IMPROVING WATER USE EFFICIENCY IN SUGARCANE CULTURE – OUR EXPERIENCE AND PERSPECTIVES*

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Water is the most critical input in sugarcane production, but its availability in adequate quantity is becoming difficult in most of the sugarcane growing areas of the country. Droughts are becoming frequent and have seriously affected sugarcane and sugar production in the recent past. Under these circumstances to sustain sugarcane production exploiting the full potential of the available water is of paramount importance. We have taken cognizance of this problem and have been working on various aspects of improving water use efficiency in sugarcane culture. This paper gives an account our research results and our perspectives for the future.

During the years 1975-76, work on drip irrigation was initiated at the Sugarcane Breeding Institute to find out its feasibility and efficacy in sugarcane cultivation under the tropical conditions. In addition to drip irrigation, skip furrow irrigation was also tried. In the initial experiment, a 50 % saving of water was aimed at in the drip irrigation method over the normal irrigation. The amount of water actually saved was 46 %. In the skip furrow, 34 % saving of water was effected. However, there was reduction in the yield in both the systems as compared to the normal furrow irrigation system. The following reasons were attributed for yield reduction viz. 1. requirement of water at later stages of crop growth might have been more than what was given, and 2. heavy termite attack in drip irrigated plots.

During the 1976-77 season, a replicated trial was taken up. In addition to drip, skip and alternate furrow systems of irrigation were also included as treatments. To overcome reduction in the yield observed in the earlier experiment, more quantity of water was added after six months. To prevent termite attack, gamma BHC was applied at the time of planting and also at 90 days. This experiment also did not show any improvement in cane yield by drip irrigation though there was considerable saving in the irrigation water.

The experiment on drip irrigation was continued during 1977-78 with five irrigation methods viz. (1) normal irrigation (conventional method), (2) drip irrigation (furrow method), (3) drip irrigation (flat method), (4) skip furrow irrigation and (5) alternate furrow irrigation. The details of amount of irrigation received during the period and yield and quality characters are presented in Table 1.

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Table 1: Details of irrigation systems with data on germination, yield and quality characters

Treatment	Amount of irrigation recd. (cm)	Rainfall during the period (cm)	Germination percentage at 45 days	CCS %	Yield (t/ha)	CCS (t/ha)
Normal irrigation	107.50	92.57	71.16	10.49	94.23	9.81
Drip irrigation furrow method	63.90	92.57	69.55	11.40	92.66	10.58
Drip irrigation flat method	63.90	92.57	63.33	10.82	107.12	12.00
Skip furrow irrigation	74.50	92.57	65.55	9.89	73.67	7.11
Alternate furrow irrigation	60.75	92.57	71.00	11.13	77.57	8.62

Water economy in terms of saving of water over normal irrigation in drip, skip furrow and alternate furrow system were 40.6 %, 30.7 % and 42.3 % respectively

There was no reduction in yield in both the drip irrigation systems tried compared to normal irrigation. Slight improvement in CCS % was observed under drip systems. There was no difference in yield between normal irrigation and the drip-furrow method. However, the drip flat method recorded about 13 tonnes more cane yield than the normal method. The drip systems recorded higher CCS yield over the normal system. Under skip furrow and alternate furrow systems, however, there was reduction in the yield.

The same experiment was repeated in the following year and the results are presented in Table 2. There was 33 %, 41.5 % and 40 % saving of water in drip irrigation, skip furrow irrigation and alternate furrow irrigation respectively compared to the conventional furrow irrigation. Increase in yield and CCS per ha were observed in drip systems, flat furrow method being better than the drip furrow method. In skip furrow irrigation method, yield was maintained on par with conventional irrigation and contrary with the results obtained in the previous year. In the alternate furrow irrigation, yields were very much reduced. In the drip irrigation method, there was significant improvement in the stalk population which led to higher yield. The studies carried out during these years (75-78) have given highly variable results. As far as water saving is concerned, drip irrigation system has proven to save around 40 % in the irrigation water. The yield improvement was observed in two trials out of four. This indicates that there is considerable possibility to save irrigation water and at the same time, to improve yields of sugarcane provided drip systems are managed properly.

Table 2: Details of irrigation, germination, yield and quality characters

Treatments	Amount of irrigation received in cm.	Rainfall during the period in cm.	Total amount of water received in cm.	Percentage saving of water over normal irrigation	Germination percentage at 45 days	No. of millable cane/ha	CCS per cent	Yield tonnes/ha	CCS tonnes/ha
Normal irrigation	136.00	67.00	203.00	--	69.05	78595	10.71	75.91	8.19
Drip irrigation – Furrow method	92.10	67.00	169.10	32.25	74.50	88219	10.92	92.45	10.08
Drip irrigation – Flat method	92.10	67.00	159.10	32.25	74.66	101800	10.87	112.96	12.26
Skip furrow irrigation	79.50	67.00	146.50	41.54	87.78	84158	10.18	76.73	7.85
Alternate furrow irrigation	82.00	67.00	149.00	39.69	69.83	68651	10.24	48.85	6.80
					* CD = 8.1726	** CD = 34960	NS	** CD = 9.924	** CD = 52634

- Significant at 5 per cent level
- Significant at 1 per cent level

Further experiments on drip systems were carried out during the years 1989-93. Results pertaining to these studies are presented in Tables 3, 4 & 5. The results showed around 44 % saving water with higher water use efficiency in drip irrigation compared to conventional furrow irrigation. Among drip irrigation systems in the plant crop, sub-surface drip (biwall) at 40/140 cm spacing recorded significantly higher number of millable canes, cane length, single cane weight compared to either conventional furrow irrigation or furrow irrigation based on IW/CPE ratio. In the ratoon crop, biwall irrigation at 60/120 cm gave significantly higher cane length and single cane weight compared in other methods of irrigation. However, cane and sugar yields in Biwall irrigations were on par with conventional furrow irrigation but superior to either surface drip or furrow irrigation based on IW/CPE ratio. In these experiments the surface drip system had the 'key clip' drippers and was attributed for inefficiency.

Table 3 : Effect of irrigation methods on yield components of sugarcane (mean of 2 years)

Sl. No.	Treatments	Number of millable canes ('000/ha)		Cane length (m)		Single cane weight (kg)	
		Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
1	Furrow, conventional	77.8	62.1	1.95	1.39	1.29	0.95
2	Furrow, IW/CPE	72.2	49.7	1.49	1.18	0.98	0.84
3	Biwall, 60/120 cm	83.4	60.2	2.17	1.65	1.43	1.13
4	Biwall, 40/140 cm	85.3	59.0	2.26	1.56	1.48	1.02
5	Surface drip, 40/140 cm	82.8	54.5	2.08	1.40	1.35	0.96
	Sed	2.94	2.32	0.08	0.04	0.06	0.04
	CD (P = 0.05)	6.06	4.79	0.18	0.08	0.13	0.09

Table 4: Effect of irrigation methods on yield and quality of sugarcane (mean of 2 years)

Sl. No.	Treatments	Cane yield (t/ha-1)		Commercial cane sugar (%)		Sugar yield (t/ha-1)	
		Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
	Furrow, conventional	94.7	59.5	11.62	11.98	11.02	7.11
1	Furrow, IW/CPE	67.9	34.8	11.18	12.00	7.69	4.17
2	Biwall, 60/120 cm	98.0	59.6	11.44	12.37	11.21	7.38
3	Biwall, 40/140 cm	98.1	56.4	11.49	12.06	11.32	6.81
4	Surface drip, 40/140 cm	90.1	47.4	11.57	12.12	10.44	5.74
	SEd	4.17	3.11	0.23	0.16	0.36	0.27
	CD (P = 0.05)	8.60	6.43	NS	NS	0.75	0.57

Table 5: Water use in different methods of irrigation (mean of 2 years)

Sl. No.	Treatments	Quantity of water applied (cm)			Water use efficiency (t cm^{-1})		
		Plant	Ratoon	Mean	Plant	Ratoon	Mean
1	Furrow, conventional	199.0	186.0	192.5	0.475	0.319	0.397
2	Furrow, IW/CPE	124.0	123.0	123.5	0.547	0.282	0.414
3	Biwall, 60/120 cm	111.2	102.5	106.8	0.881	0.581	0.731
4	Biwall, 40/140 cm	111.2	102.5	106.8	0.882	0.550	0.716
5	Surface drip, 40/140 cm	111.2	102.5	106.8	0.810	0.462	0.636

We continued studies on drip irrigation again during 1993-96 with a plant and 2 ratoon crops. Results pertaining to this experiment are furnished in Table 6. In the plant crop, the quantity of water used for irrigation was 1140 mm for the drip system, while it was 1660 mm for the conventional furrow method. Number of millable canes, cane length, number of internodes and single cane weight were better in the drip irrigated plots compared to conventional irrigation plots. Surface drip irrigation was better than the sub-surface drip system. The same trend was observed in quality characters, yield of cane and sugar. The cane yield was 96.2, 87.5 and 71.5 t/ha in the surface drip, sub-surface drip and conventional furrow irrigation systems respectively. Thus this particular study indicated significantly higher cane yield under surface drip system with considerable saving in the irrigation water.

Table 6: Effect of irrigation systems in sugarcane

		Conventional Ridges & Furrows	Sub-surface drip	Surface drip
Cane yield (t/ha)	P	71.5	87.5	96.2
	R-I	86.0	73.4	94.1
	R-II	56.1	50.5	66.8
	Mean	71.2	70.5	85.7
CCS %	P	9.41	10.28	10.37
	R-I	10.82	11.94	10.68
	R-II	11.74	11.80	11.53
	Mean	10.66	11.34	10.86
Sugar yield (t/ha)	P	6.73	9.00	9.98
	R-I	9.31	8.76	10.05
	R-II	6.59	5.96	7.70
	Mean	7.54	7.91	9.24
Quantity of irrigation water used (mm)	P	1660	1140	1140
	R-I	1680	1256	1256
	R-II	1860	1286	1286
	Mean	1733	1227	1227

P	=	Plant crop	1993-94
R-I	=	First ratoon	1994-95
R-II	=	Second ratoon	1995-96

In the following year i.e. 1994-95, the experiment on drip irrigation with the I ratoon, indicated that the quantity of water given was 1256 mm for the drip system while it was 1680 mm for the conventional furrow method. Among the drip irrigation systems, surface drip system was better than the sub-surface drip system. Yield parameters like cane length, number of internodes, single cane weight were better under surface drip irrigation compared to other methods. Sub-surface was inferior to the conventional furrow irrigation. The cane and sugar yields were more under surface drip irrigation (94.1 and 10.05 t/ha respectively)

compared to other methods. The conventional method gave 86 t/ha of cane yield of 9.9 t/ha with sugar yield.

In the II ratoon crop (95-96), the quantity of water used in the drip system was 1286 mm as compared to 1860 mm under the conventional furrow method. All the parameters like cane length, cane diameters, number of internodes, single cane weight were better under surface drip irrigation compared to the conventional ridges and furrow system and sub-surface irrigation. There was no difference in quality due to various irrigation systems. Higher cane and sugar yields were obtained in the surface drip irrigation as compared to other methods of irrigation.

The mean result from a plant and two ratoons indicated around 30 per cent saving in the irrigation water by employing drip systems. Surface drip with pressure compensating drippers was found better giving about 15 t/ha more cane yield.

Planting geometry for saving irrigation water

We have also conducted some field experiments to study the productivity of sugarcane in paired row system (60/120 cm and 60/90 cm) in comparison with 90 cm uniform rows with and without trash mulch and also to study the feasibility of skip furrow irrigation for saving irrigation water without reduction in the yield.

The results indicated that 60/90 cm paired rows either with normal furrow irrigation and trash mulch or skip furrow irrigation and trash mulch in unirrigated furrows recorded cane yield of 86.8 and 81.0 t/ha compared to 75.2 t/ha in the conventional method. However, the second treatment resulted in about 10 % saving in irrigation water with 160 cm while under control it was 180 cm (Fig. 1).

It was concluded that when there was no limitation of water, sugarcane productivity could be improved by adopting 60/90 cm paired rows with normal irrigation and trash mulch and when there was shortage of water, adoption of skip furrow irrigation in 60/90 cm with trash mulch was found superior compared to conventional 90 cm uniform furrow irrigation.

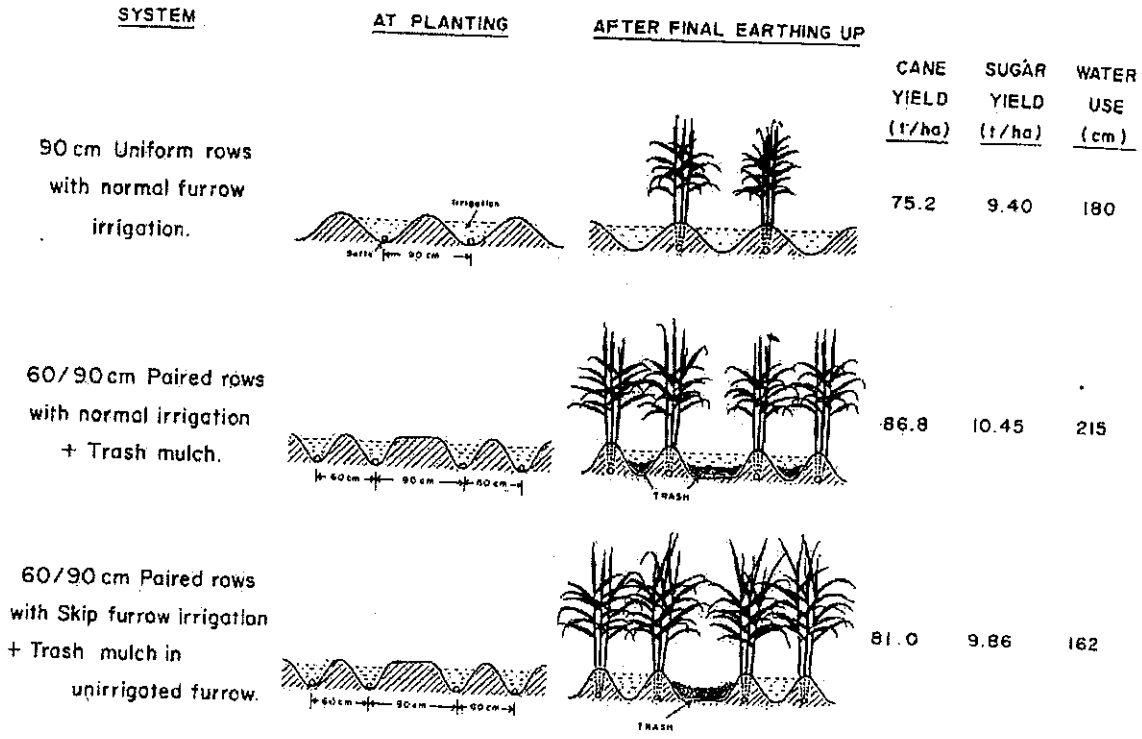

Fig. 1. Planting geometry for saving water

Management practices under moisture stress/drought

Besides, the studies on irrigation methods, we have also been carrying out extensive studies to develop management practices to raise sugarcane under limited water availability and drought. Our results based on a large number of field experiments and on-farm trials have indicated that for raising a reasonably good crop of sugarcane under drought or moisture stress, the following measures are highly useful:

1. Early planting
2. Soaking setts in saturated lime water
3. Closer row spacing of 60 – 75 cm
4. Trash mulching
5. Foliar application of urea and potassium each at 2.5 % concentration at fortnightly interval during the drought period
6. Additional potassium application
7. Planting sugarcane in trenches

These practices have become very popular and are being extensively adopted particularly in the tropical Indian States.

Drought tolerant varieties

We have identified a number of sugarcane clones which could be grown successfully under limitation of water. The following is the list of such varieties currently available with us:

Drought tolerant varieties

Co 86010	Co 90009	Co 92033
Co 86249	Co 91010	Co 94005
Co 86032	Co 91012	Co 94008
Co 87023	Co 91013	Co 96008
Co 87263	Co 91018	Co 96012
Co 88042	Co 91021	Co 96019
Co 89029	Co 92009	Co 96020
Co 89030	Co 92023	Co 97007
Co 89032	Co 92030	Co 97010
Co 89036	Co 92031	Co 98013

Managing of sugarcane under saline water irrigation

Sugarcane cultivation has expanded to the marginal soils. One of the problems confronted is salinity of water. We have also been working extensively on improving productivity of sugarcane under saline water irrigated conditions. Our results have indicated that planting of sugarcane in trenches, application of gypsum in the trenches at 10 t/ha and zinc sulphate at 20 kg/ha, and pocket manuring are helpful to raise good crops under saline water irrigated conditions. Besides, we have also identified a number of varieties of sugarcane which can tolerate salinity and can give reasonably good yield. The list of varieties available with us are furnished below:

Salinity tolerant varieties

Co 87002	Co 89010	Co 89027	Co 90010	Co 91002
Co 91005	Co 91011	Co 92012	Co 93005	Co 93009
Co 93011	Co 93015	Co 93016	Co 93018	Co 93019
Co 94004	Co 93021	Co 93079	Co 94005	Co 94008
Co 94010	Co 94011	Co 94012	Co 94015	CoJn 86141
CoJn 94141	CoG 93076	CoG 9349	MS 92121	

Our perspective plans of research towards water use efficiency in sugarcane

At present, we are concentrating on bio-technological approaches to develop water use efficient types of sugarcane cultivars and cultivars that can tolerate drought and salinity. We are building genetic stocks for this purpose, creating facilities and training the man power.

We want to initiate work on various newer micro irrigation systems and to study the related problems and evolve cost effective methods of irrigation which can sustain productivity and economise irrigation water.

We are planning on-farm trials with drought and salinity tolerant clones in various endemic locations.

We are working on multi ratooning systems which would help economical adoption of micro irrigation systems.

Some issues that need attention to improve adoption of drip irrigation in sugarcane

During the course of our investigations on drip irrigation, we have noted some important issues which need to be tackled to make the system more popular amongst the sugarcane farmers.

1. Requirement of laterals and drippers is very high as compared to wide spaced perennial crops and thus making the system very costly.
2. In India, farm holdings are small and are composed of fields of different sizes and elevations and hence create difficulty in the installation of the drip system.
3. There is a need to modify the crop geometry to suit installation of drip system.
4. Quite often the existing pumps with the farmers do not match with the requirement of the drip irrigation system. Hence replacement of old pumps or installation of additional pumps by the farmers may be required which again would add to the cost.
5. Clogging of drippers is a major problem, particularly with poor quality irrigation water.
6. At farm level, computing the exact quality of irrigation water to be applied is difficult and hence there is deficit application than the actual requirement.
7. Leakage of irrigation water in the joints of laterals and drippers is common which leads to excess irrigation in patches thus leading to ununiform crop growth and wastage of water.
8. Damage to components by animals, farm tools and implements and trampling by farm labour has been observed. This would lead to additional maintenance cost.
9. The system has too many control valves requiring frequent replacements.

10. Salt deposition in components like pressure gauges, filters and water meters have been observed and necessitates replacement and repairs thus adding to maintenance cost.
11. The adoption of drip system needs daily attention.
12. The drip irrigation components vary widely in their quality and longevity and hence farmers getting material of poor quality is common.
13. In rural areas, there are difficulty in getting skilled labourers and spares for replacement.
14. We have observed shallow rooting of sugarcane under drip system of irrigation. This may lead to lodging, affecting cane yield and quality.
15. For fertigation, availability of liquid fertilizers is difficult.
16. Shifting and reinstallation of the system also leads to damage and add to the maintenance cost.

These constraints are mentioned here only to focus attention of the designers, researchers and others concerned so that suitable remedial measures can be worked out.

Conclusion

There is urgent need to improve water use efficiency in sugarcane farming in view of the increasing scarcity of water and frequent droughts and competition from other crops and domestic and industrial users. Micro irrigation systems are a potential means of increasing water use efficiency and productivity of sugarcane and need to be extensively adopted in the years and decades to come. This calls for concerted efforts of system designers, researchers, development workers and farmers to find solutions to various problems observed.

In our considered opinion, particularly any effort made to reduce the cost of drip system would vastly help increase its adoption by large section of farming community. Longivity of the system, easy availability of quality spares and components would further help in popularizing the system. We have also considered changes in the sugarcane planting patterns and need for multi ratooning, for the success of drip system. Thus in view of the acute shortage of irrigation water existing in the country and further shortages in the future too, it is essential that micro irrigation systems are made popular since they hold promise to economise the water and sustain productivity. In this direction, researchers and development workers need to concentrate on issues relating to cost of the system, its longevity in the field, its proper operation by the farmers. At Sugarcane Breeding Institute, we would like to continue research on these issues in the years to come and we will be glad to cooperate with system developers and manufacturers to make them more popular.

Note: Materials for this paper has been drawn from the following sources:

1. Sugarcane Breeding Institute Annual Reports of the years 1976 to 1978 and 1989 to 1996
2. Ramesh, P., Kailasam, C. and Srinivasan, T.R. (1994). Performance of sugarcane (*Saccharum officinarum* L.) under surface drip, sub-surface drip (Biwall) and furrow method of irrigation. J. Agronomy & Crop Science 172: 237-241
3. The author's work on management of sugarcane under drought and salinity

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