EFFECT OF LATERAL SPACING AND METHOD OF PLANTING ON WATER USE EFFICIENCY FOR SUBSURFACE DRIP FERTIGATED SUGARCANE

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ABSTRACT

Maximizing water use efficiency for higher cane and sugar yield is therefore a strategic goal in conserving limited water resources. Water use efficiency can be defined as cane yield per unit of crop water use (evapotranspiration). Accuracy of water application allows reducing average irrigation rate to a level that coincides with soil hydraulic conductivity and minimizes percolation below the main root zone. It is comprehensive exercise using every drop of water for sugarcane production including the use of natural precipitation as well as efficient management of irrigation network through a suitable irrigation method. In this study five lateral spacing and two method of planting was evaluated to investigate water use efficiency for sugarcane under subsurface drip fertigation (SSDF) at Agricultural College and Research Institute, Madurai during 2008-09. The experiment was laid out in a randomized block design with four replications of sugarcane raised under subsurface drip fertigation. The treatments consisted of lateral spacing and method of planting viz., 120, 135, 150, 165 and 180 cm as single side planting (SSP) and double side planting (DSP) under subsurface drip fertigation. A control treatment was maintained under surface irrigation with recommended practices. Results indicated that Subsurface drip irrigation method significantly increased sugarcane yield and yield components over furrow irrigation. Furthermore, Maximum average yield (180 t ha^{-1}) was recorded under subsurface drip fertigation at 120 cm lateral spacing with double side planting. The total water requirement under subsurface drip fertigation was lesser (1115.28 mm) than conventional method (1712.00 mm) and thus a substantial quantity of water saving by 34.85 percent due to subsurface drip fertigation was observed. The higher cane yield coupled with enormous quantity of water saving under subsurface drip fertigation resulted in higher water use efficiency of 161.40 kg ha^{-1} mm^{-1} but it was only 56.07 kg ha^{-1} mm^{-1} in conventional method of sugarcane cultivation. The increase in water use efficiency under subsurface drip fertigation with 120 cm lateral spacing as double side planting was around 65 per cent compared to surface irrigation. As the total applied water decreased from 17,120 to 11,152.8 cubic meters by using subsurface drip fertigation. Subsurface drip fertigation at 1.20 m lateral spacing resulted in higher water use efficiency than the 1.80 m lateral spacing in both double side planting and single side planting. The average water use efficiency of the 1.2 m lateral spacing in the experiment was 5.88 % higher than the 1.80 m lateral spacing under subsurface drip fertigation. Although, the water use efficiency of double side planting was 6.6 to 13.17 % higher than the single side planting in all the treatments. Therefore, it was concluded that lateral spacing can have a moderate impact on water use efficiency under subsurface drip irrigation systems. The closer lateral spacing exhibited trends toward higher water use efficiency.

INTRODUCTION

Sugarcane is one of the important cash crops grown in India and plays a vital role in both agricultural and industrial economy of our country. In India, sugarcane is cultivated in about 4.2 million ha producing about 281 million tonnes of cane with an average productivity of 66.7 t/ha. Uttar Pradesh state has the largest area (2.14 m ha) with almost 50% of area under sugarcane in the country, but the productivity is maximum in Tamil Nadu (134.2 t/ha) followed by Karnataka and Maharashtra. Sugarcane is a high water requiring with an average of 20 megalitres of wate/ha. Sugarcane cultivation in 5.0 M.ha area will require about 100 BCM of water/yr. (Ashok K. Shrivastava, 2011).

Under the present water scarce conditions, productivity of high water requiring crops like sugarcane can only be sustained using technologies economizing water and could also be of advantage. Water economizing techniques like drip irrigation is ecofriendly and economically viable options to increase the cane productivity per unit quantity of applied irrigation water and will be undoubtedly play an important role in the future of the Indian agriculture. Unlike flood irrigation, the water and nutrient use efficiency are higher in drip irrigation, since this technology helps to supply the required quantity of irrigation water and nutrients directly to root zone of the crop without much loss. It provides many unique agronomic, water and energy conservation benefits that address many of the challenges facing irrigated agriculture.

Precise application of irrigation water and fertigation to sugarcane may help improve the productivity of the crop. Nutrient use efficiency in fertigation increases as a result of controlled and regular application of fertilizers. It can also enhance the yield of sugarcane/unit of water/unit of area. The present experiment was conducted mainly to study the influence of subsurface drip irrigation on the yield of sugarcane and to study the effect of different lateral spacing on the yield and water use efficiency of sugarcane.

MATERIAL AND METHODS

The field trial was conducted at Agricultural College and Research Institute, Madurai to find out influence of subsurface drip fertigation on yield and water use efficiency of sugarcane during 2008-09. The soil of the experimental field is sandy clay loam, low in organic carbon (0.4%), low in nitrogen (220 kg/ha), medium in phosphorus (19 kg/ha) and high in potassium (425 kg/ha). The pH (1:2) and EC (1:2) of the soil were 7.5 and 0.4 dS/m, respectively. The treatments comprising of five lateral spacing (120, 135, 150, 165 and 180 cm) and two method of planting (Single side planting and Double side planting) were tested in along with one control of surface irrigation with recommended practice of fertilizer application. The experiment was laid out in randomized block design with four replications. The sugarcane variety CO 86032 was used as the test crop. In double side planting, setts were planted in both sides of trenches having a width of 40 cm. The drip tape laterals was placed at the centre of the trench. Whereas, in single side planting, setts were planted in one side of trenches having a width of 30 cm and the drip tape lateral was placed on the opposite side. The recommended fertilizer dose of 275:62.5:112 kg N, P_2O_5 and K_2O ha^{-1} was followed in the experiment. The entire P_2O_5 was applied as basal in the form of single super phosphate (16 % P_2O_5) and the entire N and K were applied through urea (46 % N) and muriate of potash (60 % K_2O) in three equal splits for surface irrigation treatment. Whereas, under subsurface drip fertigation, 50 per cent of P and K was applied as basal and the remaining 100 per cent of N and 50 per cent of P and K were applied through drip as water soluble fertilizers. The fertigation was given in 30 spilts at six days interval starting from 7 dap to 210 dap through subsurface drip. Normal fertilizers viz., urea, single super phosphate, muriate of potash and water soluble fertilizers viz., poly feed (13:40:13), $CaNO_3$ and KNO_3, were used in the experiment as s source of fertilizers. The water source is an open well. Water was pumped through 7.5 HP motor and it was conveyed to the main field using 90 mm PVC pipes after filtering through sand and screen filters. From the mainline, water was taken to the field through sub mains of 63 mm diameter PVC pipes. Drip tape laterals of 16 mm diameter with 15 mill wall thickness were fixed in the sub mains and maintained the lateral spacings of 120, 135, 150, 165 and 180 cm respectively. One lateral was placed in the every subsurface of trench. The drip laterals had inline emitters spaced at 20 cm apart and the discharge rate of each emitter was 1.29 lph. The operating pressure was maintained between 0.75 to 1 kg cm^{-2}. A 16 mm tap was fixed at the head of each lateral in order to regulate the fertigation scheduling and the laterals were closed with end plug. After installation and before placing of laterals under subsurface trial run was conducted to assess the uniformity coefficient of the system.

Irrigation scheduling

For irrigation through drip, first irrigation was given immediately after planting and subsequent irrigations were scheduled once in two days based on the daily pan evaporation. The irrigation was given at 100 % PE and the quantity of water was calculated as follows

$$\text{Volume (lit ha}^{-1}) = PE \times Kp \times Kc \times \text{Area (m}^2)$$

PE - Pan Evaporation
Kp - Pan co- efficient

Kc- Crop co- efficient
Time of operation of drip system to deliver the required volume of water for research plot was computed based on the formula.

$$\text{Time of application} = \frac{\text{Volume of water required (lit)}}{\text{Emitter discharge (lit ha}^{-1}\text{) x No. of emitters/plot}}$$

Water use efficiency

Water use efficiency (WUE) is the yield that can be produced from a given quantity of water. It was worked out by using the following formula and expressed as kg mm^{-1} ha^{-1}.

$$WUE = \frac{\text{Yield of cane (kg ha}^{-1}\text{)}}{\text{Total amount of water used (mm)}}$$

RESULTS AND DISCUSSION

Consumptive use of water and Water saving

The water requirements of crop depends on the actual crop evapotranspiration were varied from 4 to7 mm/day at the early stage to the peak demand period. The total depth of irrigation water needed for sugarcane crop was estimated under subsurface drip irrigation as 11,152 cubic metres per ha. Whereas, in surface irrigation, the total depth of water used was estimated as 17120 cubic metres per ha. The quantity of water was saved 6068 cubic metres/crop under subsurface drip irrigation compared with surface irrigation.

The total water requirement under subsurface drip irrigation worked out to be only 1115.28 mm inclusive of effective rainfall which accounted for 306 mm. Under surface irrigation method, quantity of water applied through surface was 1300 mm. An effective rainfall of 412 mm was received during crop period and totally 1712 mm of water was consumed by surface irrigated crop. (Table 1.)

Table 1. Effect of subsurface drip irrigation on water saving

Irrigation method	Water applied (mm)	Effective rainfall (mm)	Total water used (mm)	Water saving (%)	Additional cultivated area (%)
Surface irrigation	1300	412	1712	-	-
Subsurface drip irrigation	809.28	306	1115.28	34.86	53.50

The saving of irrigation water was more in subsurface drip fertigation compared to surface irrigation method. The data reveal that subsurface drip irrigation can save 34.84 per cent water compared to the surface irrigation. The water saving under subsurface drip irrigation was due to low application rate at frequent interval matching actual crop water needs at various stages.

Effect of subsurface drip fertigation on water use efficiency

Different lateral spacing and method of planting significantly influence the on wate ruse efficiency of sugarcane (Figure 1.) Generally, water use efficiency indicated the effectiveness of the applied water in terms of crop yield. The increase in water use efficiency under subsurface drip fertigation was around 50 to 65 per cent compared to surface irrigation.

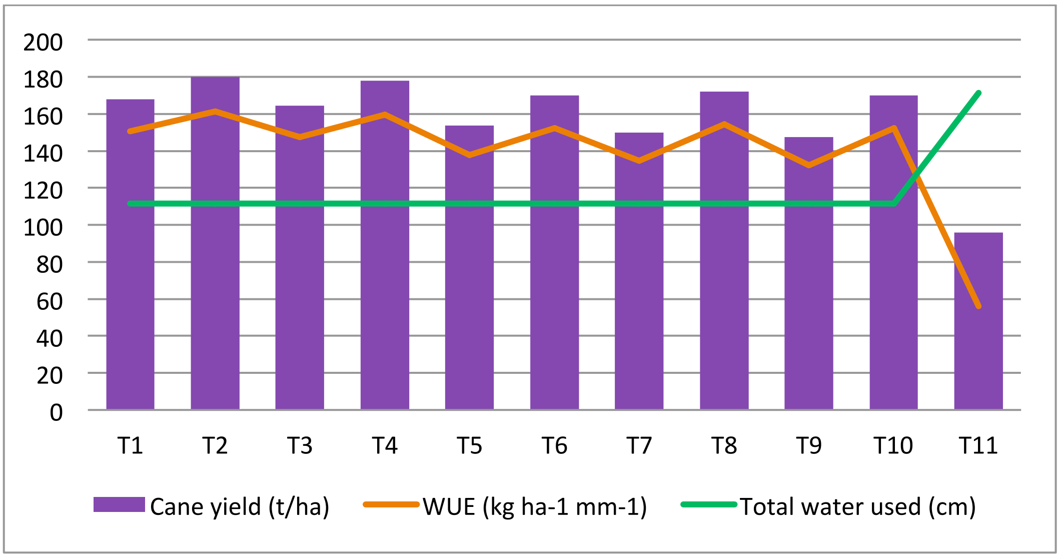

Figure 1. Effect of lateral spacing and method of planting on water use efficiency of sugarcane under subsurface drip fertigation

Higher WUE of 161.40 and 159.60 kg ha^{-1} mm^{-1} of irrigation water was recorded in 120 cm lateral spacing with DSP and 135 cm lateral spacing with DSP under subsurface drip fertigation. The surface irrigation method recorded the lowest WUE of 56.07 kg ha^{-1} mm^{-1} and this was 65 per cent lower than the subsurface drip fertigation with 120 cm lateral spacing as DSP. 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. (Banger and Chaudhari, 2004). The irrigation water use efficiency was increased in sugarcane to the extent of 52.33 per cent in subsurface drip irrigation compared to surface irrigation method. (Dhotre *et al.,* 2008)

Effect of subsurface drip fertigation on yield parameters

The yield attributes such as millable canes, cane length, number of internodes, girth of cane and individual cane weight were significantly influenced by row spacing, method of planting and subsurface drip fertigation. (Table 2)

Planting of cane at 120 cm lateral spacing with DSP under subsurface drip fertigation (T_2) recorded the maximum NMC of 1,14,645 ha^{-1} The minimum NMC of 88,382 ha^{-1} was recorded in planting of cane at 180 cm lateral spacing with SSP under subsurface drip fertigation (T_9). In addition to this, DSP was greatly superior to SSP in all the subsurface drip fertigation treatments. The increase in NMC in DSP was around 3.0 to 6.0 per cent which is higher than SSP in all the subsurface drip fertigation treatments. The more plant population with DSP by effectively utilizing the space and nutrients resulted in more millable cane production. (Khandagave, 2005).

The significantly higher individual cane weight (1.78 kg) was registered under planting of cane at 180 cm lateral spacing with subsurface drip fertigation (T_{10}). The minimum individual cane weight (1.53 kg) was found in planting of cane at 120 cm lateral spacing with SSP under subsurface drip fertigation (T_1). The increase in individual cane weight was mainly due to increased individual cane length, girth and number of internodes and this favorable influence was due to better and adequate supply of a required quantity of water and nutrients at the right time at right place. (Gaddanakeri *et al.,* 2008).

Table 2. Influence of subsurface drip fertigation on yield parameters of sugarcane

Treatments	NMC ('thousands ha^{-1})	Millable cane length (m)	Cane girth (cm)	Cane weight (kg)
T1: 120 cm lateral spacing with SSP	109.7	3.06	12.3	1.53
T2: 120 cm lateral spacing with DSP	114.6	3.07	12.4	1.57
T3: 135cm lateral spacing with SSP	107.5	3.25	12.5	1.53
T4: 135 cm lateral spacing with DSP	111.9	3.28	12.6	1.59
T5: 150 cm lateral spacing with SSP	97.8	3.49	12.4	1.57
T6: 150 cm lateral spacing with DSP	101.4	3.52	13.1	1.68
T7: 165 cm lateral spacing with SSP	90.3	3.66	13.0	1.66
T8: 165 cm lateral spacing with DSP	97.7	3.68	13.4	1.76
T9: 180 cm lateral spacing with SSP	88.3	3.71	13.2	1.67
T10: 180 cm lateral spacing with DSP	95.6	3.74	13.5	1.78
T11: Surface irrigation + farmers practice	85.7	2.02	8.4	1.12
SED	3.33	0.1	0.41	0.05
CD (P=0.5)	6.82	0.22	0.84	0.10

In addition to this, the results also revealed that millable cane diameter was significantly affected by row spacing. The results clearly indicated that, the cane diameter at 180 cm lateral spacing was higher by 8.8 per cent than 120 cm lateral spacing. This was due to less competition among cane plants grown in the 180 cm lateral spacing and consequently to better growth conditions, as compared to cane grown in lateral spaced at 120 cm apart. Higher cane girth was recorded under wider row spacing than normal spacing mainly due to the availability of more space per tiller in wider row spacing. (Arvind Misra and Tripathi, 2006). Similarly, the other characters like number of internode and internode length were also favorably influenced by wider row spacing under subsurface drip fertigation.

Cane yield and sugar yield

Subsurface drip fertigation with 120 cm lateral spacing as DSP recorded the maximum cane yield of 180 t ha^{-1} and this was comparable to subsurface drip fertigation with 180 cm lateral spacing as DSP and subsurface drip fertiagtion with 165 cm lateral spacing as DSP. Lesser cane yield of 96 t ha^{-1} was recorded in surface irrigation. The increase cane yield noticed under subsurface drip fertigation was around 46.6 percent at 120 cm lateral spacing with DSP and 44.0 percent at 180 cm lateral spacing with DSP compared to surface irrigation (Table 3.)

Table 3. Effect of lateral spacing and method of planting under subsurface drip fertigation on cane and sugar yield of sugarcane

Treatments	Cane yield (t/ha)	Sugar yield (t/ha)
T1: 120 cm lateral spacing with SSP	168.0	17.24
T2: 120 cm lateral spacing with DSP	180.0	19.33
T3: 135cm lateral spacing with SSP	164.5	17.00
T4: 135 cm lateral spacing with DSP	178.0	18.98
T5: 150 cm lateral spacing with SSP	153.6	16.54
T6: 150 cm lateral spacing with DSP	170.0	18.62
T7: 165 cm lateral spacing with SSP	150.0	16.22
T8: 165 cm lateral spacing with DSP	172.0	18.94
T9: 180 cm lateral spacing with SSP	147.6	15.97
T10: 180 cm lateral spacing with DSP	170.0	18.63
T11: Farmers recommended practices	96.0	9.4
SED	5.32	0.56
CD (P=0.5)	10.86	1.16

The maximum sugar yield of 19.33 t ha^{-1} was recorded in subsurface drip fertigation with 120 cm lateral spacing as DSP. This was comparable to 180 cm lateral spacing with DSP and 165 cm spacing with DSP under subsurface drip fertigation. Subsurface drip fertigation recorded almost more than double the sugar yield over surface irrigation (9.4 t ha^{-1}). The higher cane yield under the DSP was mainly due to the availability of sufficient sunlight with better aeration coupled with nutrients and water availability. These favorable environment resulted in better and earlier conversion of tillers to millable canes and the early vigour was maintained throughout the crop growth period due to better survival of tillers, which in turn resulted in taller stalks and improved stalk weight at harvest and continuous availability of nutrients resulted in increased cane yield. (Khandagave, 2005).

Economics

The economic analysis of subsurface drip fertigation methods revealed that the cost of cultivation under subsurface drip fertigation method was higher than the surface irrigation with soil application of recommended dose of fertilizer. The maximum net income (Rs.1,06,956 ha^{-1}) and B:C ratio (2.01) were realized in subsurface drip fertigation with 180 cm lateral spacing as DSP, which were higher than the net income (1,01,905 ha^{-1}) and B:C (1.83) ratio registered in subsurface drip fertigation with 120 cm lateral spacing as DSP.

CONCLUSION

Thus, from the forgoing discussion, besides higher yield, net income and irrigation water saving coupled with higher water and nutrient use efficiencies and also provide an opportunity to bring additional area under sugarcane cultivation to meet the domestic and export demands of sugar by adopting subsurface drip fertigation. The subsurface drip fertigation resulted higher water use efficiency and water saving compared surface irrigation. While, lateral spacing can have a moderate impact on water use efficiency under subsurface drip irrigation systems. The closer lateral spacing exhibited trends toward higher water use efficiency. Therefore, it was concluded that planting of cane with 180 cm lateral spacing as double side planting under subsurface drip fertigation was found to be economically viable as evidenced through higher economic net return.

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