Original Research Article

Irrigation Regimes and Fertigation Levels on Sugarcane under Subsurface Drip Fertigation

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A B S T R A C T

Field investigations were carried out at the central farm, Agricultural College and Research Institute, Madurai, Tamil Nadu, India during 2008-09 and 2009-2010. The experiments were laid out in Split plot design with three replications. The main plots consisted of three subsurface drip irrigations viz., 75 per cent, 100 per cent Etc and 125 per cent Etc. The subplot consisted of six fertigations viz., 75 per cent RDF as commercial fertilizer, 100 per cent RDF as commercial fertilizers, 75 per cent RDF – 50 per cent commercial and 50 per cent water soluble fertilizers, 100 per cent RDF – 50 per cent commercial and 50 per cent WSF, 75 per cent RDF as WSF and 100 per cent RDF as WSF. The results revealed that all the growth parmeters viz. plant height, number productive tillers, dry matter production and yield attributes viz. number of millable cane, cane girth and cane yield were substantially increased in subsurface drip irrigation at 125 per cent Etc along with fertigation of 100 per cent RDF as water soluble fertilizer. Subsurface drip irrigation regime of 125 per cent Etc registered higher total water use. Subsurface drip irrigation of 75 per cent Etc recorded higher water saving followed by 100 per cent in both the crops. Treatment 75 per cent Etc along with 100 per cent RDF as WSF recorded higher WUE and water productivity. Higher soil moisture content was observed by 125 Etc irrigation regime in soil layers in both crops. The combination of 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. Hence, it can be 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.

Introduction

Sugarcane is the world's primary sugar crop in the global agricultural production. Since it is C_4 plant it can able to convert upto 2 per cent of incident solar energy in to biomass. Sugarcane cultivation requires a tropical or subtropical climate. Efficient utilization of available water resources is crucial for a country like India, which shares 17 per cent of the global population with only 2.4 per cent of land and 4 per cent of the world's water

resources. The per capita per year availability, in terms of average utilizable water resources is 1250 m^3, which was 6,008 m^3 in 1947and is expected to dwindle to 760 m^3 by the year 2050. Agriculture sector is the largest consumer of water. To meet the food security, income and nutritional needs of the projected population in 2020, the food production in India will have to be almost doubled to 400 million tonnes. With increasing demands on

limited water recourses and need to minimize adverse environmental consequences of irrigation, drip irrigation technology will undoubtedly play an important role in the Indian agriculture (Neelam and Rajput, 2009).

Current cane production stands at 1590 million tonnes from 22 million hectares worldwide. Brazil and India are the world's major sugar cane producing countries, accounting for nearly 60 per cent of the global production. Sugarcane is the main sugar producing crop that contributes nearly 75 per cent to the total sugar pool at the global level (www.netafim.com).

Sugarcane is the major commercial crop cultivated in an area of 3.50 lakh ha with a total production of 46.7 million tonnes of sugarcane and 16.23 million tonnes of sugar per annum in Tamil Nadu. The sugarcane productivity has increased over the last two decades. However, the marginal increase in productivity of cane and sugar recovery has to be improved by maximizing yield and quality of sugarcane by adopting balanced fertilization (Bakiyathu Saliha *et al.,* 2009).

Since, sugarcane is the large consumer of water the subsurface drip fertigation technology has most significant role in achieving higher productivity and water use efficiency. Adoption of subsurface drip fertigation may help to increase the productivity due to multi-dimensional competition for water and nutrition.

In subsurface drip fertigation, nutrient use efficiency could be more than 90 per cent compared to 40 - 60 per cent in conventional fertilizer application methods. The amount the fertilizer lost through leaching can be less than 10 per cent in fertigation whereas it is 50 per cent in the soil application. Adoption of subsurface drip irrigation system may help to increase the

water use efficiency, productivity of crops and irrigated area. Mahendran *et al.,* (2005) stated that drip irrigation at 100 per cent of wetting in two row planting system with the spacing of 120 cm is highly profitable with higher cane yield. Sanjay Kakade *et al.,* (2017) concluded that application of 125 per cent recommended dose of N and K through fertigation (P as basal) was found better to register significantly higher growth and yield attributes and seed cotton yield compared to lower levels of N and K fertigation and soil application method. Indian farmers are adopting surface irrigation practices. This leads to excess usage and wastage of water. Application of water at the time of actual need though the subsurface drip with right quantity of water to wet the effective root zone soil is the proper irrigation management system to save the water. As competition for water resources and the need for water conservation increases, adoption of subsurface drip irrigation 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 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} (www.netafim.com).

Water soluble fertilizers are fully water soluble solid fertilizers having high content of primary nutrients with low salt index. These water soluble fertilizers can be utilized for fertigation. The simultaneous delivery of water and fertilizers to the crop through subsurface drip irrigation system ensures that plant nutrients are directed to the active root

zone. Water soluble fertilizers require keen attention as it is a new concept of subsurface drip fertigation in sugarcane. Mahesh (2009) reported that greatly improved performance of growth, yield and quality parameters of sugarcane by using water soluble fertilizers with split fertigation under low cost subsurface drip fertigation system compared to surface irrigation with soil application of fertilizers.

The information on effect of split application of commercial fertilizers, water soluble fertilizers and combination of these fertilizers through subsurface drip fertigation system on sugarcane productivity is scanty. Therefore, the present investigation was carried out to study the influence of irrigation regimes and fertigation levels on sugarcane under subsurface drip fertigation system.

Materials and Methods

The experiments were carried out at central farm of Agricultural College and Research Institute, Madurai, situated in the Periyar – Vaigai Command Area (PVC) of southern agro-climatic zone in the state of Tamil Nadu.

The experimental site is geographically situated at 9°54' North latitude and 78°54' East longitude at an altitude of 147 meters above mean sea level. The experiment was laid out in split plot design replicated thrice. A gross plot size of 132 m^2 (20 m x 6.6 m) and net plot area 53 m^2 was followed for each treatment.

Absolute control

Surface irrigation with RDF of 275: 62.5: 112.5 NPK kg ha^{-1} (Absolute control plot was maintained separately outside the experimental area and all recommended practices based on the Tamil Nadu Crop Production Guide, 2005).

Fertigation sources and application methods

75 and 100 % RDF as commercial fertilizers

P (SSP) as basal and N & K through drip as urea and KCl, respectively

75 and 100 % RDF as 50 % as commercial fertilizers + 50 % as WSF

50 % P (SSP) and K (KCl) as basal

Full dose of N, balance 50 % P & K through drip as WSF – Urea and 13:40:13& KNO$_3$

75 and 100 % RDF as WSF

13:40:13, Urea and KNO$_3$

RDF

Recommended Dose of Fertilizer**:** 344: 94: 169 kg NPK ha^{-1} (Mahendran, 2008) ICAR – Annual report of Adhoc and SUBACS scheme (2005-08)

WSF: Water Soluble Fertilizer

Source of P (SSP): Single super phosphate

Source of K: MOP (White Potash)

Source of WSF: Polyfeed (13: 40: 13 NPK), KNO$_3$ and Urea

Farm yard manure: 12.5 t ha^{-1}

Irrigation regimes

Irrigation was scheduled using the formula of Doorenbos and Pruitt (1977). Quantity of water to be applied was calculated daily by using the data of class A pan evaporimeter, pan coefficient and appropriate crop

coefficient values at different crop stages. The reference evapotranspiration and crop evapotranspiration were calculated as follows.

Crop factor for sugarcane

The following crop factor schedule was adopted to work out Etc at different stages of crop growth as follows

The daily irrigation water requirement for sugarcane crop was estimated using the following relationship,

IR = ETc – Re

Where, IR = Net depth of irrigation (mm day^{-1}); Etc = Crop evapotranspiration (mm); Re = Effective rainfall (mm day^{-1})

The irrigation was scheduled once in 3 days. The irrigation water was supplied after subtracting the effective rainfall from the crop evapotranspiration. Effective rainfall was determined by water balance method suggested by Dastane (1972). Irrigation was given at three levels *viz.,* 75, 100 and 125 per cent of Etc. Time of operation of drip system to deliver the required volume of water per plot was computed based on the formula

$$\text{Time of operation of drip system} = \frac{\text{Volume of water required}}{\text{Emitter discharge (1.5 lps) x No. of emitters}}$$

Subsurface drip design layout details

The water source was 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 1.65 m intervals and depth of lateral placement was 20 cm from the surface

soil. Inline drippers with a flow rate of 1.5 lph at 40 cm apart along the laterals were used. Each lateral placed at 1.65 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.

Canes harvested from the net plot were weighed after removing the tops and trashes and expressed in t ha^{-1}. From the values of commercial cane sugar per cent and the yield of millable cane the sugar yield in tonnes ha^{-1} was worked out by the formula suggested by Sastry and Venkatachari (1960).

$$\text{Sugar yield (t ha}^{-1}) = \frac{\text{CCS (per cent) x Cane yield (t ha}^{-1})}{100}$$

Water use studies

Quantity of water applied through subsurface drip at each irrigation for different treatments was summed up to estimate total irrigation water applied. For computing total water use, the effective rainfall was also included and expressed in mm. water use efficiency is the yield produced from a given quantity of water. Crop water use efficiency was worked out by using the following formula and expressed in kg ha^{-1} mm^{-1} (Viets, 1962).

$$\text{WUE} = \frac{\text{Cane yield (kg ha}^{-1})}{\text{Total water used (mm)}}$$

Water productivity is a function of gross income and total water used by the crop and expressed in Rs ha^{-1} mm^{-1}.

$$\text{Water productivity} = \frac{\text{Gross income (Rs ha}^{-1})}{\text{Total water used (mm)}}$$

Results and Discussion

The results of the study present study as well as relevant discussion have been summarised under following heads

Growth parameters

The higher germination of 97.9 per cent and sprouting of 150.8 thousands ha^{-1} was registered in 125 per cent ETc with 100 per cent RDF as WSF at 35 DAP but it had similar effect with 75 per cent ETc with 75 per cent RDF as WSF. The germination per cent and sprouting was low in 75 per cent ETc with 75 per cent RDF as commercial fertilizers. The germination per cent was higher in 125 per cent ETc with 100 per cent RDF as WSF due to higher availability of water soluble fertilizers and adequate available soil moisture in the sett region during germination.

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 WSFand closely comparable with 75 per cent ETc with 75 per cent RDF as WSF at 90 DAP in plant and ratoon crops. Both plant ratoon cropslinear increase of plant height was observed with 125 per cent Etc along with 100 per cent RDF as WSF which was comparable with 125 per cent Etc with 75 per cent RDF as WSF at harvest stage. However, higher plant height of 5.53 and 5.29 m with 22.9 and 26.9 per cent increase over 75 per cent ETc with 75 per cent RDF as commercial fertilizer and 33.3 and 35.3 per cent higher compared to control at harvest in both the crops were found. The increased plant height observed in 125 per cent Etc with 100 per cent RDF as WSF was mainly due to the continuous availability of the required quantity of water along with the split feeding of water soluble fertilizers based on the crop demand. Water is one of the major constituents of plant, which helps in cell division, cell elongation and ultimately the growth of the plant. The results also clearly indicated that the water soluble fertilizers played a significant role in increasing the plant height. Similarly, WSF given based on stage wise nutrient requirement of cane crop resulted in increased plant height compared to fertigation with commercial fertilizer. The favourable increase in growth attributes viz. plant height and dry matter accumulation due to drip fertigation was reported by Bhalerao *et al.,* (2011), and Ayyadurai *et al.,* (2014).

The high irrigation regime with water soluble nutrients facilitated better root proliferation and absorption of water and nutrients from the wetted soil profile. The lower plant height under lower irrigation regime with fertigation of commercial fertilizers was due to water shortage of crop and could not equalize the water and nutrient demand of crop. Matheswaran (2008) reported that 125 per cent of the recommended dose of fertilizers as water soluble fertilizers through drip fertigation registered higher plant height of 11 and 22 per cent as compared to surface irrigation with soil application of fertilizer in maize crop. This might be due to significant increase of plant height as evident with drip irrigation than furrow irrigation. Dry matter production was comparatively lower at early stage of development and steadily increased as age of the crop advanced and reached peak at harvest. The maximum dry matter production of 89.1 and 103.2 t ha^{-1} was observed in 125 per cent Etc along with 100 per cent RDF as WSF at harvest in both the crops which was 107.7 and 138.3 per cent higher compared to control. This treatment was comparable with 125 per cent Etc along with 75 per cent RDF as WSF followed by 125 per cent Etc along with 100 per cent - 50 per cent P and K as basal and full dose of N, remaining 50 per cent P and K through drip in both the crops.

Table.1 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			

Table.2 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			

Table.3 Effect of irrigation regimes and fertigation levels on WUE and Water productivity 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**

Table.4 Effect of irrigation regimes and fertigation levels on WUE and Water productivity 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

Main plot treatment: Irrigation

Treatments	Details
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

Treatments	Details
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

Fertilizers - Nutrient content (%)

Sl.No	Water soluble fertilizers	N	P_2O_5	K_2O
1	Urea	46	-	-
2	KNO_3	13	-	46
3	Poly feed (13:40:13)	13	40	13

Fertilizers	Total N	$N-NO_3$	$N-NH_3$	P_2O_5	K_2O	Ca
13:40:13	13.0 %	4.4 %	8.6 %	40.0 %	13.0 %	-
Multi K	13.0 %	13.0 %	-	-	45.0 %	-
$CaNO_3$	15.0 %	14.4 %	1.1 %	-	-	19.0 %

Irrigation regimes

$ET_o = Ep \times Kp$	$ET_c = ET_o \times K_c$
ET_o- Reference Evapotranspiration	ET_c- Crop Evapotranspiration
E_p - Evaporation (mm) (evaporimeter reading)	K_c - CropCo-efficient
K_p - Pan Co-efficient	

Crop factor for sugarcane

S.No	Growth phase	Crop Co-efficient	Days after planting
1	Germination and establishment	0.40	1-30
2	Tillering	0.40	30-60
		0.70	60-90
3	Canopy establishment	1.05	90-120
4	Grand growth period	1.20	120-270
5	Maturity period	1.15	270-300
		0.95	300-330
		0.75	330-365

This might have resulted in more uptake of nutrients and growth resulting in higher dry matter production. Bhalerao *et al.,* (2011) reported higher dry matter accumulation when fertilizers were applied through fertigation in splits. Nalayani *et al.,* (2012), Gokila (2012) and Ayyadurai *et al.,* (2014) also reported that split application of N and K in more split enhanced the dry matter production. In subsurface drip irrigation and fertigation system, irrigation and fertilizers were applied through subsurface drip irrigation in desired split doses throughout the growing period according to crop requirements, so that the losses were minimized and opportunity was provided to take up more nutrients, which reflected on the cane growth parameters and higher DMP.

Cane yield and sugar yield

The plant and ratoon crops (Table 1) revealed that Subsurface drip irrigation level of 125 per cent Etc (I_3) recorded significantly higher crop yield of 212.4 and 243.5 t ha^{-1} followed by 100 per cent Etc (I_2) (190.4 and 225.0 t ha^{-1}) in plant and ratoon crop, respectively. 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. The lower crop yield of 164.9 and 193.9 t ha^{-1} was noticed with 75 per cent Etc (I_1) in both the crops. The interaction effect of 125 per cent Etc along with 100 per cent RDF as WSF (I_3F_6) recorded higher sugar yield of 29.1 and 32.1 t ha^{-1} in plant and ratoon crop, respectively. The higher sugar yield 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 factor for crop demand and stages of crop growth. These favourable 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. Which was comparable with 125 per cent Etc along with 75 per cent RDF as WSF (I_3F_5) in both the crops. The treatment 75 per cent Etc with 75 per cent RDF as commercial fertilizer (I_1F_1) recorded lower sugar yield in both crops (Table 2).

Water use studies

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 of crop. The loss of water was minimum and

that resulted in the lower water requirement in the subsurface drip irrigation system. In this experiment, the application of 125 per cent Etc recorded higher total water use of 1485.3 and 1737.1 mm followed by 100 per cent Etc (1293.6 and 1471.7 mm) in plant and ratoon crops, respectively. Irrigation regime of 75 per cent Etc recorded lower total water use in both the crops, respectively. The total water use was higher in plant crop compared to ratoon crop. This might be due to higher rainfall received during the plant crop period. The ratoon crop received higher irrigation water than plant crop. This might be due to higher mean evaporation recorded during ratoon crop period.

The treatment 75 per cent Etc recorded higher water saving of 40 and 36.6 per cent when compared to control in both the crops, respectively. The least water saving was recorded with 125 per cent Etc in both crops. Irrigation requirement by maize grown using subsurface drip irrigation was reduced by 25 per cent (Lamm *et al.,* 1995). These results are in line with findings of Mahesh (2009) who reported total water use 1115.28 mm ha^{-1} under subsurface drip irrigation system in sugarcane.

(Tables 3 and 4) The interaction effect of 75 per cent Etc along with 100 per cent RDF as WSF recorded higher WUE and water productivity in both crops which was 213.0 per cent higher compared to control in both crops. The drip irrigation adoption in sugarcane increases water use efficiency by 60- 200 per cent by Kasuahal*et al.,* (2012).The increase in water use efficiency 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.

On the basis of two year sugarcane plant and ratoon study, it could be concluded that Increased irrigation level and 100 per cent WSF significantly increased the growth and yield attributes and drip irrigation regime of 125 per cent Etc (I$_3$) registered higher total water use followed by 100 per cent Etc cane yield compared to other treatments. The highest growth attributes, yield parameters, increased cane and sugar yield was observed by 125 per cent Etc with 100 per cent RDF as WSF (I$_3$F$_6$) but it had similar effect with followed by 125 per cent Etc with 75 per cent RDF as WSF (I$_3$F$_5$) in plant and ratoon crop, respectively. The subsurface drip irrigation regime of 125 per cent Etc (I$_3$) registered higher total water use followed by 100 per cent Etc. The lower total water used was recorded with 75 per cent Etc and control in plant and ratoon crop respectively. Subsurface drip irrigation of 75 per cent Etc recorded higher water saving per cent followed by 100 per cent Etc irrigation regime. The interaction effect of 75 per cent Etc along with 100 per cent RDF as WSF (I$_1$F$_6$) recorded higher percentage of water use efficiency and water productivity in both crops.

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