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Performance of Subsurface Drip Fertigation on Yield Attributes, Yield, Water Saving and Water Use Efficiency of Sugarcane *(Saccharum officinarum L.)*

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Field experiment was conducted at central farm, Agricultural College and Research Institute, Madurai, during late season of 2008 to study the performance of subsurface drip fertigation on yield attributes, yield, water saving and water use efficiency of sugarcane (*Saccharum officinarum* L.). 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 (SSDF). The yield attributes like number of millable canes, internodes, cane length, girth and individual cane weight were significantly higher under subsurface drip fertigation with DSP. Higher cane and sugar yield of 180 t ha^{-1} and 18.63 t ha^{-1} were registered in 120 cm lateral spacing as DSP and this was on par with 180 cm lateral spacing with DSP under subsurface drip fertigation. Subsurface drip irrigation helped to save water up to 34.84 per cent and increased water use efficiency up to 161.40 kg ha^{-1} mm^{-1}.

Key words: Subsurface drip fertigation, yield, water saving and water use efficiency

Sugarcane is one of the most important commercial crops of India. Globally India ranks second in area (20.4%) and production (18.6%) among sugarcane growing countries of the world.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 (Ramasamy, 2008). Whereas in Tamil Nadu, It is cultivated in about 0.29 million ha producing of 29.75 million tones with an average productivity of 101 t/ha. (Season and Crop report, 2012)

Under the present water scarce conditions, efficient use of irrigation water becomes an important means to increase the cane productivity per unit quantity of applied irrigation water. The use of conventional irrigation method besides resulting in considerable loss of water is also responsible for the development of wide spread salinity, water logging and leaching of nutrients from the soil.

Unlike flood irrigation, the water and nutrient use efficiency are higher in subsurface 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.

Subsurface drip irrigation (SSDI) is an efficient means for applying water and nutrients below the surface soil to conserve water, control weeds and minimize run off. Among the different irrigation systems, the subsurface irrigation is reported for its improvement in yield and quality and shorter growing season together with substantial saving in water and energy (Camp, 2000).

Fertigation a technique of application of both water and fertilizers through drip irrigation system during the recent years was shown to be very effective in achieving higher water and fertilizer use efficiencies. The water and fertilizer saving through drip fertigation system have been reported to be 40 to 70 and 30 to 50 per cent respectively (Rekha *et al.,* 2008).

However, very limited work has been reported in this field, under the Indian situation. Hence, a field experiment was conducted to study the performance of subsurface drip fertigation on yield attributes, yield, water saving and water use efficiency of sugarcane.

Materials and Methods

The experiment was conducted during late season of 2008 at Central farm, Agricultural College and Research Institute, Madurai. The soil of the experimental field was sandy clay loam with pH 7.5 and EC 0.4 dS/m, having 0.4% organic carbon, 220 kg ha^{-1} available N, 19 kg ha^{-1} available P and 425 kg ha^{-1} available K.

The experiment was laid out in randomized block design with four replications and eleven treatments. Out of eleven treatments, 10 treatments related to different crop geometry under subsurface drip fertigation and one was surface irrigation with soil application of fertilizers. The treatments consisted of lateral spacing and method of planting viz., 120, 135, 150, 165 and 180 cm with single side planting (SSP) and double side planting (DSP) under subsurface drip fertigation.

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The sugarcane variety 'Co86032' was used for the experimentation. The setts were planted in both sides of the trenches for the double side planting and setts were planted in one side of the trench for the single side planting, whereas, the setts were planted in overlapping method for control as done by the farmers.

The sugarcane was fertilized with 275: 62.5: 112.5 NPK kg ha^{-1}. From this recommendation, 50% of P and K was applied as basal and remaining 100% of N and 50% of P and K were applied in 30 splits at 7 days interval starting from 7 DAP to 210 DAP through subsurface drip as Water soluble fertilizer. Calcium nitrate @ 62.5 kg/ ha and Humic acid @ 2.5 lit/ha were applied through subsurface drip on 30 and 60 DAP as common dose to all the treatments. Similarly, liquid bio fertilizers viz., Azosphi, Phosphofix and Potash activa @ 750 ml/ha on 30, 60 and 90 DAP and Liquid bio inoculants @ 20 lit/ha on 70 DAP were applied through subsurface drip to all the treatments as common dose.

Irrigation was scheduled based on climatological approach. First irrigation was given immediately after planting both surface and subsurface drip irrigation. For surface method, irrigation was given based on IW / CPE ratio of 0.8 i.e., irrigation was given whenever the cumulative pan evaporation reaches 50 mm after previous irrigation. Subsequent irrigations were given based on the pan evaporation values from USWB Class`A' open pan evaporimeter.

Whereas in subsurface drip irrigation, subsequent irrigations were scheduled once in two days based on the daily pan evaporation. For subsurface drip irrigation the operating pressure was maintained at 1.0 kg cm^2. The irrigation was given at 100 per cent pan evaporation and the quantity of water requirement was calculated as follows,

WRc = CPE × Kp × Kc × Wp × AWRc - Computed water requirement

CPE - Cumulative pan evaporation for two days (mm)

Kp - Pan factor (0.75)

Kc - Crop factor

Wp – Wetted percentage

A- Area (m^2)

Time of operation of drip system to deliver the required volume of water for research plot was computed based on the formula,

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

For computing total water use, the effective rainfall was also included and expressed in mm.

Immediately after subsurface drip irrigation, moisture content in the root profile was assumed to be nearer to field capacity. The additional cultivated area means the area that could be cultivated by utilizing the irrigation water saved from subsurface drip irrigation.

$$\text{Additional area} = \frac{\text{Water saved from drip irrigation}}{\text{Total water used in drip irrigation}} \times 100$$

Results and Discussion

Consumptive use of water and water saving

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 and additional cultivated area in Sugarcane

Irrigation method	Water applied (mm)	Effective rainfall (mm)	Total water used (mm)	Water saving (%)	Additional cultivated area (%)
Surface irrigation	1300	412	1712	-	-
Sub surface 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 revealed that subsurface drip irrigation can save 34.84 per cent water compared to 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.

Water use efficiency (WUE)

Different lateral spacing and method of planting significantly influence the WUE of sugarcane (Table 2). 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. 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 with DSP. The increase in water use efficiency recorded under subsurface drip fertigation 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). Similarly Dhotre *et al.,* (2008) reported that the irrigation water use efficiency was increased to the extent of 52.33 per cent in subsurface drip irrigation compared to surface irrigation method.

Table 2. Influence of subsurface drip fertigation on water saving, water use efficiency and water productivity of sugarcane

Treatment	Irrigation water used (mm)	Effective rainfall (mm)	Consumptive use irrigation water (mm)	Water saving (%)	Water use efficiency (kg ha^{-1} mm^{-1})
SSDF with 120 cm lateral spacing and SSP	809.28	306	1115.28	34.86	150.64
SSDF with 120 cm lateral spacing and DSP	809.28	306	1115.28	34.86	161.40
SSDF with 135 cm lateral spacing and SSP	809.28	306	1115.28	34.86	147.50
SSDF with 135 cm lateral spacing and DSP	809.28	306	1115.28	34.86	159.60
SSDF with 150 cm lateral spacing and SSP	809.28	306	1115.28	34.86	137.72
SSDF with 150 cm lateral spacing and DSP	809.28	306	1115.28	34.86	152.43
SSDF with 165 cm lateral spacing and SSP	809.28	306	1115.28	34.86	134.50
SSDF with 165 cm lateral spacing and DSP	809.28	306	1115.28	34.86	154.22
SSDF with 180 cm lateral spacing and SSP	809.28	306	1115.28	34.86	132.34
SSDF with 180 cm lateral spacing and DSP	809.28	306	1115.28	34.86	152.43
Surface irrigation with recomm-ended practices	1300.00	412	1712.00		56.07

SSDF-Subsurface Drip Fertigation DSP-Double Side Planting SSP-Single Side Planting

Yield attributes

The yield attributes such as number of 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 3)

Number of millable cane is one of the most important parameters in cane cultivation deciding the final cane yield. The increase in number of millable canes in subsurface drip fertigation system ranged from 10.00 to 25.22 per cent higher than surface irrigation method.

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}. In addition to this, DSP produced more number of millable canes compared to SSP in all subsurface drip fertigation treatments. Wider row spacing recorded increased survival capacity of canes compared to closer row spacing. The increase in number of millable cane 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).

Table 3. Influence of subsurface drip fertigation on yield parameters, cane and sugar yield of Sugarcane

Treatment	NMC('thousands ha^{-1})	Millable cane length (m)	No. of internodes	Cane girth (cm)	Cane weight (kg)	Cane yield (t ha^{-1})	Sugar yield (t ha^{-1})
SSDF with 120 cm lateral spacing and SSP	109.7	3.06	20.2	12.3	1.53	168	17.24
SSDF with 120 cm lateral spacing and DSP	114.6	3.07	20.3	12.4	1.57	180	19.33
SSDF with 135 cm lateral spacing and SSP	107.5	3.25	21.2	12.5	1.53	164.5	17.0
SSDF with 135 cm lateral spacing and DSP	111.9	3.28	21.8	12.6	1.59	178	18.98
SSDF with 150 cm lateral spacing and SSP	97.8	3.49	23.2	12.4	1.57	153.6	16.54
SSDF with 150 cm lateral spacing and DSP	101.4	3.52	23.6	13.1	1.68	170	18.62
SSDF with 165 cm lateral spacing and SSP	90.3	3.66	26.4	13.0	1.66	150	16.22
SSDF with 165 cm lateral spacing and DSP	97.7	3.68	26.9	13.4	1.76	172	18.94
SSDF with 180 cm lateral spacing and SSP	88.3	3.71	28.7	13.2	1.67	147.6	15.97
SSDF with 180 cm lateral spacing and DSP	95.6	3.74	28.9	13.5	1.78	170	18.63
Surface irrigation with recommended practices	85.7	2.02	17.2	8.4	1.12	96.0	9.4
SED	3.33	0.1	0.77	0.41	0.05	5.32	0.56
CD (P=0.5)	6.82	0.22	1.59	0.84	0.10	10.86	1.16

SSDF-Subsurface Drip Fertigation DSP-Double Side Planting SSP-Single Side Planting

The increase in individual cane weight was around 40 to 60 per cent under subsurface drip fertigation compared to surface irrigation. Similarly, the increase in individual cane weight in wider spacing was around 12.7 per cent when compared to closer spacing under subsurface drip fertigation. Planting of cane at 180 cm lateral spacing with DSP under subsurface drip fertigation registered maximum individual cane weight (1.78 kg). 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).

The minimum individual cane weight (1.12 kg) was found in surface irrigation. The results showed that significantly higher millable cane length (3.74 m) was recorded in 180 cm lateral spacing with DSP under subsurface drip fertigation compared to surface irrigation (2.02 m). The increase in individual millable cane length in subsurface drip fertigation was around 33 to 45 per cent compared to surface irrigation method.

Significantly higher cane girth (13.5 cm) was recorded in 180 cm lateral spacing with DSP under subsurface drip fertigation compared to surface irrigation (8.4 cm). The subsurface drip fertigation increased the individual cane girth to the tune of 32.5 to 37.2 per cent compared to surface irrigation method. 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 internodes and internode length were also favorably influenced by wider row spacing under subsurface drip fertigation.

Cane and sugar yield

Subsurface drip fertigation method significantly influenced the cane and sugar yields (Table 3). Significantly higher cane yield of 180 t ha^{-1} was recorded under subsurface drip fertigation with 120 cm lateral spacing with DSP and this was comparable to subsurface drip fertigation with 180 cm lateral spacing with DSP and subsurface drip fertigation with 165 cm lateral spacing with DSP. Significantly lower cane yield of 96 t ha_{-1} was recorded under surface irrigation method.

The increased cane yield was around 28 to 46 per cent in subsurface drip fertigation compared to surface irrigation. The higher cane yield under subsurface drip fertigation was mainly due to higher water and fertilizer use efficiency with effect from water and fertilizer applied directly to the root zone of crop based on their crop needs at various growth stages. (Dhotre *et al*., 2008). The increased cane yield was recorded in all subsurface drip fertigation with double side planting compared to single side planting. 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 (Khandagave, 2005).

Table 4. Influence of subsurface drip fertigation on economics of Sugarcane

Treatment	Cost of cultivation (Rs ha_{-1})	Gross income (Rs ha_{-1})	Net income(Rs ha_{-1})	B : C ratio
SSDF with 120 cm lateral spacing and SSP	120095	210000	89905	1.75
SSDF with 120 cm lateral spacing and DSP	123095	225000	101905	1.83
SSDF with 135 cm lateral spacing and SSP	114743	205625	90882	1.79
SSDF with 135 cm lateral spacing and DSP	118118	222500	104382	1.88
SSDF with 150 cm lateral spacing and SSP	108226	192000	83774	1.77
SSDF with 150 cm lateral spacing and DSP	112326	212500	100174	1.89
SSDF with 165 cm lateral spacing and SSP	103968	187500	83532	1.80
SSDF with 165 cm lateral spacing and DSP	109468	215000	105532	1.96
SSDF with 180 cm lateral spacing and SSP	99944	184500	84556	1.85
SSDF with 180 cm lateral spacing and DSP	105544	212500	106956	2.01
Surface irrigation with recommended practices	70639	120000	49361	1.70

SSDF-Subsurface Drip Fertigation DSP-Double Side Planting SSP-Single Side Planting

Subsurface drip fertigation recorded almost double the sugar yield over surface irrigation (9.4 t ha_{-1}). The maximum sugar yield of 19.33 t ha_{-1} was recorded in subsurface drip fertigation with 120 cm lateral spacing with DSP. This was comparable to 180 cm lateral spacing with DSP and 165 cm spacing with DSP under subsurface drip fertigation.

The increase in sugar yield over surface irrigation ranges from 49.5 to 51.3 per cent under subsurface drip fertigation. The increased sugar yield obtained was mainly due to improved juice characters like brix, pol per cent, purity percentage and commercial cane sugar as a result of uniform millable cane production under subsurface drip fertigation treatments. Higher sugar yield under subsurface drip fertigation was also reported by Dhotre *et al.* (2008).

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 (Table 4). 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 with 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.

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 with 180 cm lateral spacing with double side planting was found to be economically viable as evidenced through higher economic net return.

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