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Research Paper

Growth, yield and water use in sugarcane (*Saccharum officinarum*) under drip fertigation

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ABSTRACT

An experiment was conducted to study effects of drip fertigation on growth, yield and economics of sugarcane (*Saccharum officinarum* L.) on clay soils in western Maharashtra for three consecutive years (2007–2010). The experiment comprised of 100, 80 and 60% of recommended fertilizer dose in water soluble form through drip in two fertigation schedules (A and B) and results were compared with three control treatments. In schedule A, nutrients were applied in 12 equal fortnightly splits, whereas in schedule B nutrients were applied as per growth stage of crop in 26 weekly splits. Drip fertigation @ 100% with schedule B produced maximum cane (187.8 t/ha) and sugar yield (22 t/ha) and it was on par with 100% fertigation with schedule A and 80% fertigation with schedule B. The 100% drip fertigation showed 41.8% increase in yield. Yield increased upto 25.3% by applying only 'N' through drip as against conventional method (133.4 t/ha). Fertigation also resulted into 40% fertilizer saving. The drip irrigation used less quantity of water (103.7 mm) and saved 57% water over surface irrigation method. Field water use efficiency was also improved considerably under drip fertigation. Economics revealed higher cost of cultivation involved under drip fertigation than conventional band application. The net income, total income and water productivity over conventional method were also higher in 100% fertigation schedule B but all the economical parameters were on par with 100% fertigation schedule A and 80% fertigation schedule B. Hence, 80% drip fertigation through water soluble fertilizers applied in 26 splits as per growth stages was found suitable for productive sugarcane cultivation in western Maharashtra.

Key words: Drip irrigation, Fertigation schedule, Split application, Sugarcane, Water soluble fertilizers

Sugarcane is an important commercial crop and plays vital role in Indian agriculture. India ranks 2nd after Brazil among sugarcane producing countries of the world and contributes 25% and 22.2% in area and production of world, respectively. Sugarcane occupies about 3.40% of the total cultivated area and it is contributing about 7.5% of the gross value of agricultural production in the country with an annual sugarcane production of 285 million tonnes. (Anonymous, 2011). Sugarcane plays vital role in agricultural economy of Maharashtra state. The pace of growth of sugarcane cultivation in state has been massive over the past few years. The sugarcane productivity in Maharashtra is continuously decreasing from last decade (90 t/ha in 1999–2000 to 81.8 t/ha in 2010–11). The major factors responsible for decline of sugarcane productivity in Maharashtra are poor irrigation management and imbalanced use of fertilizers. Thus, scientific control in the application of these two inputs certainly needed to improve sugarcane yield.

Most of the Indian farmers are adopting surface irrigation practices for sugarcane irrigation. This leads to excess usage and wastage of water and nutrients. The drip irrigation has potential to improve cane productivity on sustainable basis by overcoming demerits of poor irrigation practices. Increasing popularity of drip in western Maharashtra sugar industries undoubtedly increases opportunities for improved fertilizer management. Recently, drip irrigation combined with fertigation has been found to benefit farmers because of very high fertilizer use efficiency. A large number of research experiments have clearly demonstrated that the average sugarcane yield increased to the tune of 40% by applying drip fertigation to sugarcane as compared to traditional irrigation and soil application (Kolange *et al.* 2001; Veeraputhiran *et al.* 2012). It also enhances the fertilizer use efficiency, nutrient uptake, improves quality parameters and minimizes the water and nutrient losses to the extent of 25–30% (Raskar and Bhoi 2001; Singh *et al.* 2010). In recent years, water soluble

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fertilizers are emerging as a strong alternative to straight fertilizers. Optimum split applications of these fertilizer through drip improves quality and quantity of crop yield than the conventional practice (Ravikumar *et al.*, 2011). However, appropriate recommendations including optimal schedule of fertilizer application to exploit the potential of drip fertigation for sugarcane cultivation are not available. In view of this, research studies on standardization of fertigation schedule for sugarcane and to assess its effect on growth, yield, quality and water use of sugarcane was undertaken.

MATERIALS AND METHODS

The field experiment was conducted during three consecutive seasons from 2007 to 2010 at Inter faculty Department of Irrigation Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri. Agroclimatically, the area falls under the scarcity zone of Maharashtra with annual average rainfall of 520 mm which is mostly erratic and uncertain in nature. The experimental plot was uniform and leveled. The soil was alkaline in nature with pH, bulk density and electrical conductivity as 8.34, 1.27 g/cm^3 and 0.31 dS/m respectively. The soil depth was 70 cm with infiltration rate and organic carbon as 0.7 cm/hr and 0.64%, respectively. The soil texture was clay with 10.75% coarse sand, 33.75% silt and 55% clay with medium depth. The moisture contents at field capacity, permanent wilting point and available soil moisture were 41.28, 20.27 and 21.01%, respectively. The drip irrigation system was installed to meet out crop water requirement and for fertigation of water soluble fertilizers. The field experiment was laid out in randomized block design with nine treatments replicated thrice. The treatment details were as follows:

T_1: 100% of recommended dose through drip fertigation (schedule A); T_2: 80% of recommended dose through drip fertigation (schedule A); T_3: 60% of recommended dose through drip fertigation (schedule A); T_4: 100% of recommended dose through drip fertigation (schedule B); T_5: 80% of recommended dose through drip fertigation (schedule B); T_6: 60% of recommended dose through drip fertigation (schedule B); T_7: 100% recommended dose with drip (only N through drip, P and K through soil); T_8: 100% recommended dose with drip (N, P, and K through soil); T_9: 100% recommended dose with surface irrigation (N, P, and K through soil).

The recommended dose of fertilizer as 250:115:115 NPK kg/ha was considered for sugarcane. Under schedule A, all the fertilizers were applied in 12 equal splits at an interval of 15 days; whereas in schedule B the fertilizers were applied in 26 weekly splits apportioned as per growth stages as tabulated below. The schedule A are being used by farmers in some part of the state for sugarcane cultivation presently; whereas, schedule B was developed on the basis of nutrient requirement of crop during different growth stages.

Schedule B

Period after planting	Nitrogen (%)	Phosphorus (%)	Potassium (%)
1–4 weeks	15	10	10
5–9 weeks	35	35	15
10–20 weeks	50	55	35
21–26 weeks	–	–	40

For drip fertigation (T_1 to T_6) water soluble fertilizers grades as urea phosphate (17:44:0), urea and muriate of potash were used. The fertigation was done using automized fertizet system (Galicol, Israel) following respective schedule A and B. In water soluble fertilizer treatments (T_1–T_6), urea (46:0:0), urea phosphate (17:44:0) and MOP (0:0:60) were used for fertigation. In N fertigation (T_7), all the 'N' was applied through urea in 12 equal splits at an interval of 15 days, whereas P and K were applied as per conventional practices. In treatments T_8 and T_9, all the nutrients were applied through soil as per conventional practice.

The single eye bud sets (*var.* COM–265 or Phule 265) were planted twice during December 2007, 2009 and harvested during the November 2008 and 2010, respectively. The first ratoon was allowed from the 2nd fortnight of November 2008 and was harvested during the month of November, 2009. Planting was done in paired row with 0.75–1.50 m spacing and 0.30 m plant to plant spacing. Adequate plant protection measures were adopted as and when required. The amount of water (litres/day) to be applied through drip irrigation was calculated by the climatological approach (Allen *et al.* 1998). The reference evapotranspiration was estimated using Evapotranspiration Monitoring Station (ICT International, Australia) installed at research farm. Considering the crop factor as per stages and wetted area factor, the water requirement of the sugarcane was computed using following equation.

$$V = ETr \times Kc \times Ls \times Es \times Wa/\eta$$

Where, V = Volume of water applied (lit/day/plant); ETr= Reference evapotranspiration (mm/day); K_c=Crop coefficient; Ls and Es= lateral and emitter spacing; W_a = wetted area factor (0.7); η = Emission uniformity of the system (91%)

The in–line lateral with dripper having 4 lph discharge capacity were operated at a pressure of 1 kg/cm^2. The spacing between two adjacent lateral and emitter within plot was 2.25 m and 0.60 m, respectively. In drip system water was applied on every alternate day while in surface method, 80 mm depth of irrigation was applied at 75 mm of cumulative pan evaporation. The depth of water in surface method of irrigation was estimated using standard methodology. The water requirement of the crop was determined by formula used (Michael, 2008) as:

$$WR = IR + ER + S$$

Where, WR = Water requirement, (mm); IR = Irrigation requirement, (mm); ER = Effective rainfall, (mm); S = Soil moisture contribution, (mm)

The soil moisture contribution was considered as nil as the water table was too deep from soil surface. The field water use efficiency (FWUE) of crop to total water used during its life period was estimated as;

$$\text{FWUE (kg/ha–cm)} = \frac{\text{Total yield (kg/ha)}}{\text{Total water applied (cm)}}$$

RESULTS AND DISCUSSION

Growth contributing characters

The means (2007–08, 2008–09, 2009–10) of all the growth contributing characters pooled over three years were significantly higher in drip fertigated plots as compared to conventional method (Fig.1 to 3).

The number of internodes decreased with decreasing levels of fertilizer from 100 to 60% (Fig. 1). The higher number and length of internodes were noticed under 100% fertigation schedule B (28.5 and 16.2 cm), however it was on par with 100% fertigation schedule A (26.9 and 15.6 cm) and 80% fertigation schedule B (26 and 14.7 cm). The adequate supply of water and nutrient at different stages of crop growth showed better utilization of nutrients in sugarcane. The similar trend of results was found in number of functional leaves per plant and girth of internodes (Fig. 2). The number of leaves in 60% fertigation as per schedule B (5.8) was at par with conventional method (5.4). The conventional method of irrigation and fertilizer application produced lesser values of all growth attributes and it was significantly inferior than 60% fertigation levels.

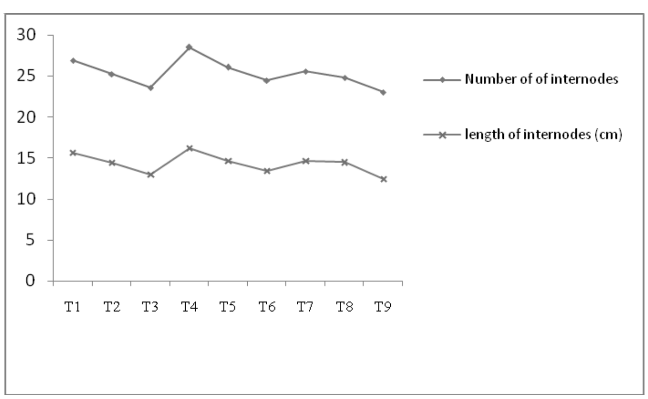

Fig. 1. Number and length of internodes

Likewise, 100% fertigation using schedule B registered higher height of cane and milliable cane (350.2, 310.4 cm) however, these values were at par with 100% fertigation schedule A (343.9, 303.6 cm) and 80% fertigation schedule B (335.1, 295 cm). The heights observed when straight fertilizers used in conventional method were significantly lower (303.4, 262.1 cm) than that of 60% fertigation in schedule A (316.5, 273.8 cm) and B (320.4, 279.7 cm). It revealed the superiority of water soluble fertilizers over straight fertilizer (Fig. 3). These results are in conformity with the finding of Kolange *et al.* (2001).

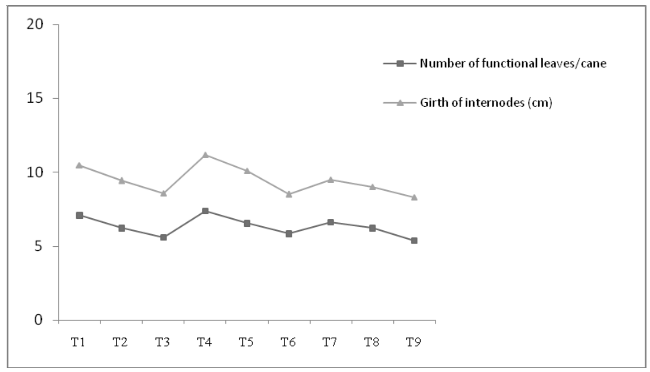

Fig. 2. Number of functional leaves and girth of internodes

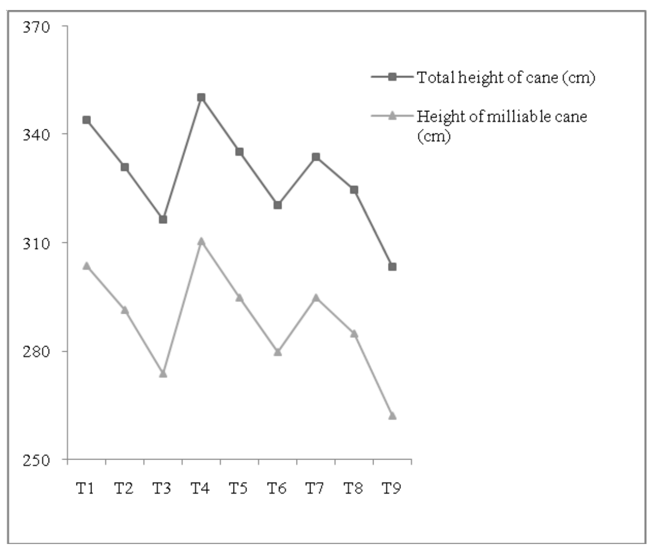

Fig. 3. Height of cane and milliable cane

Yield contributing characters

The pooled data for three years revealed that the fertigation significantly improved yield contributing characters of sugarcane as compared to drip irrigation without fertigation (Table 1). The weight of millable cane (3.1 kg) was significantly superior under 100% fertigation given in 26 splits as per growth stages of crop. It was followed by 100% fertigation in 12 splits and 80% fertigation in 26 splits as per growth stages (2.8 kg). The favorable influence on cane weight was occurred due to supply of required quantity of water and nutrients at the right time and at right place. The surface method of irrigation produced lowest weight of single cane (2.2 kg). As regards to number of cane /ha the treatments did not differ significantly. Fertigation was reported to give enhanced yield attributes as compared to conventional method (Mahendran and Dhanalakhmi, 2003).

Cane yield

Significantly superior sugarcane yield of 187.8 t/ha was noticed in 100% fertigation using schedule B (Table 1). However, cane yields in 100% fertigation schedule A and 80% fertigation schedule B were on par with 100% fertigation schedule B. The more yield of cane under drip fertigation scheduled as per crop growth stages might have been due to continuous availability of nutrients as per crop requirement and favorable soil moisture throughout the growth period of sugarcane. The yield levels in 80 and 100% fertigation were statistically on par, indicated that applying 80% fertigation (schedule B) can be an optimum scheduling criteria for sugarcane cultivation. The cane yield obtained under N fertigation (165.9 t/ha) indicates considerable increase in sugarcane yield by applying only urea through drip.

The cane yield under 60% fertigation schedule B (156.7 t/ha) was on par with only drip irrigation (156.3 t/ha), where 100% fertilizers applied through soil, revealed potential saving of 40% fertilizers in fertigation using water soluble fertilizers without affecting the yield. The results are in conformity as reported by Singh *et al.* (2010). The surface method of irrigation produced lowest cane yield (155.5 t/ha). The reasons of low yield in surface irrigation might be that crop had to undergo water stress between two irrigations. The sugar yield also showed similar trend as that of cane yield.

Water use

The drip method of irrigation resulted into lowest water applied (88.1 cm) as compared to surface method of irrigation (210 cm). The total water requirement in drip including effective rainfall was much less (103.7 cm) than conventional method (241.8 cm) indicated that drip can save water to the extent of 57% as against conventional irrigation (Table 1). The results also figure out that, drip irrigation remarkably increased yield to the extent of 17.6% over conventional method, where as 100% fertigation (schedule B) resulted into 41.8% improvement in cane yield over conventional method. The 80% fertigation schedule B was the next best treatment resulted into 27.3% improved productivity with 20% fertilizer saving and 57% water saving. Veeraputhiran *et al.* (2012) also reported superiority of drip fertigation over conventional method in terms of productivity and saving of fertilizer.

The water use efficiency was improved in drip (1501.4 kg/ha–cm) as compared to 563.2 kg/ha–cm in conventional method of irrigation. The water saving in drip irrigation to the tune of 57% with 17.6% increase in yield was the key reason for improving water use efficiency in drip as against surface method. The combined effect of drip and fertigation @ 100% using schedule B resulted higher field water use efficiency (1,803.7 kg/ha–cm) which was 3 times more than conventional method.

Quality of juice

The brix, pol, purity, and commercial cane sugar (CCS) were improved by drip fertigation as compared to conventional method of irrigation but the difference was in sig-

Table 1. Yield and water use characters as influenced under sugarcane fertigation (Pooled data of three years).

Treatment	No. of miliable cane (× 10^3/ha)	Weight of milliable cane (kg)	Cane yield (t/ha)	Sugar yield (t/ha)	Effective rainfall (cm)	Water applied (cm)	Total water use(cm)	FUWE (kg/ha–cm)	Water Saving (%)*	Increase in yield (%)**
100% fertigation (A)	78	3.0	178.6	19.7	15.6	88.1	103.7	1,714.6	56.8	35.3
80% fertigation (A)	73	2.6	164.4	17.2	15.6	88.1	103.7	1,579.4	56.8	24.0
60% fertigation (A)	72	2.4	149.2	13.9	15.6	88.1	103.7	1,433.7	56.8	12.1
100% fertigation (B)	78	3.1	187.8	22.0	15.6	88.1	103.7	1,803.4	56.8	41.8
80% fertigation (B)	73	2.8	168.3	18.1	15.6	88.1	103.7	1,616.2	56.8	27.3
60% fertigation (B)	75	2.4	156.7	15.3	15.6	88.1	103.7	1,505.6	56.8	18.0
100% CF (NTD)	75	2.7	165.9	16.4	15.6	88.1	103.7	1,593.5	56.8	25.3
100% CF + DI	73	2.6	156.3	15.5	15.6	88.1	103.7	1,501.4	56.8	17.6
100% CF + SI	63	2.2	133.4	12.5	31.8	210	241.8	563.2	–	–
SEm±	18.0	0.2	6.5	1.4	–	–	–	–	–	–

*Water saving over conventional (T_9); **Increase in yield over conventional (T_9); A, B–fertigation schedules; CF–Conventional fertilizers; NTD–Nitrogen through Drip; DI–Drip Irrigation; SI–Surface Irrigation nificant (Table 2). The maximum brix reading (21.1%) and pol (19.6%) were recorded in 100% fertigation in 26 splits. The early development of milliable canes with uniform maturity at harvest under fertigation resulted into higher brix value. Application of fertilizers as per growth stages also had positive effect on CCS value and it was improved to 11.2% in drip fertigation schedule B from 9.3% over conventional method. Conventional method registered lowest values of quality parameters of sugarcane.

Economics

The total cost of cultivation (average of three years) was computed by adding the capital investment on drip irrigation and operational cost (Table 2). The seasonal fixed cost of drip system for 0.75–1.5–0.30 m paired row planting for sugarcane was estimated as ₹18,904/ considering the depreciation cost, interest on capital investment and cost towards repairs and maintenance. It is seen from Table 4 that higher cost of cultivation was incurred in drip fertigation because of high market cost of water soluble fertilizers. The cost of cultivation for conventional method was lowest (₹53,521). As regards to net income, higher value as ₹2,26,195 was obtained under 100% fertigation schedule B, which was on par with 100% fertigation schedule A (₹2,08,311), N fertigation (₹1,99,869) and 80% fertigation schedule B (₹1,96,864/ha). In conventional method, the net income was ₹1,59,949/ha, which was lowest due to lowest yield recorded. However, the low cost of cultivation in conventional method reflected into higher B:C ratio (4.68), followed by N fertigation (4.25) and 100% fertigation using schedule B (4.15). All the fertigation treatments gave lesser B: C ratio as costs of water soluble fertilizers are 3–5 times high than straight fertilizers. The higher income accrued under fertigation was reported to be mask by straight fertilizers owing to the high cost of water soluble fertilizer (Raskar and Bhoi, 2001).

Moreover, drip irrigation for sugarcane cultivation exhibited 57% water saving, which can bring 1.33 ha additional area under irrigation. Taking into consideration the additional income due to this additional area, the total net income estimated in 100% fertigation schedule B (₹5,31,045) was on par with schedule A (₹4,89,322), N fertigation (₹4,68,420) and 80% fertigation schedule B (₹4,62,280) as compared to (₹1,59,949) in conventional method. When profit of sugarcane cultivation in terms of water use was analyzed it revealed that water productivity of ₹4,907/cm of water was obtained in 100% drip fertigation as that of ₹663/cm of water under conventional method. Drip fertigation @ 100% using schedule B resulted into higher productivity of sugarcane. However, it was statistically on par with 100% fertigation schedule A and 80% fertigation using schedule B. Sugarcane cultivation under drip resulted into 57% water saving with 17.6% increase in yield whereas drip combined with fertigation using 80% fertigation resulted 27.3% increase in yield. The 60% fertigation in 26 splits gave 18% more yield than conventional method indicated that through fertigation 40% fertilizers can be saved. The quality of sugarcane was improved due to fertigation through drip but difference was non–significant. The net income, B: C ratio, total income and water productivity were found in significantly different in treatments 100% schedule B, 100% schedule A and 80% schedule B.

It is concluded from the present investigation that sug-

Table 2. Quality analysis and economics of sugarcane as influenced by different treatments (Pooled data of three years).

Treatment	Brix%	Pol%	Purity%	CCS%	Seasonal cost (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	B:C ratio	Total income (× 10^3 ₹/ha)	Water productivity (× 10^3 ₹/cm of water used)
100% fertigation (A)	19.8	18.1	91.7	11.1	84.3	208.3	3.7	489.3	4.7
80% fertigation (A)	20.1	18.5	92.0	10.6	80.2	190.9	3.8	447.9	4.1
60% fertigation (A)	19.2	17.4	90.3	9.5	76.1	167.8	3.6	393.6	3.6
100% fertigation (B)	21.1	19.6	92.7	11.2	84.3	226.2	4.2	531.0	4.9
80% fertigation (B)	19.8	18.4	92.5	10.9	80.2	196.9	3.8	462.3	4.3
60% fertigation (B)	18.8	17.2	91.6	9.9	76.1	179.8	3.7	421.8	3.9
100% CF (NTD)	19.4	17.9	92.5	10.2	70.9	199.9	4.3	468.4	4.3
100% CF + DI	18.7	17.3	90.7	10.0	70.9	182.4	3.9	427.2	3.9
100% CF + SI	18.0	16.5	90.0	9.3	53.5	159.9	4.7	159.9	0.7
SEm±	1.15	1.4	1.4	1.4	–	10.8	0.3	25.7	0.3
CD (P=0.05)	NS	NS	NS	NS	–	31.2	NS	77.1	1.0

A, B–fertigation schedules; CF–Conventional fertilizers; NTD–Nitrogen through Drip; DI–Drip Irrigation; SI–Surface Irrigation arcane cultivation at spacing with 0.75 – 1.50 × 0.30 m under paired row planting with 80% application of water soluble fertilizers as per schedule B through drip irrigation is useful to sugarcane growers in increasing the productivity as well as saving the fertilizers and water.

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