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Studies on the effect of surface and subsurface methods of irrigation and method of fertilizer application on growth and yield parameters, yield, economics and water use efficiency in sugarcane

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Abstract
Field experiment was conducted to find out the effect of surface and subsurface methods of irrigation and the method of fertilizer application on movement of nutrients in sugarcane, at Agricultural Research Station, Bhavanisagar. 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 - Subsurface irrigation at 100% PE and 5 subplot treatments, *ie.,* 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) and replicated thrice. The result of the experiment revealed that subsurface irrigation at 100% PE with manual - hole placement application of N, P and K fertilizers) is superior in enhancing the growth and yield attributes and yield of sugarcane when compared to other treatment combinations.

Keywords: PROM, groundnut, sulphur, iron, growth, yield, quality

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) [2] depending on physical characteristics, economic considerations 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) [3]. 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) [4]. However, continuous evaluation and maintenance require farmers to invest time and money that they may not have. Traditionally, most sugarcane farming systems used surface (specifically furrow) irrigation because of its simplicity and low cost. But the increasing cost of energy and labor and the increasing demand for scarce water resources has led to greater adoption of overhead or drip irrigation methods. However, furrow irrigation is still the major method used worldwide (McGuire *et al.,* 2010) [5]. The major drawbacks of furrow irrigation and the main reasons for its unpopularity among sugarcane farmers are the high labor requirement and low WUE stemming from percolation and tail-water losses (Narayanamoorthy, 2005) [6]. 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 (Torres *et al.*, 2010) [7], surge irrigation (Young *et al.*, 2017) [8] 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 labor requirement.

Subsurface 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 subsurface drip lines varies between 10 and 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, subsurface drip irrigation wets an area about 50% larger than surface drip irrigation does (Mahesh *et al.*, 2016) [10] reported that subsurface and surface drip irrigation can save 31% and 23% of water relative to surface irrigation. They further reported significantly higher sugarcane yield and WUE with subsurface fertigation than with surface irrigation with a conventional fertilizer application. However, subsurface drip irrigation entails some drawbacks, such as low germination if there is poor capillary movement, salinity, nozzle clogging and uneven water distribution.

Moreover, it does not always assure high efficiency and good yield because it requires an accurate design and a skilled operator (Dlamini, 2005) [12]. Therefore, new methods or strategies must be introduced to subsurface irrigation systems to achieve better precision, while overcoming the inherent disadvantages of available subsurface irrigation methods.

Materials and Methods

The experiment was conducted at Agricultural Research Station, Bhavanisagar, Erode district, Tamil Nadu. The initial soil sample was 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) (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 - Subsurface irrigation at 100% PE and 5 subplot treatments, i.e., 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) and replicated thrice. Sugarcane seedlings of 30 days old were planted at a spacing of 5 feet between rows and 2 feet between plants. Intercultural operations like gap filling, spraying herbicides, hand weeding were followed as per crop production guide. The irrigation and fertigation were followed as per the treatment schedule.

Fertigation Schedule kg/acre

Days	Urea	Super	Potash	Days	Urea	Super	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, Potash/acre.

Results and Discussion

Table 1: Initial soil Characteristics

Soil Texture	Sandy Loam
pH	7.13
EC (dsm^{-1})	0.13
Bulk density (Mg m^{-3})	1.25 Mg/m^3
Particle density	1.82 Mg/m^3
Pore space	31.25 Per cent
Organic carbon (%)	0.20
Available Nitrogen (kg ha^{-1})	275
Available Phosphorus (kg ha^{-1})	14.0
Available Potassium (kg ha^{-1})	290

Growth parameters of sugarcane influenced by treatments

The biometric observations on growth and yield parameters were recorded during 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 and reported below.

Treatments	Plant height (cm)			No. of leaves (cm)			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	
	SED		CD (P=0.05)	SED		CD (P=0.05)	SED		CD (P=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
S x M	14.12		29.94	0.80		1.69	5.2		11.08

The data indicated that, among the main plot treatments the highest plant height (326.0 cm) was recorded by M_2 (subsurface irrigation at 100% PE) and there was no significant difference between M_1 and M_2. Among the subplot treatments the highest plant height (343.2 cm) was registered by S_3 (manual-whole placement application of N, P and K fertilizers). The treatments S_2, S_3, S_4 and S_5 were on par with each other. The plant height was not significantly influenced by the interaction effect.

With respect to number of leaves and leaf length, among the main plot treatments the highest values of 10.3 and 137.2 cm were recorded by M_2 (subsurface irrigation at 100% PE) and there was no significant difference between the main plot treatments. Among the subplot treatments the highest number of leaves and leaf length were recorded by S_3 (manual - hole placement application of N, P and K fertilizers) and the treatments S_2, S_3, S_4 and S_5 were on par with each other and the lowest number of leaves and leaf length were recorded by S_1.

Yield parameters of sugarcane influenced by treatments

Treatments	No of tillers			Cane yield (t ha^{-1})		
	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	
	SED		CD(P=0.05)	SED		CD(P=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
S x M	1.04		2.21	18.4		NS

The data indicated that, among the main plot treatments the highest number of tillers (13) and cane yield (127.5 t ha^{-1}) were recorded by M_2 (subsurface irrigation at 100% PE) and there was no significant difference between M_1 and M_2. Among the subplot treatments the highest number of tillers (14.2) and cane yield (142.0) were registered by S_3 (manual-whole placement application of N, P and K fertilizers). The treatments S_3 and S_4 were on par with each other. The number of tillers and cane yield were not significantly influenced by the interaction effect. These results confirm the observation of Mahendran *et al.* (2005), who reported application of 100 per cent of the recommended dose of N and K in 14 equal spilts (up to 210 DAP) to sugarcane crop.

Economics

Irrigation regimes and fertilizer treatments increased the net return. Subsurface irrigation at 100% PE with manual - hole placement application of N, P and K fertilizers (M_2S_3) recorded the highest B : C ratio of 3.74, followed by 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 (M_2S_3) as 3.64. The lowest B: C ratio of 2.78 was recorded with drip irrigation at 80% PE once in two days with 1.5 m lateral with no fertilizer (M_1S_1).

Sugarcane

Treatments	Yield (tha^{-1})	Income (Rs.)	Cost of cultivation (Rs.)	Net return (Rs.)	B:C Ratio
M_1S_1	92.8	225504	81057	144447	2.78
M_1S_2	110.9	269487	90000	179487	3.00
M_1S_3	136.3	331209	91000	240209	3.64
M_1S_4	124.9	303507	90000	213507	3.37
M_1S_5	118.0	286740	94635	192105	3.03
M_2S_1	95.5	232065	80172	151893	2.89
M_2S_2	122.7	298161	95000	203161	3.14
M_2S_3	147.7	358911	96000	262911	3.74
M_2S_4	137.3	333639	95000	238639	3.51
M_2S_5	134.3	326349	99635	226714	3.28

Cost of sugarcane = Rs. 2430/t

Total water used and water use efficiency

The water use efficiency was worked out and furnished below. The results showed that, the highest total water used was noticed in M_2 (subsurface irrigation at 100% PE) as 1157.8 mm. The water use efficiency of treatments indicated that, the highest water use efficiency value (117.7 kg/ha.mm) was noted with drip irrigation at 80% PE once in two days with 1.5 m lateral with manual-whole placement application of N, P and K fertilizers and the lowest value (70.0 kg/ha.mm) was noted with subsurface irrigation at 100% PE with application of nutrients through water soluble fertilizers.

Particulars and Treatments	Yield (t/ha)	Total water used (mm)	WUE (kg/ha.mm)
M_1S_1	92.8	1157.7	95.0
M_1S_2	110.9	1157.7	94.1
M_1S_3	136.3	1157.7	117.7
M_1S_4	124.9	1157.7	107.9
M_1S_5	118.0	1157.7	91.7
M_2S_1	95.5	1752.8	77.1
M_2S_2	122.7	1752.8	76.6
M_2S_3	147.7	1752.8	101.4
M_2S_4	137.3	1752.8	78.3
M_2S_5	134.3	1752.8	70.0

Conclusion

The study demonstrates that subsurface irrigation significantly enhances sugarcane growth and yield compared to traditional methods. Specifically, subsurface irrigation at 100% potential evapotranspiration (PE) resulted in the highest plant height, number of tillers, and cane yield, indicating its effectiveness in optimizing water use efficiency. Additionally, the manual hole placement application of fertilizers further improved growth parameters and economic returns, achieving the highest benefit-cost ratio. While subsurface irrigation presents some challenges, such as potential clogging and uneven water distribution, its advantages in water conservation and yield enhancement make it a viable alternative for sugarcane cultivation. Overall, adopting advanced irrigation techniques can lead to more sustainable and profitable sugarcane farming practices.

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