H-1: 4 harrowing	19.1	19.2	19.2	18.9	19.1	19.0	14.6	14.7	14.6
SEm±	0.12	0.10	0.11	0.14	0.11	0.11	0.10	0.07	0.08
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V. %	2.77	2.38	2.57	3.21	2.49	2.64	3.07	2.07	2.37
Interaction (S x H)									
SEm±	0.26	0.23	0.25	0.30	0.24	0.25	0.22	0.15	0.17
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

#Interaction effect of year with all factors found non significant

Table 2: Effect of subsoiling and preparatory tillage operation on purity (%) and C.C.S. (%)

Treatments	Purity (%)			C.C.S. (%)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Subsoiling (S)						
S-0: No subsoiling	90.4	90.7	90.5	13.7	13.8	13.8
S-1: SS at 1.5 m distance	91.1	91.3	91.2	13.9	13.9	13.9
S-2: SS at 2.0 m distance	90.9	91.1	91.0	13.9	13.9	13.9
S-3: CSS at 1.5 m distance	91.2	92.2	91.7	14.2	14.3	14.3
S-4: CSS at 2.0 m distance	91.1	91.8	91.4	14.1	14.1	14.1
SEm±	1.25	0.89	1.07	0.15	0.11	0.12
CD (P=0.05)	NS	NS	NS	NS	0.33	NS
C.V. %	3.89	2.76	3.31	2.96	2.14	2.47
Preparatory tillage (H)						
H-1: 2 harrowing	90.7	91.3	91.0	13.9	14.0	13.9
H-1: 4 harrowing	91.1	91.5	91.3	14.0	14.0	14.0
SEm±	0.75	0.25	0.49	0.10	0.07	0.08
CD (P=0.05)	NS	NS	NS	NS	NS	NS
C.V. %	3.66	1.20	2.42	3.08	2.33	2.68
Interaction (S x H)						
SEm±	1.67	0.55	1.10	0.22	0.16	0.19
CD (P=0.05)	NS	NS	NS	NS	NS	NS

#Interaction effect of year with all factors found non significant

Table 3: Effect of subsoiling and preparatory tillage operation on commercial cane sugar (C.C.S.) yield (t ha^{-1}) and fibre (%)

Treatments	C.C.S. (t ha^{-1})			Fibre (%)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Subsoiling (S)						
S-0: No subsoiling	14.2	14.7	14.4	12.5	12.6	12.6
S-1: SS at 1.5 m distance	15.5	15.7	15.6	13.1	13.0	13.1
S-2: SS at 2.0 m distance	15.2	15.6	15.4	12.8	13.0	12.9
S-3: CSS at 1.5 m distance	18.2	18.6	18.4	13.4	13.3	13.3
S-4: CSS at 2.0 m distance	16.1	17.2	16.6	13.2	13.2	13.2
SEm±	0.73	0.80	0.77	0.19	0.14	0.16
CD (P=0.05)	2.26	2.48	2.36	NS	NS	NS
C.V. %	13.1	13.9	13.5	4.02	3.06	3.53
Preparatory tillage (H)						
H-1: 2 harrowing	15.4	15.8	15.6	13.0	12.9	12.9
H-1: 4 harrowing	16.3	16.9	16.6	13.1	13.1	13.1
SEm±	0.36	0.4	0.4	0.03	0.07	0.07
CD (P=0.05)	NS	NS	NS	NS	NS	NS
C.V. %	10.2	10.5	10.3	1.10	2.51	2.51
Interaction (S x H)						
SEm±	0.80	0.86	0.83	0.07	0.16	0.12
CD (P=0.05)	NS	NS	NS	NS	NS	NS

#Interaction effect of year with all factors found non significant

Table 4: Economic evaluation of subsoiling and preparatory tillage operation (pooled)

Treatments	Cane yield (t ha^{-1})	Cost of cultivation (₹ ha^{-1})	Gross realization (₹ ha^{-1})	Net realization (₹ ha^{-1})	BCR
Subsoiling (S)					
S-0: No subsoiling	103.6	129468	362694	233226	2.80
S-1: SS at 1.5 m distance	113.9	135468	398611	263143	2.94
S-2: SS at 2.0 m distance	109.8	134268	384279	250011	2.86
S-3: CSS at 1.5 m distance	128.8	141468	450780	309312	3.19
S-4: CSS at 2.0 m distance	118.1	139068	413282	274214	2.97
Preparatory tillage (H)					
H-1: 2 harrowing	112.1	134748	392447	257699	2.91
H-1: 4 harrowing	117.5	137148	411411	274263	3.00

(A) Price of produce

Sugarcane : ₹ 3500 t^{-1}

(B) Price of inputs

(a)	Seed cost	Sugarcane	:	₹ 3300t^{-1}
(b)	Fertilizer	Nitrogen	:	₹ 6.26 kg^{-1}
		Phosphorus	:	₹ 7.42 kg^{-1}
		Potassium	:	₹ 11.8 kg^{-1}
(c)	Herbicide	Atrazine	:	₹ 756kg^{-1}

CONCLUSION

On the basis of two years experiments, it can be concluded that highest net realization and C.C.S. yield (t ha^{-1}) of sugarcane obtained by adopting cross subsoiling at 1.5 m distance along with two harrowing under south Gujarat condition.

REFERENCES

1. Ahmad, N., Fayyazul, H., Qadir, G., Effect of subsurface soil compaction and improvement measures on soil properties. *International Journal of Agriculture and Biology* **9(3):** 509-513 (2007).
2. Anonymous. India Stat.com (2015).
3. Flowers, M. D., Lal, R., Axle load and tillage effects on soil physical properties and soybean grain yield on a mollicochraqualf in northwest Ohio. *Soil and Tillage Research* **48:** 21-35 (1998).
4. George, P. M., Cane sugar hand book (9^{th} Edn). *Johan Willey and Sons*, Inc., New York, London, (1963).
5. Hashemi, A., Shokuhfar, A. R., The Effect of ratooning practice in cane yield and quality parameters of sugarcane. *Research on Crop Ecophysiology* **10(1):** 25-31 (2015).
6. Jagtap, R. B., Kamathe, S. D., Athare, V. R., Gunjal, B. B., Pawar, R. V., Hapase, D. G., Effect of subsoiling with excess water, or with hard pan, on soil properties and sugarcane quality and yield. *International Society of Sugar Cane Technologists* **21(2):** 501-513 (1992).
7. JiuHao, L., ZhongWen, T., XiWen, L., YingGang, O., HongBo, L., Effects of tillage and mulch methods on sugarcane production. *Nongye JixieXuebao Transactions of the Chinese Society of Agricultural Machinery* **35(5):** 70-73 (2004).
8. Kumar, M., Thakur, T. C., Study on combined effect of different tillage methods in sugarcane plant-ratoon cropping system for sustainable ratoon productivity. *Journal of Agricultural Engineering* **50(3):** 9-16 (2013).
9. Kumar, R., Kumar, N., Singh, H., Singh, D., Evaluation of tillage practices on the productivity and profitability of sugarcane in calcareous soil of Bihar. *Indian Journal of Sugarcane Technology*. **26(2):** 1-3 (2011).
10. Malagi, M. T., Angadi, S. S., Yogendra, N. D., Dinesh, S. P., Mahendra, A. C., Sujay, Y. H., Response of sweet sorghum (*Sorghum bicolour*) to tillage and spentwash on juice quality and economics.

The Madras Agricultural Journal **10(1-3):** 167-170 (2013).

11. Singh, K., Choudhary, O. P., Singh, H., Effects of subsoiling on sugarcane productivity and soil properties. *Journal of Sugarcane Research* **2(1):** 32-36 (2012).
12. Singh, P., Saini, S. K., Thakur, T. C., Bkatnagar, A., Effect of subsoiling and differential rate placement of fertilizers on growth, productivity and juice quality of sugarcane. *International Journal of Basic and Applied Agriculture research* **13(1):** 10-16 (2016).
13. Surendran, U., Ramesh, V., Jayakumar, M., Marimuthu, S., Sridevi, G., Improved sugarcane productivity with tillage and trash management practices in semi arid tropical agro ecosystem in India. *Soil and Tillage Research* **158:** 10-12 (2016).
14. Thakur, T. C., Subsoil structure modification and its fortification-A necessity for introduction of sugarcane harvesters in Northern India. All India Seminar on Mechanization of Sugarcane Harvesting Opportunities and Challenges held at *Indian Institute of Sugarcane Research (ICAR)*, Lukhnow during 27th April, 28-38 (2012).
15. Torres, J. S., Yang, S. J., Villegas, F., Soil compaction and cane stalk damage by semi-mechanized harvesting systems in the wet season. *Sugar Cane*. **5:** 12-16 (1990).