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CONTENTS

Study on the effect of different irrigation and fertilizer application methods on yield and water use efficiency in sugarcane

S THENMOZHI[1], G THIYAGARAJAN[2], SK NATARAJAN[3], M MANIKANDAN[4] and J BHUVANESWARI[5]

[1]ICAR – Krishi Vigyan Kendra, TNAU, Pongalur, Tiruppur 641667 Tamil Nadu, India
[2]Forest College and Research Institute, TNAU, Mettupalayam 641301 Tamil Nadu, India
[3]Controllerate of Examinations, Tamil Nadu Agricultural University
Coimbatore 641003 Tamil Nadu, India
[4]Agricultural Research Station, TNAU, Kovilpatti 628501 Tamil Nadu, India
[5]Agricultural College and Research Institute, TNAU, Killikulam 628252 Tamil Nadu, India
Email for correspondence: thiyagu@tnau.ac.in

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ABSTRACT

Field experiment was conducted to find out the effect of surface and sub-surface methods of irrigation and the method of fertilizer application on movement of nutrients in sugarcane at Agricultural Research Station, Bhavanisagar, Tamil Nadu. The experiment was laid out in strip plot design in plot size of 45 m^2 with 2 main plot treatments viz M_1 (Drip irrigation at 80% PE once in two days with 1.5 m lateral) and M_2 (Sub-surface irrigation at 100% PE) and 5 sub-plot treatments viz S_1 (Absolute control), S_2 (Manual – band application of N, P and K fertilizers), S_3 (Manual – hole placement application of N, P and K fertilizers), S_4 (Application of N and K through irrigation water and P as basal) and S_5 (Application of nutrients through water soluble fertilizers N, P and K), treatments replicated thrice. The results of the experiment revealed that sub-surface irrigation at 100 per cent PE with manual – hole placement application of N, P and K fertilizers was superior in enhancing the growth and yield attributes and yield of sugarcane as compared to other treatment combinations. Maximum water use efficiency was achieved in drip irrigation at 80 per cent PE once in two days with manual – hole placement application of N, P and K fertilizers.

Keywords: Irrigation; fertilizer; sugarcane; yield; water use efficiency

INTRODUCTION

Sugarcane (*Saccharum officinarum* L) is one of the most important crops in the world. It plays a vital economic role in sugar and bioenergy production and has an important social role in the rural communities of sugar producing nations worldwide. Surface, overhead and drip irrigation methods are most commonly used to irrigate sugarcane crops (Carr and Knox 2011) depending on physical characteristics, economic factors and social and other considerations.

The performance of irrigation systems directly affects crop performance, water use efficiency (WUE), cost of production and profit and is, therefore, of keen interest to farmers (Mudima 2002, Thiyagarajan et al 2011). The same irrigation method and the same amount of water can produce significant differences in yield with different patterns of water application. Therefore, more uniform irrigation application needs to be targeted through design, continuous evaluation and maintenance practices (Lecler and Jumman 2009).

However, continuous evaluation and maintenance require farmers to invest time and money that they may not have. Traditionally, most sugarcane farming systems use surface (specifically furrow) irrigation because of its simplicity and low cost. But the increasing cost of energy and labour and the increasing demand for scarce water resources has led to greater adoption of overhead or drip irrigation methods. Globally, agriculture uses 70 per cent of the planet's freshwater resources and 95 per cent of the world's farmers use flood irrigation (https://www.agrivi.com/blog/modern-management-of-centennial-furrow-irrigation/).

The major drawbacks of furrow irrigation and the main reasons for its unpopularity among sugarcane farmers are the high labour requirement and low WUE stemming from percolation and tail-water losses (Narayanamoorthy 2005). Furrow irrigation is remarkably less efficient in light textured soils than overhead and drip irrigation systems.

Although measures such as the use of low flow rates, surge irrigation and local modifications can increase the efficiency of furrow irrigation to a degree, such refinements have not been able to achieve satisfactory levels of efficiency and do not obviate the high labour requirement (Gunarathna et al 2018).

Sub-surface drip irrigation enhances growth and yield not only through the precise application of the right amount of water but also by maintaining adequate aeration of the root zone. Further, it promotes the effectiveness of applied fertilizers by minimizing losses through processes such as denitrification, deep percolation and runoff which can occur with other irrigation methods.

The optimum depth of sub-surface drip lines varies between 10 to 80 cm depending on the soil type, soil depth and crop type, as capillary action ensures water uptake by upward water movement. With the same amount of water, sub-surface drip irrigation wets an area of about 50 per cent larger than surface drip irrigation does.

Mahesh et al (2016) and Manikandan et al (2019) reported that sub-surface and surface drip irrigation can save 31 and 23 per cent of water compared to surface irrigation. They further reported significantly higher sugarcane yield and WUE with sub-surface fertigation than with surface irrigation with conventional fertilizer application.

However, sub-surface drip irrigation entails some drawbacks, such as low germination if there is poor capillary movement, salinity, nozzle clogging and uneven water distribution (Kaushal et al 2012). Moreover, it does not always assure high efficiency and good yield because it requires an accurate design, use of models and a skilled operator (Dlamini 2005, Aravind et al 2021). Therefore, new methods or strategies must be introduced to sub-surface irrigation systems to achieve better precision while overcoming the inherent disadvantages of available sub-surface irrigation methods.

MATERIAL and METHODS

The experiment was conducted at Agricultural Research Station, Bhavanisagar, Erode district, Tamil Nadu. The initial soil samples were collected, processed and analysed for physical properties viz bulk density, particle density and pore space; chemical properties viz pH, EC, CEC and organic carbon and fertility parameters (available nutrients) as given in Table 1.

The experiment was laid out in strip plot design in a plot size of 45 m^2 with 2 main plot treatments viz M_1 (Drip irrigation at 80% PE once in two days with 1.5 m lateral) and M_2 (Sub-surface irrigation at 100% PE) and 5 sub-plot treatments viz S_1 (Absolute control), S_2 (Manual – band application of N, P and K fertilizers), S_3 (Manual – hole placement application of N, P and K fertilizers), S_4 (Application of N and K through irrigation water and P as basal) and S_5 (Application of nutrients through water soluble fertilizers N, P and K), treatments replicated thrice.

Thirty days old sugarcane seedlings were planted at a spacing of 5 feet between rows and 2 feet between plants. Intercultural operations like gap filling, spraying herbicides, hand weeding etc were followed as per crop production guide. The irrigation and fertigation were followed as per the treatment schedule (Table 2).

Table 1. Initial soil characteristics

Component	Characteristic/value
Soil texture	Sandy loam
pH	7.13
EC (dS/m)	0.13
Bulk density (Mg/m^3)	1.25
Particle density (Mg/m^3)	1.82
Pore space (%)	31.25
Organic carbon (%)	0.20
Available nitrogen (kg/ha)	275
Available phosphorus (kg/ha)	14.0
Available potassium (kg/ha)	290

Table 2. Fertigation schedule (kg/acre)

Days	Urea	Super phosphate	Potash	Days	Urea	Super phosphate	Potash
20	11	0	0	130	17	13	4
30	11	0	0	140	9	0	4
40	11	0	0	150	9	0	4
50	14	24	2	160	9	0	4
60	14	24	2	170	9	0	4
70	14	24	2	180	9	0	4
80	16	19	3	190	9	0	6
90	16	19	3	220	3	0	6
100	16	19	3	230	3	0	6
110	17	13	4	240	3	0	6
120	17	13	4	250	3	0	6

Recommended dose: 240:168:78 kg urea, super phosphate and potash/acre

Table 3. Growth parameters of sugarcane

Treatment	Plant height (cm)			Number of leaves			Leaf length (cm)		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
S_1	286.8	287.0	286.9	8.4	7.5	7.9	121.7	129.3	125.5
S_2	311.3	346.7	329.0	10.6	10.4	10.5	133.6	139.0	136.3
S_3	340.0	346.3	343.2	12.1	10.3	11.1	143.3	141.9	142.6
S_4	349.7	319.7	334.7	10.7	11.3	11.0	143.9	138.4	141.2
S_5	315.7	330.5	323.1	9.8	12.1	10.9	133.9	138.0	135.0
Mean	320.7	326.0		10.2	10.3		135.3	137.2	

	Plant height		Number of leaves		Leaf length	
	SED	$CD_{0.05}$	SED	$CD_{0.05}$	SED	$CD_{0.05}$
M	11.42	NS	0.56	NS	4.04	NS
S	9.98	21.2	0.57	1.20	3.70	7.83
M x S	17.03	NS	0.91	2.69	6.2	NS

M_1: Drip irrigation at 80% PE once in two days with 1.5 m lateral, M_2: Sub-surface irrigation at 100% PE; S_1: Absolute control, S_2: Manual– band application of N, P and K fertilizers, S_3: Manual– hole placement application of N, P and K fertilizers, S_4: Application of N and K through irrigation water and P as basal, S_5: Application of nutrients through water soluble fertilizers (N, P and K); NS: Non-significant

RESULTS and DISCUSSION

Effect of treatments on growth parameters of sugarcane

The biometric observations on growth and yield parameters were recorded at the harvest of the crop. The growth and yield parameters viz the plant height, number of tillers, number of leaves and leaf length were recorded (Table 3).

The data show that plant height was 320.7 and 326.0 cm in M_1 (Drip irrigation at 80% PE once in two days with 1.5 m lateral) and M_2 (Sub-surface irrigation at 100% PE) respectively which were at par.

Higher plant height of 329.0, 343.2, 334.7 and 323.1 cm was recorded in S_2 (Manual– Band application of N, P and K fertilizers), S_3 (Manual– hole placement application of N, P and K fertilizers), S_4 (Application of N and K through irrigation water and P as basal) and S_5 [Application of nutrients through water soluble fertilizers (N, P and K)] respectively, all four being statistically at par as compared to 286.9 cm in S_1 (Absolute control). In case of interaction effect, the treatments differed non-significantly for plant height.

Number of leaves was 10.2 and 10.3 in M_1 and M_2 respectively which were statistically at par. As in case of plant height, the treatments S_2 (10.5), S_3 (11.1), S_4 (11.0) and S_5 (10.9) had no significant difference for number of leaves which was higher than S_1 (7.9). In case of interaction effect, S_1 x M_2 (7.5), S_1 x M_1 (8.4) and S_5 x M_1 (9.8) were at par for number of leaves which was lower as compared to other treatments.

Leaf length in case of M_1 (135.3 cm) and M_2 (137.2 cm) differed non-significantly. It was higher in S_2 (136.3 cm), S_3 (142.6 cm), S_4 (141.2 cm) and S_5 (135.0 cm) as compared to S_1 (125.5 cm), the first four being at par. However, there was no significant effect of interactions on leaf length.

Yield parameters of sugarcane as influenced by treatments

The data in Table 4 show that number of tillers in M_1 (11.9) and M_2 (13.0) did not differ significantly. The treatments S_2 (12.6), S_3 (14.2), S_4 (14.1) and S_5 (13.0) were at par for number of tillers which was higher as compared to S_1 (8.4). There was no significant interaction effect of the treatments on number of tillers.

Table 4. Yield parameters of sugarcane

Treatment	Number of tillers			Cane yield (tons/ha)		
	M_1	M_2	Mean	M_1	M_2	Mean
S_1	7.6	9.2	8.4	92.8	95.5	94.2
S_2	11.7	13.3	12.6	110.9	122.7	116.8
S_3	14.2	14.1	14.2	136.3	147.7	142.0
S_4	14.1	14.1	14.1	124.9	137.3	131.1
S_5	11.7	14.3	13.0	118.0	134.3	126.2
Mean	11.9	13.0		116.6	127.5	

	Number of tillers		Cane yield	
	SED	$CD_{0.05}$	SED	$CD_{0.05}$
M	0.43	NS	14.3	NS
S	0.74	1.56	13.0	27.5
M x S	1.03	NS	21.8	NS

M_1: Drip irrigation at 80% PE once in two days with 1.5 m lateral, M_2: Sub-surface irrigation at 100% PE; S_1: Absolute control, S_2: Manual– band application of N, P and K fertilizers, S_3: Manual– hole placement application of N, P and K fertilizers, S_4: Application of N and K through irrigation water and P as basal, S_5: Application of nutrients through water soluble fertilizers (N, P and K); NS: Non-significant

M_1 (116.6 tons/ha) and M_2 (127.5 tons/ha) were at par for cane yield. The treatments S_2 (116.8 tons/ha), S_3 (142.0 tons/ha), S_4 (131.1 tons/ha) and S_5 (126.2 tons/ha) were at par for cane yield which was higher as compared to S_1 (94.2 tons/ha). There was no significant effect of interactions on the cane yield.

Economics

Irrigation regimes and fertilizer treatments had a significant effect on sugarcane economics (Table 5). M_2S_3 (Sub-surface irrigation at 100% PE with manual- hole placement application of N, P and K fertilizers) recorded the highest income (Rs 3,58,911) followed by M_2S_4 (Sub-surface irrigation at 100% PE with application of N and K through irrigation water and P as basal) (Rs 3,33,639), net return (Rs 2,62,911) followed by M_1S_3 (Drip irrigation at 80% PE once in two days with 1.5 m lateral with manual – hole placement application of N, P and K fertilizers) (Rs 2,40,209) and B-C ratio (3.74) followed by M_1S_3 (Drip irrigation at 80% PE once in two days with 1.5 m lateral with manual – hole placement application of N, P and K fertilizers) (3.64).

Highest cost of cultivation was recorded in M_2S_5 [Sub-surface irrigation at 100% PE with application of nutrients through water soluble fertilizers (N, P and K)] (Rs 99,635) followed by M_2S_3 (Sub-surface irrigation at 100% PE with manual- hole placement application of N, P and K fertilizers) (Rs 96,000). Minimum income (Rs 2,25,504), cost of cultivation (Rs 81,057), net return (Rs 1,44,447) and B-C ratio (2.78) were recorded in M_1S_1 (Drip irrigation at 80% PE once in two days with 1.5 m lateral with absolute control).

Total water used and water use efficiency

The water use efficiency was worked out (Table 6). The data show that the highest total water used was noticed in interactions having M_2 (Sub-surface irrigation at 100% PE) (1,752.8 mm) as compared to the interactions having M_1 (1,157.7 mm).

The highest water use efficiency was recorded in M_1S_3 (Drip irrigation at 80% PE once in two days with 1.5 m lateral with manual– hole placement application of N, P and K fertilizers) (117.7 kg/ha.mm) and the lowest (70.0 kg/ha.mm) in M_2S_5 [Sub-surface

Table 5. Economics of sugarcane

Treatment	Income (Rs)	Cost of cultivation (Rs)	Net return (Rs)	B-C ratio
M_1S_1	2,25,504	81,057	1,44,447	2.78
M_1S_2	2,69,487	90,000	1,79,487	3.00
M_1S_3	3,31,209	91,000	2,40,209	3.64
M_1S_4	3,03,507	90,000	2,13,507	3.37
M_1S_5	2,86,740	94,635	1,92,105	3.03
M_2S_1	2,32,065	80,172	1,51,893	2.89
M_2S_2	2,98,161	95,000	2,03,161	3.14
M_2S_3	3,58,911	96,000	2,62,911	3.74
M_2S_4	3,33,639	95,000	2,38,639	3.51
M_2S_5	3,26,349	99,635	2,26,714	3.28

M_1: Drip irrigation at 80% PE once in two days with 1.5 m lateral, M_2: Sub-surface irrigation at 100% PE; S_1: Absolute control, S_2: Manual– band application of N, P and K fertilizers, S_3: Manual– hole placement application of N, P and K fertilizers, S_4: Application of N and K through irrigation water and P as basal, S_5: Application of nutrients through water soluble fertilizers (N, P and K)

Table 6. Total water used and water use efficiency

Treatment	Component	
	Total water used (mm)	WUE (kg/ha.mm)
M_1S_1	1,157.7	95.0
M_1S_2	1,157.7	94.1
M_1S_3	1,157.7	117.7
M_1S_4	1,157.7	107.9
M_1S_5	1,157.7	91.7
M_2S_1	1,752.8	77.1
M_2S_2	1,752.8	76.6
M_2S_3	1,752.8	101.4
M_2S_4	1,752.8	78.3
M_2S_5	1,752.8	70.0

M_1: Drip irrigation at 80% PE once in two days with 1.5 m lateral, M_2: Sub-surface irrigation at 100% PE; S_1: Absolute control, S_2: Manual– band application of N, P and K fertilizers, S_3: Manual– hole placement application of N, P and K fertilizers, S_4: Application of N and K through irrigation water and P as basal, S_5: Application of nutrients through water soluble fertilizers (N, P and K)

irrigation at 100% PE with application of nutrients through water soluble fertilizers (N, P and K)].

CONCLUSION

From the results of the experiment it was concluded that sub-surface irrigation at 100 per cent PE with manual – hole placement application of N, P and K fertilizers recorded the highest income (Rs 3,58,911), net return (Rs 2,62,911) and B-C ratio (3.74) as compared to other treatments. Thus this combination of treatments was the best for better yield and water use efficiency in sugarcane.

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