Subsurface Drip Fertigation: A Tool for Practicing 4R Nutrient Stewardship in Sugarcane

By R. Mahesh, B. Patil, and H.A. Archana

Dr. Mahesh amongst robust growth of sugarcane receiving the right method of fertilizer application through sub-surface drip irrigation (SSDF) using a mix of water soluble fertilizers (WSF).

Subsurface drip fertigation , an advanced method for co-application of water and nutrients following the principles of 4R Nutrient Stewardship (right source, rate, time, and place), has the capability to deliver nutrients uniformly within the effective root volume zone where most of the active roots are concentrated.

When adopted in the sugarcane fields of Tamil Nadu, this system demonstrated an overall increase in cane yield of 62 t/ha while improving nutrient use efficiency and farm net income.

KEYWORDS:
4R Nutrient Stewardship; fertigation; water soluble fertilizers.

ABBREVIATIONS AND NOTES:
N = nitrogen; P = phosphorus; K = potassium; DAP = diammonium phosphate; MAP = monoammonium phosphate; KCl = potassium chloride; KNO_3 = potassium nitrate; K_2SO_4 = potassium sulfate; US$1= 64.37 Indian Rupee (Rs.).

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Researchers are finding that India's sugarcane production systems are suffering from incremental stress as they attempt to raise production to meet growing demands. In recent years, yields have declined due to inappropriate water and nutrient management practices. Large vegetative growth with heavy tonnage removes substantial amounts of nutrients from the soil that need to be replenished. Conventional nutrient management practices lead to N losses through immobilization, denitrification, volatilization, and leaching. Applied P and K is susceptible to soil fixation, which contributes to their imbalance within the rhizosphere. Applying fertilizers in limited splits at inappropriate timings reduces nutrient use efficiency (NUE).

Study Description

The experiment described below compared subsurface drip fertigation (SSDF), surface drip fertigation (SDF), and traditional surface-applied granular fertilizers (GF) combined with in-furrow, surface irrigation (SI). Mixtures of

Table 1. Outline of treatment details applied to sugarcane, Tamil Nadu, India.

Treatment/ Source	% of State rec.	Rate, kg $N-P_2O_5-K_2O$/ha	No. of applications
Subsurface Drip Fertigation (SSDF)			
T1: WSF[1]	75	225-75-150	
T2: WSF[2]	100	300-100-200	
T3: WSF[2]	75	225-75-150	
T4: GF[3]	100	300-100-200	
T5: GF	75	225-75-150	
T6: WSF[2]+GF	75	225-75-150	27
	25	75-25-50	
T7: WSF[2]+GF	50	150-50-100	
	50	150-50-100	
T8: WSF[2]+GF	25	75-25-50	
	75	225-75-150	
Surface Drip Irrigation			
T9: WSF[2]	100	300-100-200	27
T10: GF	100	300-100-200	
Surface Irrigation (SI)			
T11: GF	100	300-100-200	1

[1]Mixture of fertilizers (WSF grade) solubilized in water: 19-19-19, Urea phosphate (17-44-0), K_2SO_4 (0-0-50), Urea (46-0-0)
[2]Mixture fertilizers (WSF grade) solubilized in water: 19-19-19, MAP (12-61-0), KNO_3 (13-0-45), Urea
[3]Mixture of urea, DAP, and KCl (0-0-60)

solubilized fertilizer (WSF) were also compared with GF in different combinations designed around the state recommendation (SR = 300-100-200 kg $N-P_2O_5-K_2O$/ha) for a yield target of 200 t cane/ha (**Table 1**).

The SSDF design included 16 mm lateral distribution lines that were laid out belowground at a spacing of 1.65 m. The emitter spacing was 0.4 m. The water discharge

Table 2. Fertigation schedules for sugarcane growing season, Tamil Nadu, India.

Stage (days)	Concentrations of nutrients applied, % N	P_2O_5	K_2O	No of applications[1]
1 to 30	5.0	10.6	1.8	3
31 to 60	4.6	8.0	2.2	4
61 to 90	4.6	4.8	2.2	4
91 to 20	5.0	4.3	2.7	4
121 to 180	2.7	0	4.4	8
181 to 210	1.8	0	7.7	4

[1]Each application was scheduled at seven-day intervals.

rate was 4 l/hr. Nutrient stock solutions were prepared by dissolving fertilizers within a 1:5 mixture of fertilizer to water. During each fertigation schedule, the drip system was flushed with water prior to the application of the fertilizers. This was followed by another flushing of drip system for five to ten minutes every second day. Surface and subsurface drip fertigation were carried out by slightly wetting of the root zone before fertigation, followed by flushing the nutrients with water. The control for this study was the SI treatment, which applied all the P basally as granular DAP and all the N (granular urea) and K (granular KCl) were applied in three equal splits at 30, 60, and 90 days after planting. Irrigation occurred every second day and fertigation events occurred at one week intervals (**Table 2**). The fertigation schedule was designed to meet the sugarcane nutrient requirement at different stages of crop growth. A total of 27 fertigation applications occurred between 15 and 210 days after planting.

The Case for Subsurface Drip Fertigation

The option of SSDF offers an ideal opportunity to place soluble nutrients from fertilizer in the root zone, along with irrigation water. SSDF also ensures that nutrients are sup-

View of subsurface drip fertigation system under sugarcane.

Location
Puttuvikki village, Coimbatore, Tamil Nadu
Semi-arid zone
Max/min temperature – 32/22° C
Daily evaporation – 5.5 mm (84% RH)
Annual rainfall – 605 mm

Soil Characteristics
Soil pH – 7.6
Org. C – 0.48%
Available N – 199 kg/ha (low)
Available P – 44 kg/ha (high)
Available K – 676 kg/ha (high)
Bulk density – 1.25 g/cm^3
Particle density – 1.82 g/cm^3
Pore space – 31%
Infiltration rate – 1.95 cm/hr
Field capacity – 29%

plied precisely in the area of most intensive root activity.

This study found SSDF to be most effective compared to the SDF or SI systems (**Table 3**). The average cane yield for all SSDF treatments was 158 t/ha, which was 5% higher than SDF, and 65% higher than the SI control. Bresler (1997) attributed higher cane yields under SSDF to minimizing the potential for wide fluctuations in soil water content during the irrigation cycle. This is an important and advantageous feature of drip irrigation. Its implementation leads to better water use, higher nutrient uptake, and better maintenance of soil-water-atmosphere relationship due to a higher oxygen concentration in the root zone (Raina et al., 2011).

Table 3. Interaction effect of 4R nutrient management on sugarcane (variety Co.86032) yield, NUE, and net income, Tamil Nadu.

	------ Yield ------		--------- NUE ---------		---- Net income[1] -----	
Treatment	t/ha	% increase over control	kg yield/kg NPK applied	% increase over control	'000 Rs./ha	% increase over control
Subsurface Drip Fertigation (SSDF)						
T1	160	67	356	122	195	53
T2	186	94	310	93	228	79
T3	165	72	366	129	197	55
T4	143	49	235	47	174	36
T5	127	32	282	76	148	16
T6	176	84	294	84	218	72
T7	156	63	261	63	186	46
T8	150	56	250	56	182	43
Average	**158**	**65**	**294**	**84**	**191**	**50**
Surface Drip Fertigation (SDF)						
T9	168	75	280	75	194	52
T10	133	39	222	39	162	22
Average	**151**	**57**	**251**	**57**	**178**	**37**
Surface Irrigation (SI) + Soil Applied Fertilizers						
T11	**96**	**-**	**160**	**-**	**127**	-
SEd	7.4	-	-	-	-	
CD (p = 0.05)	15.5	-	-	-	-	

[1]Data used to calculate net income: Price of sugarcane = Rs. 2,100/t, Prices of fertilizers (Rs./kg): urea = 5.36, DAP = 24.0, KCl = 16.8, 19:19:19 = 86, MAP = 78, Urea phosphate = 40, KNO_3 = 80, K_2SO_4 = 70, Total annualized drip cost for SSDF = 29,805/ha, Total annualized drip cost for SDF = Rs. 27,660/ha

Application of WSF at the full SR produced the best yield of 186 t/ha, which was 94% higher than the control (**Figure 1**). The next highest yield of 176 t/ha was achieved with a combination of WSF (75%) and GF (25%), which

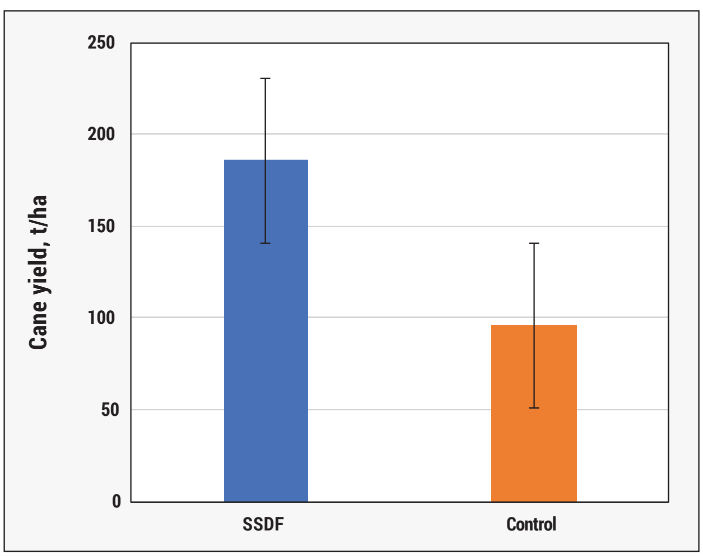

Figure 1. Comparison of cane yields resulting from the best treatment using subsurface drip fertigation (SSDF) of water soluble fertilizer at the state recommendation (SR) and the Control treatment of surface irrigation of surface applied granular fertilizers applied at the SR, Tamil Nadu.

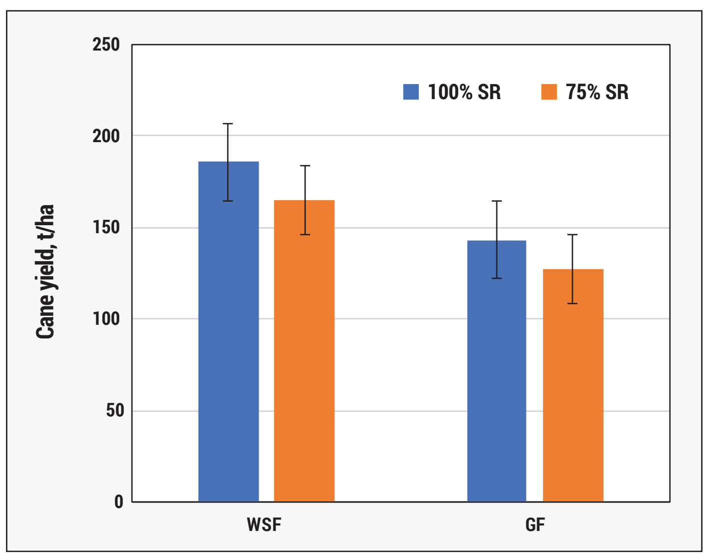

Figure 2. Comparison of cane yields resulting from either the full or reduced (75%) state recommendation (SR) using either water soluble fertilizers (WSF) or granular fertilizers (GF) using subsurface drip fertigation, Tamil Nadu.

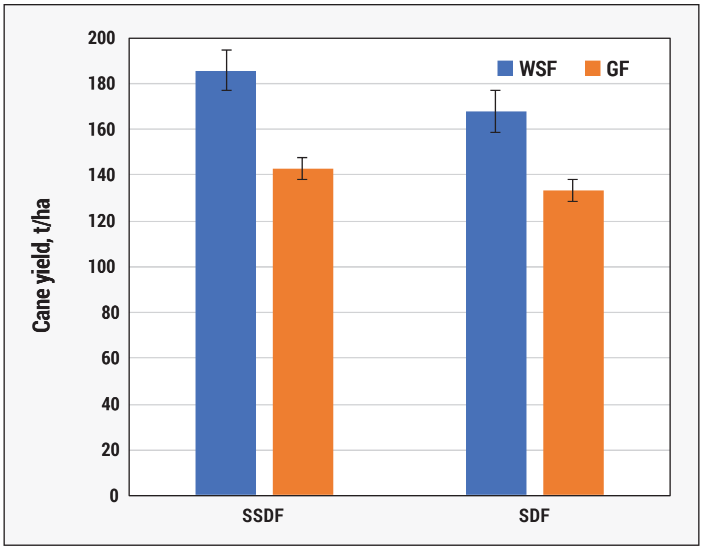

Figure 3. Comparison of cane yields resulting from either water soluble fertilizers (WSF) or granular fertilizers (GF) applied at the state recommendation (SR) under subsurface drip fertigation (SSDF) and surface drip fertigation (SDF), Tamil Nadu.

also fulfilled the SR. Application of either WSF or GF at the full SR was superior (+13%) to the reduced rate tested (**Figure 2**), which confirms fit of the current SR in meeting a 200 t/ha yield goal.

Mixes of WSF were superior to GF in both SSDF and SDF (**Figure 3**). Yield was 30% higher with WSF+SSDF and 26% higher with WSF+SDF (**Figure 3**). Amongst the options tested, the WSF mix of 19-19-19; MAP, KNO_3, and urea proved to be more effective than the mix of 19-19-19; urea phosphate, K_2SO_4, and urea.

This study measured differences in NUE amongst treatments through the performance indicator called partial factor productivity (PFP), which answers the question ... How did the crop respond to the nutrient input?

$$PFP_{NPK} = \frac{\text{kg cane yield/ha}}{\text{kg applied NPK/ha}}$$

The highest-yielding SSDF treatment using the full SR had a PFP of 309 kg/kg NPK applied, which was 11 and 94% higher than the corresponding treatment under SDF and SI, respectively (**Figure 4**).

The SSDF treatments using the reduced rate (75% SR) did record even higher PFP values (**Table 3**), but lower fertilizer inputs can commonly intersect on a steeper part of the yield response curve, and as in this case, one should consider the value of the yield gap caused by a reduction in fertilizer input. Economic data found SSDF of WSF at the SR to be most favorable—mainly due to higher cane yield. In spite of an additional investment of Rs.40,040/ha for WSF over GF (data not shown), WSF returned an additional Rs.55,290/ha.

Conclusion

Subsurface drip fertigation facilitates the practice of efficient nutrient management through 4R principles of Nutrient Stewardship, which resulted in higher cane yield, improved NUE, and better net income. Results of the above experiment showed that for achieving a yield target of about 200 t/ha, sugarcane required an application of the right rate of nutrients (300-100-200 kg N-P_2O_5-K_2O/ha) applied through a mixture of water soluble fertilizers (urea, 19-19-19, MAP, and KNO_3). This was most probably due to the right timing of nutrients through 27 split applications at an interval of seven days, applied through the subsurface drip fertigation system. Large-scale adoption of 4R nutrient management through subsurface drip fertigation provides an opportunity to bridge nutrient-related yield gaps in sugarcane and increase the net income for sugarcane growers in an environmentally sustainable manner. **BC**

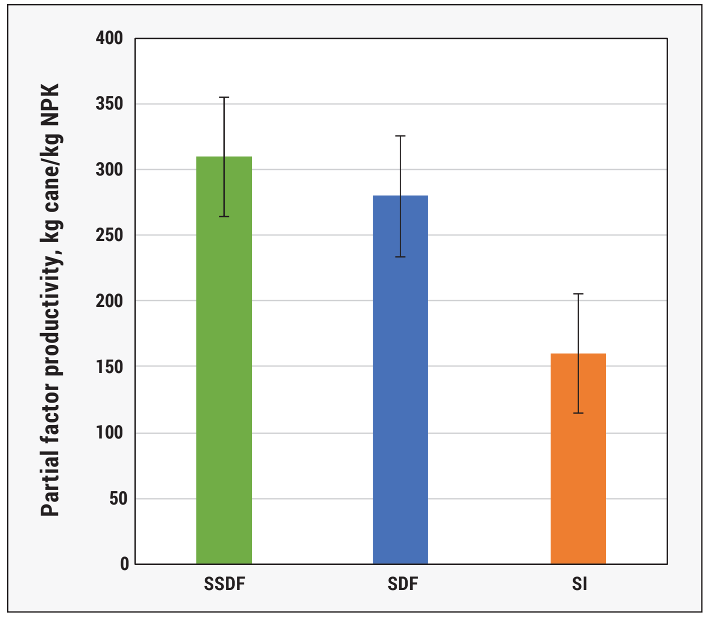

Figure 4. Comparison of partial factor productivity obtained from subsurface drip fertigation (SSDF), surface drip fertigation (SDF), and surface irrigation (SI) using the state recommendation for 200 t cane/ha, Tamil Nadu.

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