DRIP IRRIGATION IN SUGARCANE: A REVIEW

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ABSTRACT

Sugarcane (Saccharum officinarum L.), a major cash crop in India has a unique role in sustaining agro industrial economic growth. Sugarcane being a long duration crop produces huge amount of biomass, and requires large quantity of water (1100-2200 mm) and is mostly grown as an irrigated crop using surface irrigation. The drip irrigation adoption in sugarcane increases water use efficiency (60-200%), saves water (20-60%), reduces fertilization requirement (20-33%) through fertigation, produces better quality crop and increases yield (7-25%) as compared with conventional irrigation. However, if not installed properly, it may result in wastage of water, time, money and yield. The subsidy and technical support to farmers acts as an incentive to adopt this method on a large scale in India. Adoption of drip irrigation (surface or subsurface) system in sugarcane is technically feasible and economically viable and needs to be vigorously followed.

Key words: Sugarcane, Drip irrigation, Fertigation, Water use efficiency, (WUE).

Sugarcane (Saccharum officinarum L.), one among the major cash crops in India has a unique role in sustaining agro industrial economic growth of our country. India is the world’s second largest producer of sugarcane with estimated production of 348,187,900 tonnes per year (Wikipedia, 2011). This production accounts for approximately one fifth of total production 1,743,092,995 tonnes of world. Sugarcane is an important raw material for production of sugar, industrial alcohol, filter cake (a fertilizer), bagasse (fuel), cattle feed and paper industry. Sugar is a Rs 30,000 crore industry with about 3.5 crore farmers engaged in sugarcane cultivation. It is cultivated in about 4.09 million ha, however the average yield is about 69 t ha⁻¹ (Jain Irrigation Ltd., 2011). One of the main reasons of low yield is scarcity of water. Sugarcane being a long duration crop produces huge amount of biomass, and requires large quantity of water and is mostly grown as an irrigated crop. It is important to judiciously use the already existing water resources by adopting appropriate irrigation technology that not only increases sugarcane production per unit area but also per unit of water used. Thus a scientific and efficient management of water is needed especially in hot dry months of pre monsoon period, to enhance water use efficiency and cane yield which is possible by drip irrigation.

Water requirement of sugarcane

The water requirement of sugarcane is high and against the background of the rapid decline in irrigation water potential and low water-use efficiency in the flood (conventional) method of irrigation, drip irrigation is known to save a substantial amount of water and helps to increase the productivity as reported by several workers. (Shinde et al., 1999; Shinde and Jadhav, 2000; Raskar and Bhoi, 2001 and Rajanna and Patil, 2003). The water requirement of sugarcane from Akola has been estimated by Zade (2001). The average weekly values of reference evapotranspiration (ET) were calculated by modified Penman formula and distribution was fitted for the same. The 70% probability value of ET for sugarcane was 2065.30 mm while the total water requirement was 1633.41 mm.

Gulati and Nayak (2002) studied the growth, cane yield and water use efficiency of sugarcane as influenced by irrigation and planting dates in Orissa, during 1994-96. The study reported 4 irrigation levels (IW:CPE ratio of 0.6, 0.8, 1.0 and 1.2) and...
1.2) and 6 dates of planting (October, November, December, January, February and March) on sugarcane (cv. Co 6304). The highest cane yield of 156.65 t ha\(^{-1}\) was recorded from planting sugarcane during the third week of October at 1.2 IW:CPE, with the corresponding irrigation and water requirements of 132 and 218 cm. The crop extracted more moisture from the 0-30-cm depth in all treatments.

Arulkar et al. (2004) reported the water requirement estimation of sugarcane crop from climatological data by probability analysis at Nagpur district. Weekly rainfall data for the 25 years (1971-95) were analyzed and rainfall curves were drawn at various probability levels. The values of reference evapotranspiration were calculated on a weekly basis by using weather data on relative humidity, temperature, wind speed and cloudiness. Crop coefficient values were worked out to get the crop water requirement of sugarcane. Annual reference evapotranspiration and crop water requirement was found to be 2125.69 and 1982.29 mm, respectively.

The application of water balance studies in irrigated sugarcane from Karnataka has been reported by Rajegowd et al. (2004). It was observed that the crop coefficient value during initial stage was around 0.5 and then gradually increased during vegetative phase and reached maximum during flowering and reproductive phase and decreased to 0.6 at the time of maturity. The available water holding capacity of the soil was approximately 115.5 mm for 100 cm soil depth. The total water requirement was 1346 mm. The results indicated that the irrigated sugarcane crop planted during the month of July with field capacity can grow without any further irrigation until December. Under the annual rainfall of 843.7 mm in the zone, the annual surplus was approximately 138 mm; the total water available for the crop growth from the rainfall was approximately 818.3 mm. The additional need of approximately 528.6 mm was met through supplementary irrigation.

Kumar et al. (2005) conducted experiment on probabilistic irrigation water requirement of major crops at Udham Singh Nagar district of Uttaranchal state. The water requirement estimated using daily rainfall and observed class-A type pan evaporimeter data. The irrigation water requirements of sugarcane were calculated at 50 and 80% probability of occurrence of effective rainfall. The seasonal average water irrigation requirement was found to be 1119 mm for sugarcane crops at 80% probability.

The water requirement for seasonal and annual sugarcane crop (per plant basis) using open pan evaporation method from Akola, Maharashtra was reported by Ingle (2007). Sugarcane crop water requirement increased from 0.52 litres day\(^{-1}\) to 10.96 litres day\(^{-1}\) on 21 MW (meteorological week), and then decreased gradually to 1.80 litres day\(^{-1}\) at 26 MW. The maximum WRs for, suru sugarcane, adsali sugarcane were 121.8, 147.8, m\(^{3}\) day\(^{-1}\) ha\(^{-1}\) respectively.

Larger yield in sugarcane depends upon the availability of adequate quantity of water. Water is most important input in an assured sugarcane production system, especially in area where sugarcane production suffers due to scarcity and or irregular distribution of rainfall specially from mid April to end of June (before the onset of monsoon). Drip irrigation is a method by which one can overcome scarcity of water for Sugarcane crop.

**Advantages of drip irrigation in sugarcane**

In drip irrigation system water is applied in the form of drops directly to the plant through drip nozzle from which it drops into the soil slowly and frequently to keep the soil moisture within the desired range for healthy plant growth so that the plant do not experience any moisture stress throughout their life cycle. It is particularly suited to soil with very low and very high infiltration rate under the condition of water scarcity and in area where drainage of excess water is difficult. Advantages of drip irrigation in Sugarcane are as follows: saving of irrigation water; low fertilizer/nutrient loss due to localized application and reduced leaching; high water application efficiency; grading of the field not necessary; ability to irrigate irregular shaped fields; allows better use of recycled water; moisture within the root zone can be maintained at field capacity; less weed growth; soil type plays less important role in frequency of irrigation; minimized soil erosion; highly uniform distribution of water i.e., controlled by output of each nozzle; lower labour cost; variation in supply can be regulized by valves and drippers; fertigation can easily be included with minimal waste of fertilizers; foliage remains dry thus reducing the risk of disease.
and decreased energy costs due to reduced pumping time to irrigate a given design area. It leads to optimum soil water air relations contributing to better germination, uniform field emergence and maintenance of optimum plant population with higher cane and sugar yields.

**Drip irrigation in sugarcane**

**a. Indian scenario**

Three levels of drip irrigation (low, medium and high) were compared, based on IW/CPE ratio of 0.75, 1.00 and 1.25, respectively, for surface irrigation, and ratios of 0.40, 0.55 and 0.70, respectively for drip irrigation by Ahluwalia *et al.* (1998) for sugarcane. The medium level of irrigation for surface irrigation method (IW/CPE=1.00) was the optimum level in terms of cane yield (81.4 t ha\(^{-1}\)) and WUE (0.484 t hacm\(^{-1}\)). While the low level of irrigation was the optimum level of drip-irrigated sugarcane in terms of cane yield (80.6 t ha\(^{-1}\)) and WUE (0.779 t hacm\(^{-1}\)). The drip irrigation method resulted in saving of water by 38.0% with consequent increase of 60.9% in WUE over the surface irrigation method. Juice extraction percentage in surface-irrigated sugarcane was higher than in the drip-irrigated crop. The sugar yield with drip irrigation was reported higher than that with surface method.

Shinde and Jadhav (1998) compared drip irrigated sugarcane with conventional irrigated in a study carried out at Pune, Maharashtra, India, in 1986-94. Different surface and subsurface drip irrigation methods were compared with conventional irrigation. The result indicated that the automatically controlled drip irrigation used up to 56% less water, increased yield up to 52% and increased water use efficiency by about 2.5-3 fold.

The effect of fertigation and planting techniques on yield and quality of sugarcane under drip irrigation was studies by Bhoi *et al.* (1999). Sugarcane was grown in paired rows (75 cm), four rows (90 cm) and drip irrigated. Fertilizer -N (Nitrogen) was applied through drip irrigation in 4, 10 and 20 splits. Mean cane yield of 171.4 t ha\(^{-1}\) was found highest with four row planting and 20 splits. Paired row planting with 20 splits of N produced similar yield of 169.9 t ha\(^{-1}\).

The influence of planting techniques and fertigation through drip irrigation on yield, quality and economics of sugarcane has been reported by Shinde *et al.* (1999) from Rahuri, Maharashtra, on seasonal sugarcane and its ratoon. Planting technique of one skipped furrow (90 cm) after four planted furrows gave higher cane yield (mean 151.57 t ha\(^{-1}\)), net returns (Rs 44 451 ha\(^{-1}\)) and B: C ratio (1.75) than paired row planting. Fertigation of liquid fertilizers through drip irrigation gave 25% fertilizer saving and 20.74% higher yield. Kumar *et al.* (2000) reported on evaluation of drip irrigation systems adopted for sugarcane crop in Vertisols. Among the two systems of drip irrigation evaluated for sugarcane crops in Karnataka, India (1994), both microtube and bi-wall systems of drip irrigation were found to be suitable for sugarcane crops. The microtube system was more efficient, recording higher growth and yield parameters, as compared to the bi-wall system of drip irrigation.

The field performance of pressure compensating, non pressure compensating and inline drip irrigation systems in sugarcane crop has been compared with furrow irrigation by Shinde and Jadhav (2000). The results revealed that pressure compensating and inline drip irrigation systems saved irrigation water up to 50% along with 17 to 20% increase in cane yield. The commercial cane sugar production of more than 16 t ha\(^{-1}\) and uniformity of water distribution to the tune of 93% was observed in pressure compensating and inline drip irrigation systems.

Raskar and Bhoi (2001) studied the productivity of sugarcane as influenced by planting techniques and sources of fertigation under drip irrigation at Rahuri, Maharashtra, India. Four separate trials were conducted to study the effect of source and levels of fertigation with modified planting techniques on yield and quality of sugarcane under drip irrigation. The results of the first two trials indicated 19 to 25% higher cane yield in one row skip after four row planting with drip irrigation than conventional planting under surface irrigation. In the third trial sugarcane yield and comercial cane sugar (CCS) yield increased with increase in levels of fertilizer and found maximum in 125% fertilizer levels (157.19 and 17.35 t ha\(^{-1}\)). However, the yield obtained due to application of 75 and 100% recommended dose of water soluble fertilizer was on par, indicating 25% savings in fertilizer. Among
the various sources, yield of water soluble fertilizer (145.73 t ha⁻¹) was at par with the yield obtained by fertigation of urea, Diammonium phosphate and Muriate of potash. The overall increase in cane yield and total water savings by use of drip irrigation ranged from 20 to 30% and 42 to 52%, respectively. The water use efficiency ranged from 10.17 to 14.03 q hacm⁻¹ as in drip irrigation compared to 4.82 to 6.00 q hacm⁻¹ in surface method.

The opinions of drip adopters about nature and extent of benefits due to drip irrigation system used for sugarcane crop of a total of 102 sugarcane farmers from 20 villages employing drip irrigation for sugarcane have been compiled by Chavai et al. (2003) from Maharashtra. The major benefits accrued and reported by majority of the farmers were, savings in water ranging from 20 to 60%, in labour and fertilizer, reduction in weed intensity and increase in sugarcane yield.

The scheduling of drip irrigated sugar cane using the “index” tensiometer method has been reported by Muthy et al. (2003). An array of eight tensiometers was used to schedule irrigation and was compared to the water budget method over one crop cycle (plant cane and 8 ratoons). More water was applied with ‘index’ tensiometer, on average, an additional amount of 165 mm year⁻¹. This resulted in extra cane yields of 11.6 tonnes ha⁻¹ year⁻¹. The efficiency of irrigation water use with tensiometer and water budget was 0.055 and 0.051 tonne ha⁻¹ mm⁻¹, respectively. In addition to this higher irrigation water use efficiency, the financial analysis showed a net profit of approximately MUR 11400 ha⁻¹ year⁻¹ in favour of the ‘index’ tensiometer technique. Scheduling drip irrigation of sugarcane using tensiometers was found to be a viable practice for Savannah SE.

Four specific irrigation schedules for sugarcane crop through drip system viz., I₁ (0.6, 0.8, 1.0, 0.8 etc.), I₂ (0.8, 1, 1.2, 0.6 etc), I₃ (1.0, 1.2, 0.8, 0.6 etc), through drip and I₄ (1.00 etc), by gravity flow permuted with fertilizer treatments viz., application of RDF (F₁, 250:115:115 NPK), through soil, F₂ (100% RDF), F₃ (80% RDF) and F₄ (60% RDF) have been reported by Digrase et al. (2004). Results showed that irrigation applied through drip produced significantly higher cane yield (162.24 tonnes ha⁻¹) than gravity flow irrigation (95.52 tonnes ha⁻¹). Irrigations applied through drip at I₄ schedule (0.8, 1.0, 1.2, 0.6 etc.) proved significantly superior to rest of the schedules. It required 1981 ha mm water against 2549 ha mm in gravity flow to maximize the yield. Application of 80% recommended dose of fertilizers has produced higher cane yields than its application at RDF through soil resulting in 20% saving in fertilizer cost. The sugarcane crop responded quadratically to irrigation water so also to fertilizers. The resource use efficiency under drip was appreciably higher than gravity flow.

Narayanamoorthy (2004) reported 23% higher yield, 44% water saving and 1059 kwh ha⁻¹ electricity saving by using drip irrigation in comparison with flood method of irrigation for sugarcane grown in India.

The feasibility of drip irrigation for sugarcane in Harayana has been reported by Goel et al. (2005). A field experiment was conducted to compare drip (1.0 and 0.8 IW/CPE ratio) and furrow (1.0 IW/CPE ratio) irrigation effects on water use, yield, juice quality and net returns of sugarcane. As compared to furrow irrigation, drip irrigation at 1.0 IW/CPE ratio increased cane yield, number of millable cane, sugar yield, water use efficiency and nutrient content in the index leaf of plant ratoon. The net profit under drip irrigation method was insignificant (Rs. 1610 ha⁻¹ for plant crop and Rs. 1820 ha⁻¹ for first ratoon crop).

Sosa et al. (2008) studied the response of sugarcane to distinct drip irrigation thresholds. Rainfall during the period was 1245.8 mm, and the irrigation treatments applied were none, and treatments that consumed 10, 30 or 50% of the water used (irrigation thresholds of 90, 70 and 50%). The result showed that all the irrigated plots gave better growth and yield than the un-irrigated plot, and better sugar contents and yields. The best treatment was the 10% irrigation (threshold 90%) but this was not significantly different from the 30% (threshold 70%) treatment, although it was significantly different from the 50% (threshold 50%) treatment, although the 30% (threshold 70%) and 50% (threshold 50%) treatments were not significantly different.

The effect of fertigation on emission uniformity of drip irrigation system for sugarcane have been reported by Kadam (2009). The recommended dose of NPK nutrients for sugarcane
was applied in the form of commercially available water soluble fertilizers along with the irrigation water through drip irrigation system. The entire fertilizer dose of NPK was applied in ten equal splits at fortnightly interval. Each level of application was considered as separate treatment (T1 = 10%RD, T2 = 20%RD, T3 = 30%RD, T4 = 40%RD, T5 = 50%RD, T6 = 60%RD, T7 = 70%RD, T8 = 80%RD, T9 = 90%RD and T10 = 100%RD). The average discharges before and after application of fertigation was recorded and analysed to assess the per cent reduction in discharge and emission uniformity. The average reduction in initial discharge was found as 8.79 per cent. The reduction in initial discharge is suggestive to have one acid treatment at the end of the season when the quality of irrigation water is C3S1 and water soluble fertilizer as acidic. The field emission uniformity values were found in the range of 90.34 to 93.01 per cent with an average value of 92.39 per cent for the entire unit. The per cent reduction in field emission uniformity was to the extent of 3.49% at the end of passing of 100% of RD. The reduction in discharge and the variation in EU were due to the variation in discharge of emitters due to clogging. It was found that the source of water was mainly responsible for clogging of emitters. The analysis of deposits in emitters and laterals revealed that the dissolved salts in water source dominated by carbonates, bicarbonates, chlorides and sulphates of calcium and magnesium are responsible for the emitter clogging. Thus, the reduction in discharge and emission uniformity was attributed to the water quality (C3S1) and not to the fertigation.

The socio economic analysis of drip irrigation in sugarcane at Tamil Nadu was reported by Shanthy and Kumar (2010). Results from the study concluded that drip irrigation for sugarcane cultivation is a valuable technology and that in the long run it was economical to lay a drip system for sugarcane.

Ravikumar et al. (2011) from Coimbatore has evaluated a fertigation schedule for sugarcane using a vadose zone flow and transport model, HYDRUS-2D, and showed that the urea requirement can be reduced by 30% while at the same time providing enough N for its assimilation at all stages of crop growth.

b. World scenario

Brazil is the largest producer of sugarcane in the world. Nunes et al. (2003) conducted a study on the effect of sub superficial drip irrigation system at three spacing of dripping tubes and four planting densities of sugarcane crop at Northeast Brazil. The results indicated that smallest spacing between dripping tubes increased sugarcane’s yields. Highest yields were achieved when a 1.0x1.0 m and 1.2x1.2 m between plant rows and dripping tubes were used, attaining yields of 136.9 and 154.7 tons ha⁻¹, respectively, which corresponded to a 32.0 and 35.0% increase in relation to the same cropping system under dry farm conditions. The uses of double sugarcane rows (1.4x0.6 m) and (1.2x0.8 m), with 2.0 m spaced dripping tubes had attained the lowest yields, however, it still exceeded in 15.6 tons ha⁻¹ the yield of non irrigated plots.

Romero et al. (2003) conducted a study on the effects of trickle irrigation (with drip lines buried in all the furrows, with drip lines buried in alternate furrows and with drip lines buried in alternate interfurrows) for sugarcane crop at Argentina. The population, weight and height of stalks and crop yield increased under all the drip irrigated treatments. Trickle irrigation with drip lines buried in all the furrows resulted in the highest increase in crop production (55%).

The sensitivity analysis of sugar cane productions with two irrigation technologies (drip and gravity) has been compared by Torres et al. (2010) in Mexico. Three variables were considered in the sensitivity analysis: cane production per hectare (made sensitive to low prices), selling price of sugarcane per tonne (made sensitive to low prices), and variations in direct costs of production (made sensitive to high prices). The three variables showed differences, with favourable results for the drip irrigation system over the gravity irrigation system.

Kwong et al. (1999) reported after conducting a study in Mauritius that drip fertigation may be used as a mean for reducing fertilizer nitrogen in sugarcane. Under the soil and climatic conditions that prevailed at the study site, fertilizer- N was reduced by 30%. The growth pattern (as reflected by tiller density and leaf area development) and sugarcane yields from drip fertigation applied at the rate of 80 kg N ha⁻¹ per year were not inferior to those obtained with the standard practice of burying 120 kg N ha⁻¹ per year along the cane rows.
Wei et al. (2008) conducted a study on water requirement and effect of fertilizer on sugarcane in China. It was reported that distribution of rainfall in spring, autumn and winter did not satisfy the water requirement of sugarcane, as it provided only 74.4, 68.6 and 35.7% of the water requirement of sugarcane at the seedling, tillering and maturity stages, respectively. Fertigation enhanced sugarcane fertilizer and water use efficiency.

The irrigated sugarcane production functions from South Africa were reported by Lecler (2009). The typical practice of increasing irrigation water application amounted to account for low irrigation uniformity. The results indicated that the maximum crop yields in Komatipoort required at least 1150 mm of irrigation water on shallow, 0.6 m deep sandy clay loam soils compared with only 900 mm on 1.2 m deep sandy clay loam soils.

The irrigation scheduling in sugarcane based on atmospheric evaporative demand (AED) from Australia has been reported by Attard et al. (2003). Two alternative scheduling techniques were developed that utilize simple tables and computerized systems based on AED, knowledge of crop response to water stress, and soil water holding capacity. The simple scheduling tables indicated that irrigation should be as frequent as 10 days prior to the wet season and as infrequent as 21 days after the wet season.

Brouwers et al. (2008) compared the mineral nitrogen contents in cane cropped vertisols of Sudan and Guadeloupe as influenced by urea application management. The effects of two methods of urea application management on soil mineral N levels in ratoon cane at two sites were measured and compared. Both experiment sites were on vertisols and received different irrigation practice. In Sudan (site S) cane is grown under furrow irrigation, and urea is broadcast and then buried on the rows by hilling up. In Guadeloupe (site G) cane is grown rainfed with complementary drip irrigation, and urea is broadcast on and near the cane rows. Site G results showed that, one week after urea application, all applied N was recovered in the topsoil. At site S, however, only 70% N was recovered. The results also revealed that at site S, where yield was higher, the amount of mineral N in the topsoil was at a higher level than the pre-application amount for a far longer period than at site G. Of the application methods tested, the best commercial practice to extend the time that mineral N is at an adequate level in the rooting zone, and thus enhancing cane yield, appears to be hilling-up of the cane rows after broadcasting the urea.

**Drip fertigation in sugarcane**

Drip irrigation systems provide a convenient method of applying fertilizers and chemicals with irrigation which is called fertigation using special devices. The fertigation devices include pressure differential systems (fertilizer tank), suction produced by a venturi principle (venturi injectors) and pumps (diaphragm or piston or electrically operated). The fertilizer unit is an integral part of control head. Drip fertigation may be used as a mean for reducing fertilizers in sugarcane as reported by many authors as described below. For sugarcane crop the Fertilizer-N was reduced by 30% in a study conducted by Kwong et al. (1999). Shinde et al. (1999) studied the influence of planting techniques and fertigation through drip irrigation on yield, quality and economics of sugarcane by conducting a field experiment in Maharashtra, on seasonal sugarcane and its ratoon. Planting technique of one skipped furrow (90 cm) after four planted furrows gave higher cane yield (mean 151.57 t ha⁻¹), net returns (Rs 44 451 ha⁻¹) and B: C ratio (1.75) than paired row planting. Fertigation of liquid fertilizers through drip irrigation gave 25% fertilizer saving and 20.74% higher yield.

Mahendran and Dhanalakshmi (2003) reported the effect of crop geometry and drip fertigation on growth and yield of sugarcane crop in a field experiment conducted at Madurai, Tamil Nadu. The experiment consisted of surface irrigation at 0.75 irrigation water/cumulative pan evaporation ratio to a depth of 6 cm (T₁), drip irrigation in paired row (60:100) at 100% crop evapotranspiration (ETc) with and without fertigation (T₂ and T₃), drip irrigation in 80 cm spacing at 50, 75 and 100% ETc with fertigation (T₄, T₅, T₆), drip irrigation in 120 cm spacing at 50, 75 and 100% ETc with fertigation (T₇, T₈, T₉). Fertigation was given at biweekly intervals starting from 15 days after planting (DAP) onwards up to 150 DAP in 10 equal splits. Growth parameters such as germination percentage, plant height, tiller production, leaf area index and dry
matter production were higher in 120 cm spaced sugarcane under drip irrigation at 100% ETc level with fertigation. The same treatment recorded higher yield attributes like number of millable canes, millable cane length and girth. Higher cane and sugar yield of 181.6 and 26.14 t ha⁻¹ were recorded in drip and fertigation plots, respectively at 100% ETc level fewer than 120 cm spacing.

Rajanna and Patil (2003) studied the effect of fertigation on yield and quality of sugarcane in a medium black soil at Belgaum district, Karnataka. N and K were applied at recommended rates of 250 and 185 kg ha⁻¹ respectively. N was applied at 6-day intervals starting from 30 days after planting (DAP) to 240 DAP. Results showed that fertigation through drip irrigation produced a 24.34% higher yield, and saved 46.52% water compared to the recommended fertilizer rate applied with surface irrigation (106.48 t ha⁻¹). Quality parameters such as brix, pol and percentage commercial cane sugar were not affected by fertigation.

Shukla et al. (2009) reported that the potassium (K) fertigation in sugarcane increased the number of buds per stubble, number of stalks, dry matter accumulation, number of millable canes and individual cane weight in ratoon cane. Potassium content of stubble increased by 16.7% with K fertigation. The content of reducing sugars in buds at the time of ratoon initiation improved significantly with K fertigation. Ratoon cane yield increased by 15.21% (74.1 t ha⁻¹) while sugar yield increased by 13.9% (8.2 t ha⁻¹) as compared with control with K fertigation.

**Economical viability of drip irrigated sugarcane**

Economic viability of sugarcane has been established with drip irrigation as emphasized by the following authors. More and Bhoi (2004) studied the economic analysis of suru sugarcane (CO-86032) and its ratoon under drip irrigation and wide row planting system. There were 12 treatment combinations involving three row spacings (150, 180 and 270 cm) and two planting techniques (single row and paired row), with two intercrops (cucumber and watermelon). Additional two control treatments of planting systems without intercrops (100x30 cm spaced normal planting with surface irrigation and 90x30 cm spaced four row planting with drip irrigation) were also taken for comparison. The irrigations were scheduled with drip system to all the treatments at alternate day on the basis of cumulative pan evaporation, while in surface irrigation, irrigations were scheduled at 75 mm CPE with 8 cm depth. In wide-spaced paired row planting at 75-150 and 90-180 cm, 19.92 and 12.97% higher cane yield with 54.50 and 54.24% saving in irrigation water over 100 cm spaced normal planting was recorded. The net profit/cm of water in paired row planting of 75-150 and 90-180 cm were Rs 676.53 and Rs 752.63 with benefit:cost (B:C) ratio of 2.09 and 2.18, respectively, which were higher than 100x30 cm normal planting (Rs 284.05 net profit and 2.31 B:C ratio) and 90x30 cm 4 row planting (Rs 526.32 net profit and 1.38 B:C ratio).

Raskar and Bhoi (2003) conducted a study on response of sugarcane to planting materials, interrow spacings and fertilizer levels under drip irrigation. The response of sugarcane to intra-row spacing (30, 60 and 90 cm), fertilizers treatment (75, 100 and 125% of the recommended fertilizer rate) and source of planting material (tissue culture plantlets and polybag settlings) were studied under drip irrigation. Sugarcane yield, commercial cane sugar, gross monetary net returns and water use efficiency increased with increasing intra-row spacing and fertilizer rate, and were higher with the use of polybag settlings.

The economics of drip irrigation in sugarcane cultivation using data collected from a case study in Sivagangai district, Tamil Nadu, India has been reported by Narayanaamoorthy (2005). Results showed productivity gains of 54% and water saving of 58% due to drip irrigation as over flood irrigation. Discounted cash flow analysis suggested that investment in drip irrigation in sugarcane cultivation was economically viable even without subsidy. The benefit-cost ratio varies from 1.98 to 2.02 without subsidy and 2.07 to 2.10 with subsidy at different rates of discount. Similarly, Torres et al. (2010) from Mexico have also reported favourable economic results for the drip irrigation system over the gravity irrigation system.

**Disadvantages of drip irrigation**

There is a chinese proverb that says “You can’t expect both ends of a sugar cane are as sweet”. So, along with the advantages of drip irrigated
sugarcane, as mentioned above, there are certain disadvantages of drip irrigation like initial high expense. The other unfavourable factors are as follows; the sun can affect the drip irrigation components, shortening their usable life; Clogging may occur if the water is not properly filtered and the equipment not properly maintained; drip lateral causes extra clean up costs after harvest; waste of water, time and yield may occur, if system is not installed properly; germination problems may occur in lighter soils subsurface drip may be unable to wet the soil surface for germination. Most drip systems are designed for high efficiency, meaning little or no leaching fraction. Without sufficient leaching, salts applied with the irrigation water may build up in the root zone, usually at the edge of the wetting pattern. On the other hand, drip irrigation avoids the high capillary potential of traditional surface-applied irrigation, which can draw salt deposits up from deposits below.

**Conclusions and future prospects**

Sugar cane is an important cash crop in India. Surface irrigation is the prevalent irrigation method. Drip irrigation in sugarcane is a relatively new innovative technology that can conserve water, energy and increase profits. Thus, drip irrigation may help solve three of the most important problems of irrigated sugarcane - water scarcity, rising pumping (energy) costs and depressed farm profits in India. The application of drip irrigation in sugarcane has convincingly shown that the technique results in high water use efficiency, saves water, reduces fertilization requirement, provides better quality crop and higher yield. However, if not installed properly, it may result in waste of water, time and yield. Application of drip irrigation requires careful study of all the relevant factors like land topography, soil, water, crop and agro-climatic conditions, and suitability of drip irrigation system and its components. The subsidy and technical support to farmers may be an incentive to adopt this method in India on a large scale. Adoption of drip irrigation (surface or subsurface) system in sugarcane cultivation is technically feasible and economically viable and needs to be vigorously followed.

**REFERENCES**


