STUDY ON THE INFLUENCE OF IRRIGATION REGIMES AND FERTIGATION LEVELS ON SUGARCANE UNDER SUBSURFACE DRIP FERTIGATION SYSTEM

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ABSTRACT

Field investigations were carried out at the central farm, Agricultural College and Research Institute, Madurai, Tamil Nadu during 2008-09 and 2009-2010, to elicit information on the influence of irrigation regimes and fertigation levels on sugarcane under subsurface drip fertigation system. The experiments were laid out in Split Plot Design with three replications. The main plots treatment consisted of three subsurface drip irrigation regimes viz., 75 per cent Etc (I_1), 100 per cent Etc (I_2) and 125 per cent Etc (I_3). The subplot treatment consisted of six fertigation levels viz., 75 per cent RDF as commercial fertilizers (F_1), 100 per cent RDF as commercial fertilizers (F_2), 75 per cent RDF – 50 per cent commercial and 50 per cent water soluble fertilizers (WSF) (F_3),.
100 per cent RDF – 50 per cent commercial and 50 per cent WSF (F_4), 75 per cent RDF as WSF (F_5) and 100 per cent RDF as WSF (F_6).The sugarcane variety CO 86032 was used for this study. Subsurface drip irrigation was given once in 3 days and fertigation was given once in 6 days.
Tiller production and number of millable canes were higher in drip irrigation at 125 per cent Etc along with fertigation of 100 per cent RDF as WSF (I_3F_6) which was comparable with 125 per cent Etc along with 75 per cent RDF as WSF (I_3F_5) in both plant and ratoon crop. The combination of drip irrigation at 125 per cent Etc with 100 per cent RDF as WSF registered higher cane and sugar yield but it was comparable with 125 per cent Etc along with 75 per cent RDF as WSF in both crops. Surface irrigation with soil application of fertilizers recorded lower cane and sugar yield when compared to subsurface treatments. The subsurface drip irrigation regime of 125 per cent Etc registered higher total water use followed by 100 per cent Etc and 75 per cent Etc in plant and ratoon crops. The treatment combination of 75 per cent Etc along with 100 per cent RDF as WSF (I_1F_6) recorded higher WUE and water productivity. Higher net return was recorded in 125 per cent Etc with 75 per cent RDF as water soluble fertilizers in plant crop however in ratoon crop, higher net return was observed in 125 per cent Etc with 100 per cent RDF as WSF. Higher BC ratio was associated with drip irrigation at 125 per cent Etc in combination with 100 per cent RDF as commercial fertilizers followed by drip fertigation of 75 per cent RDF as commercial fertilizers at 125 per cent Etc in both crops.

Key Words: Subsurface drip irrigation regimes, Dip fertigation, cane yield, water use efficiency, water productivity

Introduction

Indian sugarcane farmers are adopting surface irrigation practices. This leads to excess usage and wastage of water. Application of water at the time of actual need

through subsurface drip with right quantity of water to wet the effective root zone soil is the proper irrigation management system to save the precious water. As competition for water resources and the need for water conservation increases, adoption of subsurface drip fertigation system (SSDF) is a must in future. This technology very precisely place water, nutrients and other chemicals in the plant root zone at right time and right frequency.

Sugarcane is a heavy feeder of nutrients. Its root system is shallow and fibrous, therefore, fertigation is recommended for higher nutrient availability and use efficiency. The aim of the fertigation program is to bridge the gap between crop nutrient demand and supply. The nutrient requirements of drip irrigated sugarcane are relatively high: 250 to 300 kg ha^{-1} N, 80 to 100 kg ha^{-1} P_2O_5 and 125 to 250 kg K_2O ha^{-1}.

Increased application of water soluble fertilizers and fertilization methods have become the only solution for the demand of global sugarcane production. Modern agriculture must supply crops with optimal rates of nutrients throughout the growth cycle in the most efficient manner and without degrading soil and water resources. This can be achieved through adoption of subsurface drip fertigation system with water soluble fertilizers.

MATERIAL AND METHODS

Field experiments were carried out to study the influence of irrigation regimes and fertigation levels on sugarcane under subsurface drip fertigation system at Agricultural College and Research Institute, Madurai, Tamil Nadu during the year 2008-09 and 2009-10.

The experimental field was ploughed with tractor drawn disc plough followed by two ploughing with cultivator and the clods were broken with rotovator to bring the soil to fine tilth. After uniform leveling, trenches were dug out at a width of 40 cm at 140 cm apart. The furrow depth was maintained at 30 cm. The sugarcane variety CO 86032 was used for this study. Two budded setts were planted on both sides of trenches with centre gap of 30 cm and the loose soil was filled to a depth of 5 cm. Eight setts per running meter were planted on trench as continuous planting. Gap filling was done on 20 DAP.

The water source is an open well. Water was pumped through motor and it was conveyed to field using PVC pipes of 90 mm after filtering through disk filter. From the main line water was taken to the field through sub mains of 63 mm diameter pipes. From the sub main, 16 mm size laterals were fixed at a spacing of 1.80 m and depth of lateral placement was 25 cm from the surface soil. Inline drippers with a flow rate of 4.9 lph at 60 cm apart along the laterals were used. Each lateral placed at 1.80 m interval was used to irrigate each row of plants. The operating pressure was maintained at 1.5 kg cm^{-2}. The subsurface drip irrigation system was well maintained by flushing and cleaning the filters.

Polyfeed (13-40-13) and potassium nitrate (13-0-46) of imported grade water soluble fertilizers and urea were used for fertigation. Single Super Phosphate and MOP (White potash) as a source of P and K were used for soil application. The recommended fertilizer dose of 344:94:169 kg NPK ha^{-1} was followed in the experiment. Fertigation was given once in six days as per the treatment schedule starting from 15 to 210 DAP.

Treatments

Main plot treatment: Irrigation regimes

Treatments

- I_1 Subsurface Drip Irrigation at 75 % Etc
- I_2 Subsurface Drip Irrigation at 100 % Etc
- I_3 Subsurface Drip Irrigation at 125 % Etc

Subplot treatment: Fertigation levels
Treatments

F_1 75 % RDF as commercial fertilizers

F_2 100 % RDF as commercial fertilizers

F_3 75 % RDF as 50 % commercial fertilizers + 50 % WSF

F_4 100 % RDF as 50 % commercial fertilizers + 50 % WSF

F_5 75 % RDF as WSF

F_6 100 % RDF as WSF

A control plot with surface irrigation and soil application of RDF (275:62.5:112.5 kg NPK ha^{-1}) was maintained separately and all recommended practices were done based on the Tamil Nadu Crop Production Guide, 2005).

Results and Discussion

Tiller production

The subsurface drip irrigation regimes and fertigation levels had significant influence on tiller production of planted as well as ratoon crop. The higher tiller production of 190.5 and 228.6 thousands ha^{-1} were observed with 125 per cent ETc with 100 per cent RDF as WSF at 90 DAP in plant and ratoon crop. The combination of 125 per cent Etc with 100 per cent RDF as WSF recorded 30.7 and 26.1 per cent higher tillers when compared to 75 per cent ETc with 75 per cent RDF as commercial fertilizer and 15.2 and 35.8 per cent higher over control in both the crops.

The increase in number of tillers under subsurface drip fertigation was mainly due to early vigorous growth of the plant with the availability of required quantity of water and water soluble nutrients compared to lower irrigation regime and commercial fertilizer application wherein the fluctuation in nutrient availability was very wide. Continuous supply of water with plant nutrients might result in higher growth. Nitrogen was the prime promoter of tillering in sugarcane and protein synthesis was higher in tillering stage.

Table 1. Effect of irrigation regimes and fertigation levels on number of tillers (thousands ha^{-1}) in plant crop

Treatments	**Number of tillers (thousands ha^{-1}) at 90 DAP**			
	I_1	I_2	I_3	Mean
F_1	145.8	158.6	166.9	157.1
F_2	149.1	165.2	170.4	161.6
F_3	150.1	168.9	178.5	165.8
F_4	152.8	172.6	182.5	169.3
F_5	163.0	175.6	186.3	175.0
F_6	167.1	178.2	190.5	178.6
Mean	154.7	169.9	179.2	
	I	F	I x F	F x I
SEd	2.5	1.0	3.0	1.7
CD (0.05)	7.0	2.0	7.6	3.5
Control	165.3			

Table 2. Effect of irrigation regimes and fertigation levels on number of tillers (thousands ha^{-1}) in ratoon crop

Treatments	Number of tillers (thousands ha^{-1}) at 90 DAR			
	I_1	I_2	I_3	Mean
F_1	181.3	195.2	200.7	192.4
F_2	186.7	199.3	203.2	196.4
F_3	188.2	202.0	211.3	200.5
F_4	191.5	204.3	217.0	204.3
F_5	194.3	210.6	225.9	210.3
F_6	196.1	214.6	228.6	213.1
Mean	189.7	204.3	214.4	
	I	F	I x F	F x I
SEd	3.6	1.4	4.2	2.4
CD (0.05)	9.9	2.9	10.8	5.0
Control	168.4			

Gouthaman (1997) reported that irrigation scheduled at IW/CPE of one during tillering phase significantly increased the tiller production as compared to 0.6 IW/CPE. The results indicated that higher irrigation frequency produced significantly higher tiller population because of enhanced nutrient uptake. Mahesh (2009) reported that higher tiller production obtained under subsurface drip fertigation in double side planting of sugarcane.

Number of millable canes (NMC)

Subsurface drip irrigation regimes and fertigation levels influenced the NMC in plant and ratoon crops. Drip irrigation at 125 per cent Etc along with fertigation of 100 per cent RDF as WSF recorded 40.1 and 41.6 per cent higher NMC than 75 per cent Etc with 75 per cent RDF as commercial fertilizers. This was comparable with drip irrigation at 125 per cent Etc and fertigation of 75 per cent RDF as WSF.

Table.3. Effect of irrigation regimes and fertigation levels on number of millable canes in plant and ratoon crop

Treatments	Number of millable canes (Thousands ha^{-1})							
	Plant crop				Ratoon crop			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
F_1	107.9	118.6	124.2	116.9	121.8	138.0	142.1	134.0
F_2	110.2	125.7	133.4	123.1	126.3	142.4	147.5	138.7
F_3	113.5	130.8	138.6	127.6	128.7	144.1	156.3	143.0
F_4	115.6	135.7	142.6	131.3	132.1	145.6	160.3	146.0
F_5	120.4	137.1	147.0	134.8	137.6	150.6	164.6	150.9
F_6	126.9	139.5	151.2	139.2	142.4	155.2	172.5	156.7
Mean	115.8	131.2	139.5		131.5	146.0	157.2	
	I	F	I x F	F x I	I	F	I x F	F x I
SEd	2.5	1.0	2.9	1.7	3.2	1.6	4.0	2.7
CD (0.05)	6.8	2.0	7.5	3.5	8.9	3.2	10.1	5.5
Control	86.9				88.2			

The synchronized tiller production with higher survival capacity under sub surface drip fertigation system might have helped to get uniform millable canes. The results indicated higher NMC production under increased levels of irrigation and also under

increased nutrient availability. This might be due to better and early conversion of tillers to millable canes otherwise this might have resulted in excess production of tillers in the early stages and would have diverted the plant nutrients unnecessarily for unproductive purpose. The same result of increased NMC under higher irrigation levels with fertigation was observed by Mahendran *et al*. (2005). He found that the number of millable cane had direct correlation with irrigation regime and fertigation level.

Cane Yield

Subsurface drip irrigation and fertigation positively influenced the yield of sugarcane in both plant and ratoon crop. The cane yield was significantly improved by combined application of irrigation regimes, different dose and sources fertilizers through subsurface drip fertigation which could be due to boosted tiller production, grand growth and biological efficiency of the cane. The combination of 125 per cent Etc along with 100 per cent RDF as WSF recorded higher cane yield of 240.7 and 280.5 t ha^{-1}. This was 64.5 and 59.7 percent increase over drip irrigation at 75 per cent Etc along with fertigation of 75 per cent RDF as commercial fertilizers in plant and ratoon crops, respectively. When compared to control, 153.4 and 189.2 per cent increased yield was noticed in 125 per cent Etc along with 100 per cent RDF as WSF in both crops.

Table 4. Effect of irrigation regimes and fertigation levels on cane yield (t ha^{-1}) in plant and ratoon crop

Treatments	Plant crop				Ratoon crop			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
F_1	146.3	167.0	180.2	164.5	175.6	198.3	210.6	194.8
F_2	148.7	173.6	190.8	171.0	182.6	213.5	223.5	206.5
F_3	156.1	185.7	210.8	184.2	188.5	220.5	235.7	214.9
F_4	163.7	192.7	218.8	191.7	196.4	228.6	245.6	223.5
F_5	185.6	206.1	233.2	208.3	205.6	238.5	265.2	236.4
F_6	189.1	217.4	240.7	215.8	214.6	250.6	280.5	248.6
Mean	164.9	190.4	212.4		193.9	225.0	243.5	
	I	F	I x F	F x I	I	F	I x F	F x I
SEd	4.9	2.4	6.2	4.2	6.1	2.9	7.6	5.0
CD (0.05)	13.5	4.9	15.4	8.6	17.1	5.9	19.2	10.1
Control	95.0				97.0			

The optimized parameters such as moisture movement, nutrient mobility, availability and uptake of applied nutrients due to higher soil moisture content, prevention of losses such as leaching, volatilization and denitrification resulted in increased total cane yield. Due to the improved plant-water-nutrient status under subsurface drip fertigation system, all the plant growth and yield characters viz., dry matter production, number of millable cane and cane weight were increased significantly which ultimately resulted in increased production of cane yield. These results are in agreement with the findings of Mahendran *et al*. (2005) who reported that fertigation up to 150 per cent of recommended dose of N and K in 14 equal splits up to 210 DAP to sugarcane crop resulted in higher cane yield of 173.5 t ha^{-1}. The irrigation schedule of 0.6, 0.8, 1.0 and 0.8 Etc coupled with 80 per cent RDF gave significantly higher cane yield of 200 t ha^{-1} (Vaishnava *et al*., 2002). Mahesh (2009) reported that

application of water soluble N, P and K fertilizers significantly increased the cane yield when compared to straight fertilizers under subsurface drip fertigation in sugarcane

Sugar yield

Subsurface drip irrigation and fertigation had significantly influenced the sugar yield in both plant and ratoon crop. Drip irrigation of 125 per cent Etc along with fertigation of 100 per cent RDF as WSF recorded higher sugar yield of 29.1 and 32.1t ha^{-1} which is 129.1 and 143.2 per cent higher than the sugar yield obtained under control and 98.0 and 86.6 per cent higher compared to drip irrigation at 75 per cent Etc along with fertigation of 75 per cent RDF as commercial fertilizers in plant and ratoon crop respectively.

Table 5. Effect of irrigation regimes and fertigation levels on sugar yield (t ha^{-1}) in plant and ratoon crop

Treatments	Plant crop				Ratoon crop			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
F_1	14.7	17.0	19.2	17.0	17.4	20.2	22.1	19.9
F_2	15.0	17.9	20.7	17.9	18.2	21.9	23.6	21.2
F_3	15.9	19.7	23.3	19.6	18.8	22.8	25.0	22.2
F_4	16.9	20.8	25.0	20.9	19.6	23.5	26.6	23.3
F_5	19.7	23.3	27.7	23.5	20.8	25.5	29.8	25.4
F_6	20.4	24.9	29.1	24.8	21.8	27.1	32.1	27.0
Mean	17.1	20.6	24.2		19.4	23.5	26.5	
	I	F	I x F	F x I	I	F	I x F	F x I
SEd	0.8	0.4	1.0	0.7	0.9	0.4	1.1	0.7
CD (0.05)	2.2	0.8	2.5	1.4	2.4	0.8	2.7	1.4
Control	12.7				13.2			

The higher sugar yield under sub surface drip fertigation was mainly due to the availability of higher moisture with better aeration coupled with water soluble nutrients in all the stages of cane growth and water given based on the crop demand. These favorable environments resulted in better and earlier conversion of tillers to millable cane and the early vigor was maintained during the crop growth period due to continuous availability of nutrients and resulted in increased cane and sugar yield. The increased sugar yield was mainly due to improved juice quality parameters with the result of uniform millable cane production under this treatment.

Water use efficiency and water productivity

Subsurface drip irrigation is an efficient method to deliver water and nutrients to root zone of plants because water is directly applied in subsoil layer to effective root zone

Table.6. Effect of irrigation regimes and fertigation levels on WUE (kg ha^{-1} mm^{-1}) and Water productivity (Rs mm^{-1}) in plant crop

Treatments	WUE (kg ha^{-1} mm^{-1})				Water productivity (Rs mm^{-1})			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
F_1	132.9	129.1	121.3	127.8	166.1	161.4	151.7	159.7
F_2	135.1	134.2	128.5	132.6	168.9	167.8	160.6	165.7
F_3	141.8	143.6	141.9	142.4	177.3	179.4	177.4	178.0
F_4	148.8	149.0	147.3	148.3	185.9	186.2	184.1	185.4
F_5	168.7	159.3	157.0	161.7	210.8	199.2	196.3	202.1
F_6	171.8	168.1	162.1	167.3	214.8	210.1	202.6	209.2
Mean	149.9	147.2	143.0		187.3	184.0	178.8	
	I	F	I x F	F x I	I	F	I x F	F x I
SEd	1.3	1.5	2.7	2.5	1.7	1.8	3.4	3.2
CD (0.05)	3.9	3.0	6.0	5.2	4.8	3.7	7.6	6.5
Control	51.8				64.7			

of crop. The loss of water was minimum and that resulted in the lower water requirement in the subsurface drip irrigation system.

Table 7. Effect of irrigation regimes and fertigation levels on WUE (kg ha^{-1} mm^{-1}) and Water productivity (Rs mm^{-1}) in ratoon crop

Treatments	WUE (kg ha^{-1} mm^{-1})				Water productivity (Rs mm^{-1})			
	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
F_1	147.3	134.7	121.2	134.4	235.6	215.6	194.0	215.1
F_2	153.1	145.1	128.7	142.3	245.0	232.1	205.9	227.7
F_3	158.1	149.8	135.7	147.9	252.9	239.7	217.1	236.6
F_4	164.7	155.3	141.4	153.8	263.5	248.5	226.2	246.1
F_5	172.4	162.1	152.7	162.4	275.9	259.3	244.3	259.8
F_6	180.0	170.3	161.5	170.6	288.0	272.4	258.4	272.9
Mean	162.6	152.9	140.2		260.2	244.6	224.3	
	I	F	I x F	F x I	I	F	I x F	F x I
SEd	1.5	1.5	2.8	2.6	2.3	2.4	4.1	4.2
CD (0.05)	4.0	3.1	6.3	5.3	6.4	4.9	9.2	8.5
Control	51.6				82.6			

Drip irrigation at 75 per cent Etc along with fertigation of 100 per cent RDF as WSF recorded higher WUE and water productivity in both crops. The increase in WUE recorded under subsurface drip irrigation system was mainly due to better performance of the crop and increased yield by effective utilization of available water and nutrients that were supplied at regular intervals throughout the crop period to meet the crop demand.

Economics

Subsurface drip fertigation is an innovative technology for maximizing the yield of cane crop. Though the cost of subsurface drip fertigation unit was very high, considering the longer life period of subsurface drip irrigation system, the benefit accrued out of drip irrigation will be for longer period. Fertigation involved an additional cost of using new speciality WSF viz., plolyfeed-13:40:13, Multi K.

However, the additional cost towards WSF was largely equalized by higher return obtained by higher cane and sugar yield with quality parameters. The economic parameters were higher in ratoon crop when compared to plant crop.

The higher cost of cultivation and gross return was noticed with interaction of drip irrigation at 125 per cent Etc along with fertigation of 100 per cent RDF as WSF but 125 per cent Etc with 75 per cent RDF as WSF registered higher net return of Rs.147039 with 70.6 per cent increase compared to drip irrigation of 75 per cent Etc with fertigation of 75 per cent RDF as 50 per cent P and K in basal balance NPK through WSF in plant crop however in ratoon crop, net return of Rs 2,95,890 was recordede by 125 per cent Etc with 100 per cent RDF as WSF. This was 48.3 per cent higher over 75 per cent Etc with 75 per cent RDF as commercial fertilizers.

Table 8. Effect of irrigation regimes and fertigation levels on net return and BC ratio in plant crop

Treatments	Net return (Rs ha^{-1})			BC Ratio		
	I_1	I_2	I_3	I_1	I_2	I_3
F_1	92686	111665	126634	2.03	2.15	2.28
F_2	93370	118295	135485	2.01	2.20	2.32
F_3	86196	115810	140886	1.79	2.00	2.15
F_4	86619	115625	141741	1.73	1.92	2.08
F_5	99431	129063	147039	1.75	2.00	2.02
F_6	90291	118655	141942	1.62	1.77	1.89
Control	45380.8			1.62		

Drip fertigation of 100 per cent RDF as WSF at 125 per cent Etc recorded 224.0 and 243.7 per cent higher net return over surface irrigation with soil application of RDF. The higher BC ratio of 2.32 and 3.76 was registered under drip fertigation of 100 per cent RDF as commercial fertilizers in plant and ratoon crops respectively. The lower BC ratio was registered by drip irrigation at 75 per cent Etc with fertigation of 100 per cent RDF as WSF in both crops. This might be due to low cost of commercial fertilizers (Urea, SSP and MOP) whereas in water soluble fertilizer treatments the cost is very high

Table 9. Effect of irrigation regimes and fertigation levels on net return and BC ratio in ratoon crop

Treatments	Net return (Rs ha^{-1})			BC Ratio		
	I_1	I_2	I_3	I_1	I_2	I_3
F_1	199501	228395	246751	3.45	3.57	3.74
F_2	207200	248915	262415	3.44	3.69	3.76
F_3	200616	243816	264336	2.99	3.24	3.34
F_4	204096	247566	270516	2.85	3.09	3.21
F_5	207396	260931	287856	2.71	3.16	3.11
F_6	206925	255525	295890	2.52	2.76	2.94
Control	86100.8			2.25		

The cost of cultivation was less in ratoon crop when compared to plant crop and increased gross and net returns in ratoon crop under higher irrigation levels were mainly due to the increased cane, sugar yield and their price. This was in conformity with the findings of Selvakumar (2006) who observed that drip irrigation at 100 per cent WRc with 100 per cent RDF registered the highest additional net return, BC ratio over surface irrigation in chillis. Higher net return, BC ratio and lower payback period were associated with drip fertigation of WSF based on crop growth stage in green chilli (Subramani, 2008).

From the foregoing, it is concluded that adoption of subsurface drip irrigation at 125 per cent Etc along with fertigation of 100 per cent RDF as water soluble fertilizer was found to record higher cane and sugar yield. The next best treatment in increasing cane and sugar yield was 125 per cent Etc with 75 per cent RDF as water soluble fertilizers. However based on BC ratio and partial budgeting adoption of 125 per cent Etc along with 100 per cent RDF- P as basal (SSP) and N and K applied as urea and KCl through drip was found to be good.

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