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Effect of irrigation regime and fertilizers on sugarcane productivity and soil health enhancement under sub surface fertigation system of planting

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Abstract
Sugarcane (*Saccharum officinarum* L.) is an important economically valuable crop of our country. It plays a significant role in the economic up-lift of the country and provides raw material for sugar industry. Sub surface drip fertigation is a highly effective method of water application, which is also ideally suited for controlling the placement and supply rate of water soluble fertilizers in sugarcane cropping system. Proper fertigation management requires the knowledge of fertigation rate and nutrient uptake by the crop to ensure maximum crop productivity. In this study the effect of fertigation and irrigation systems on sugarcane yield, quality and nutrient distribution pattern in soil were evaluated at sugarcane research station, Cuddalore, Tamil Nadu in subsurface fertigation system of sugarcane planting. The experiment was laid out in spilt plot design with variety CoC (SC) 24. Three irrigation regimes viz., at 75,100 and 125% photo evaporation were allotted to main plots and six fertilizer levels were accommodated in the sub plots. Among the irrigations levels, irrigation at 125% photo evaporation registered a maximum yield of 129.46 t/ha. Among the sub plot treatments, application of 100% recommended dose of fertilizers fully as water soluble fertilizers as urea and potassium nitrate applied plots registered higher mean cane yield of 128.92 t ha^{-1}. Considering the interactions effects, irrigation and fertigations levels, the treatment received drip irrigation at 125% photo evaporation with 100% recommended dose of fertilizers fully as water soluble fertilizers as urea and potassium nitrate was found to be the best one for getting an economic cane yield. The results on available nutrient status of soil at four different depths at 15, 30, 45 and 60 cm depths of soil indicated that application of 100% recommended NPK as water soluble fertilizers registered the higher available nitrogen, phosphorus and potassium status of soil. Among the irrigation regimes, application of water at drip irrigation at 125% photo evaporation - irrigating 4 hours once in two days increases the available nitrogen and phosphorus status of the soil at 15 cm soil layers followed by 30 cm soil layers. The soil potassium was found to be maximum at 60 cm layer followed by 45 cm soil layer.

Keywords: sugarcane-fertigation-potassium nitrate-nitrogen accumulation-crop productivity-irrigation regimes

Introduction
Sugar Industry is an agro-based industry and sugarcane is cultivated by about 5 lakhs farmers in Tamil Nadu. The registered sugarcane crop is cultivated in an area of 2.5 to 3.0 lakh hectares comprising of about 2% of the total cultivable area. Sub surface drip fertigation is an efficient means for applying water and nutrients to crops and 10-30% water savings can be realized compared to conventional surface irrigation systems. Therefore, subsurface drip irrigation and fertigation with water soluble fertilizers can result in optimum sugarcane yield, quality and economic return, without polluting losses of N to ground water (Pier and Doerge, 1995) [7]. Hutmacher *et al*., (1993) [3] showed that the cost of water soluble sources of P and K fertilizers suitable for fertigation were approximately 80% higher than those of conventional granular sources, requiring a substantial increase in sugar yield (1.45 t/ha) to break even when fertigating. There are data to develop the growth curve nutrition concept for P and K in sugarcane crop (Thompson, 2003) [12] but it is unlikely that the cost of fertigating with P and K fertilizer would be outweighed by increases in yield or efficiency.

There are few sources of information on which to base practical guidelines for the fertigation of sugarcane. Research is needed to determine the effects on the soil nutrient dynamics and sugarcane yield resulting from fertilizing through a subsurface drip irrigation system over several years. This paper reports on the initial results of an experiment programme to test the benefits, nutrient dynamics under sub surface drip fertigation would be useful in designing efficient fertigation systems and also to evaluate the performance of new sugarcane variety.

The objectives of the research are

i) To study the influence of sub surface fertigation on crop productivity and nutrient status of soil
ii) To optimize the level of water soluble fertilizer N and K for maximizing the cane yield under sub surface drip cum fertigation system

In this paper, results of experiment on the movement and distribution of nitrogen, phosphorus and potassium under sub surface drip fertigation are presented.

Materials and Methods

The study was carried out at the experimental farm of Sugarcane Research Station, Cuddalore, Tamil Nadu during 2009-2010 in one plant crop. The mean maximum and minimum temperature of the location was 31.7 ºC and 24.1 ºC respectively. The mean annual rainfall was 1200 mm. The soil of the experimental field was sandy clay loam, with low available N (186.84 kg ha^{-1}), medium in available 'P' (16.5 kg ha^{-1}) and medium in available potash (265 kg ha^{-1}). The pH of the soil is 7.2. The fertilizer N and K was given as per the following treatment schedule through drip at 14 equal splits starting from the 15^{th} day of planting at 15 days interval. The following treatment, replicated four times, were used in the experiment.

Treatment details

Design	:	Split plot
Replication	:	Four
Variety	:	CoC (SC) 24

Factor 'A'-Irrigation systems

I_1- Drip irrigation at 75% PE-irrigation for 2 hours once in two days

I_2- Drip irrigation at 100% PE-irrigation for 3 hours once in two days

I_3- Drip irrigation at 125% PE-irrigation for 4 hours once in two days

Factor B-fertigation

F1	75% RDF-P as basal and N&K through drip as urea and KCl + LBF.
F2	100% RDF-P as basal and N & K through drip as urea and KCl
F3	75% RDF-50% P & K as basal and N, P & K through drip as WSF-urea & KNO_3 + LBF
F4	100% RDF-50% P & K as basal and N, P & K through drip as WSF-urea & KNO_3
F5	75% RDF-Fully WSF as urea+KNO_3+LBF
F6	100% RDF-Fully WSF as urea & KNO_3

LBF-Liquid Bio Fertilizers
KCl-Potassium Chloride
KNO_3-Potassium Nitrate
PE-Photo Evaporation

Field experiment was laid out in subsurface drip fertigation system. Drip main and laterals were placed and fertigation were given as per the treatment schedule. In the drip system, the amount of water applied in every alternate day. Soil sampling was done from 15, 30, 45 and 60 cm depths of soil layers. The available soil nitrogen (Subbiah an Asija, 1956) [10], phosphorus (Olsen *et al.*, 1954) [6] and potassium (Standford and English, 1949) [9] were analyzed. The yield were recorded along with the quality parameters.

Results and Discussion

Cane yield

The data recorded on cane yield is presented in Table 1. Different fertigation levels had significant influence on cane yield. The yield data showed that among the irrigations levels, irrigation at drip irrigation at 125% PE registered a maximum yield of 129.46 t ha^{-1} and the minimum yield was noticed at I_1 (110.31 t ha^{-1}).

Table 1: Effect of irrigation regimes and nutrient levels on cane yield (t/ha)

Treatments	F 1 75% RDF + comm fertilizer + LBF	F2 100% RDF comm fertilizer	F3 75% RDF (50%RDF + 50% WSF +LBF)	F4 100% RDF (50%RDF + 50% WSF)	F5 75% RDF (WSF + LBF)	F6 100% RDF (WSF)	Mean
I1-irrigation regime (2 hours)	102.37	109.29	108.24	111.87	109.6	119.5	110.31
I2-irrigation regime (3 hours)	117.77	120.30	119.43	124.63	121.43	129.63	122.19
I3-irrigation regime (4 hours)	127.33	129.43	125.40	130.60	126.37	137.63	129.46
Mean	115.82	119.67	117.69	122.37	119.13	128.92	

	SEd	C.D. (P= 0.05)
I	0.43	1.18
F	0.77	1.57
I at F	1.29	2.74
Fx I	1.32	2.72

Among the sub plot treatments, application of 100% recommended dose of fertilizers fully as water soluble fertilizers as urea and KNO_3 applied plots registered higher mean cane yield of 128.92 t ha^{-1} while 75% recommended fertilizer as KCl and liquid bio fertilizers recorded the mean yield of 115.82 t ha^{-1}.

Considering the interactions effects, irrigation and fertigations levels, the treatment received drip irrigation at 125% PE with 100% recommended dose of fertilizers fully as water soluble fertilizers as urea and KNO_3 was found to be the best one for getting an economic cane yield. These results confirm the observation of Mahendran *et al.* (2005) [5], 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 resulted in higher cane yield. Many reports on substantial yield increase in sugarcane through drip fertigation are available (Sundara and Reddy, 1994; Gill, 1995) [11, 2].

Sugar yield

The sugar yield recorded at the harvest stage (Table.2.) was found to be significant for all the parameters. The highest value of 16.19 t ha^{-1} was recorded with the application drip irrigation of 125% PE. Application of 100% recommended dose of fertilizers fully as water soluble fertilizers as urea and KNO_3 applied plots increased the sugar yield to 16.28 t $ha^{-1.}$ Considering the interactions effects, irrigation and fertigations levels, and the treatment received drip irrigation at 125% PE with 100% recommended dose of fertilizers fully as water soluble fertilizers as urea and KNO_3 increased the sugar yield to 17.14 t ha^{-1}. This might be due to the application of nutrients through subsurface drip irrigation system, which can efficiently supply nutrients in the root zone. This may also be due to the uniform growth of cane with better assimilation of photo synthesis (Dhanalakhsmi and Mahendran, 1998) [1].

Table 2: Effect of irrigation regimes and fertilizers levels on sugar yield (t ha^{-1})

Treatments	F1 75% RDF + comm fertilizer + LBF	F2 100% RDF comm fertilizer	F3 75% RDF (50%RDF + 50% WSF + LBF)	F4 100% RDF (50%RDF + 50% WSF)	F5 75% RDF (WSF + LBF)	F6 100% RDF (WSF)	Mean
I1-irrigation regime (2 hours)	12.66	14.06	14.08	14.42	14.03	15.46	14.12
I2-irrigation regime (3 hours)	15.11	15.09	14.97	15.85	15.45	16.23	15.45
I3-irrigation regime (4 hours)	15.94	16.01	15.82	16.36	15.89	17.14	16.19
Mean	14.57	15.05	14.95	15.54	15.12	16.28	

	SEd	C.D. (P= 0.05)
I	0.06	0.17
F	0.22	0.44
I at F	0.35	0.72
F at I	0.37	0.77

Nutrient dynamics

The data on soil available nutrients distribution patterns at 15, 30, 45 and 60 cm depths of soil are presented in Figures 1, 2 and 3. The available nitrogen, phosphorus and potassium status of soil were analyzed at different growth stages of crop growth viz., tillering, maturity and at harvest. But for discussion, only 150 days after planting is presented hereunder.

Available nitrogen

The distribution of nitrogen for six fertigations and three irrigation regimes are presented in Figures 1 and 2. The spatial distribution patterns are controlled by the buried irrigating drip line, thereby carrying ammonia and nitrate to depths. The nitrogen and phosphorus remained near the drip line, there was progressive increase in its availability from initial status with corresponding increase in levels of NPK. The higher rate of mineralization and release of nitrogen from the soil and fertilizer could be contributed for the increase in the available nitrogen in the soil. Application of 100% recommended NPK as water soluble fertilizers registered the higher available nitrogen due to the sub surface drip fertigation, maximum accumulation was found to be at 15 cm layer (near the drip) than other layers in all irrigation regimes.

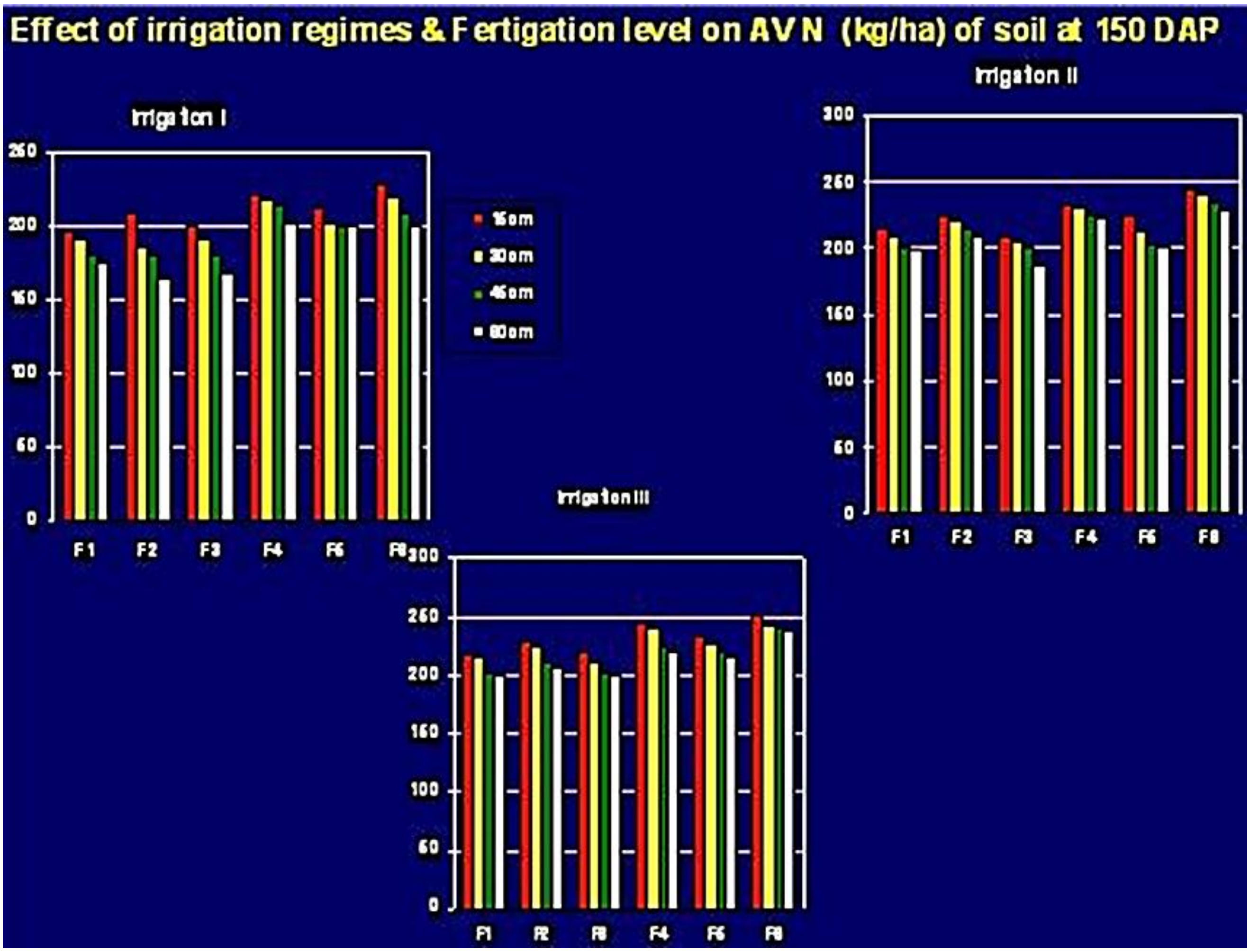

Fig 1: Effect of irrigation regimes and fertigation on available nitrogen (kg/ha.) at 150 Days after planting

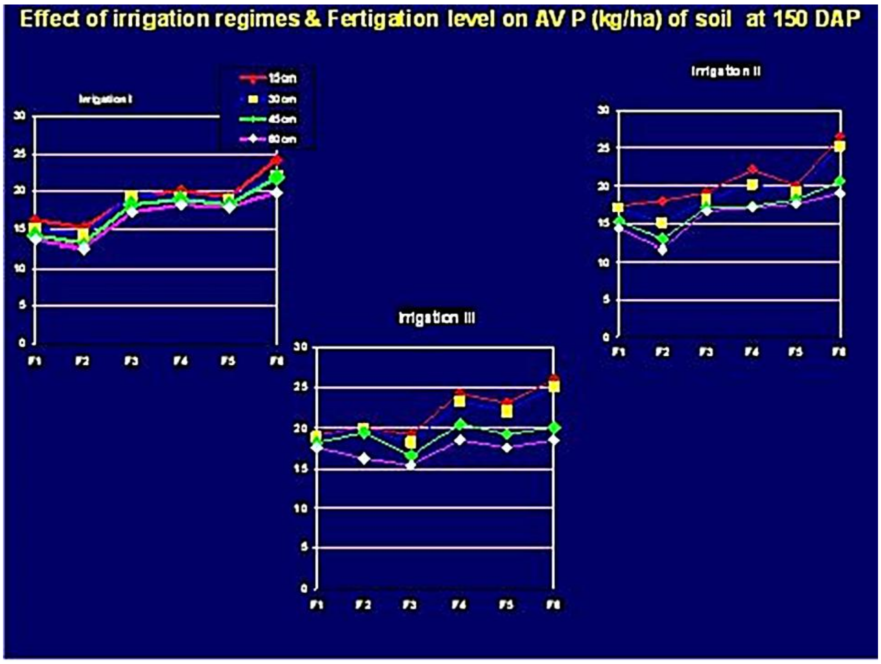

Fig 2: Effect of irrigation regimes and fertigation on available phosphorus (kg/ha.) at 150 Days after planting

Among the irrigation regimes, application of water at drip irrigation at 125% PE - irrigating 4 hours once in two days increases the available nitrogen status at 15 cm soil layers followed by 30 cm soil layers which increases the mobility of nutrients and in turn increase the cane yield. As for N remained concentrated in the immediate vicinity of the drip line at all irrigation systems and fertigation strategies there was only slight movement, because of soil adsorption and subsequent fast nitrification and root uptake. (Hutson *et al*., 1991) [4].

Soil phosphorus

The phosphorus content of soil were analysed at 150 days after planting and the data showed that 100% water soluable fertilizers significantly increased the available phosphorus status in all three irrigation regimes.

The phosphorus remained near the drip line, there was progressive increase in its availability from initial status with corresponding increase in levels of NPK. As expected high phosphorus concentrations developed at upper part of the root zone above drip line due to capillary upward movement and fertigation. At most times, P beyond 15 cm soil depth are hardly available for plant uptake because the supply of nutrients occurred directly at the center of root zone and moved out in all directions.

More roots would permeate the greater soil volume to which P was delivered. Surface application of P fertilizers has resulted in irregular distribution where greater amounts of P may remain near the soil surface (Thompson *et al*., 2003) [12].

Soil potassium

The soil available potassium content at 15, 30, 45 and 60 cm depths are presented in Figure-3. Application of 100% water soluable fertilizers increased the available potassium content of soil at 150 days after planting in all irrigation regimes. In respect of irrigation regimes, application of water at drip irrigation at 125% photo evaporation - irrigating 4 hours once in two days increases the available phosphorus status of soil.

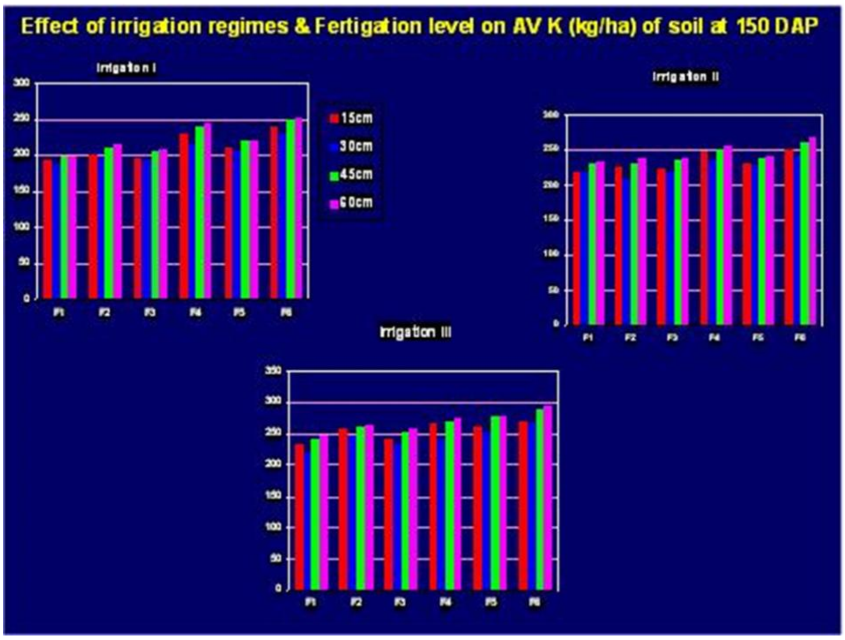

Fig 3: Effect of irrigation regimes and fertigation on available potassium (kg/ha.) at 150 Days after planting

The available potassium was higher at 60 cm followed by 45 and 15 cm soil layers irrespective of irrigation treatments. Available K throughout the profile tended to move with water toward the edge of the wetting front particularly at the end of fertigation period. The potassium concentration was significantly higher in the root zone (60 cm) depth of the sub surface drip irrigation than those surface soil layers. These results are supported by the findings of Singh *et al.* (2005) [8].

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