



## Enhancing nutrient use and sugarcane (*Saccharum officinarum*) productivity with reduced cost through drip fertigation in western Maharashtra

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### ABSTRACT

A field experiment was conducted at Interfaculty Department of Irrigation Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra) during three consecutive years 2007-2010 to study the yield, nutrient use and cost economics for sugarcane (*Saccharum officinarum* L.) cultivation under different fertigation schedules. The experiment comprised 100, 80 and 60 per cent water soluble fertilizers (WSF) applied through drip in two schedules and results were compared with three control treatments. The 100 per cent fertigation as per growth stages (schedule B) showed higher cane yield (187.85 tonnes/ha) and sugar yield (22.00 tonnes/ha); however, it was on par with 100% fertigation in uniform equal splits (schedule A) and 80% fertigation (schedule B). The study indicated that drip irrigation resulted into 25 % increase in sugarcane yield whereas drip with fertigation resulted into 42 % increase in yield as compared to conventional method. Application of water soluble fertilizers had positive effect on periodical availability of nutrients and uptake than conventional fertilizer. The higher net seasonal income (₹ 226 195 per ha) and net extra income over conventional method (₹ 66 246 per ha) were obtained in 100 % fertigation as per schedule B however, the economical parameters were on par with 100 % fertigation as per schedule A and 80% fertigation as per schedule B. The application of 80 % water soluble fertilizers as per schedule B through drip irrigation was found best practice to obtain better yield, improve nutrient and water use as well as cost economics among the practices studied.

**Key words:** Economics, Fertigation schedule, Nutrient availability, Nutrient uptake, Water soluble fertilizers

The right combination of water and nutrients is the key for high yield and quality of produce. Micro-irrigation has become an optimal means for providing water and nutrients to crops. Since drip irrigation delivers water uniformly and directly to the root zone with little run-off, application of fertilizers through drip system could provide a key for enhancing fertilizer use (Ng Kee Kwong and Deville 1994). The sugarcane (*Saccharum officinarum* L.) crop needs plentiful supply of fertilizers for high production and its yield is affected under deficit nutrients availability. Its luxuriant vegetative growth and heavy tonnage removes substantial amount of nutrients from the soil that need to be replenished to maintain the soil fertility (Shukla 2007). A number of research experiments have clearly demonstrated that for producing high yield and maximum sugar recovery application of recommended doses of essential nutrients at appropriate growth stages are necessary. The reduced

nutrient-use efficiency due to immobilization of nitrate-N results imbalanced nutritional state at rhizosphere and hinders crop growth, shoot population, stalk weight and cane yield (Singh *et al.* 2010). The drip fertigation promotes faster and earlier growth of sugarcane, increases number of tillers, improved elongation and widening of stalk at later growth stage, and increases yield as compared to the conventional fertilization without drip irrigation (Dalri and Cruz 2008, Veeraputhiran *et al.* 2012). Application of fertilizers through drip increases the nutrient concentration in specified volume of root zone and thus, enhances the fertilizer use efficiency, nutrient uptake, improves quality parameters and minimizes the water and nutrient losses (Mahendran *et al.* 2007).

There is an ample scope for improving the efficiency of fertilizer use through fertigation, if the crop fertilizer relations and concentration of fertilizers in the soil are well understood. Simple conventional fertilizers containing nitrogen, phosphorous, and/or potassium can be applied using drip irrigation if they are soluble in water. Urea and potash fertilizers are better soluble than phosphate fertilizers, and therefore fertigation with urea and potash fertilizers is getting popular among farmers. However, due to the lower

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solubility of phosphate fertilizers, the practice of using phosphorous fertigation is less common (Ravikumar *et al.* 2011). However, without appropriate recommendations regarding fertigation schedules, there could be a tendency towards leaching and denitrification associated with poor timing and excessive application of fertilizers by fertigation. Thus, issue that needs to be explored immediately includes optimal schedule of fertilizer application to exploit the potential of drip fertigation. Further, while adopting drip fertigation for sugarcane, it is also necessary to find its economic viability as water soluble fertilizers are costly than conventional fertilizers. Thus, research studies on standardization of fertigation schedule using water soluble fertilizer, its effect on yield, nutrient availability, uptake and economics for sugarcane in fine textured soil of western Maharashtra was undertaken.

#### MATERIALS AND METHODS

The field experiment was conducted during three consecutive seasons from 2007 to 2010 at research farm of Interfaculty 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 well drained, alkaline in nature with pH of 8.34. 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 bulk density of soil was 1.27 g/cm<sup>3</sup> and electrical conductivity was 0.31 dS/m. The soil was high in available N (206 kg/ha), and P (12.58 kg/ha) and very high in available K (471 kg/ha) content. The moisture content at field capacity, permanent wilting point and available soil moisture was 41.28, 20.27 and 21.01%, respectively. The field experiment was laid out in Randomized Block Design (RBD) with nine treatments replicated thrice. The treatments comprised 100, 80 and 60% recommended dose (RD) in form of water soluble fertilizers (WSF) in two different schedules A and B (T<sub>1</sub> to T<sub>6</sub>), N fertigation (T<sub>7</sub>), drip without fertigation (T<sub>8</sub>) and conventional method of irrigation and fertilizer application (T<sub>9</sub>).

Under schedule A, all the fertilizers were applied in 12 uniform fortnightly splits; whereas in schedule B the fertilizers were applied in 26 weekly splits apportioned as per growth stages as tabulated below.

Month	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

The fertigation was done using automatized fertizet system (Galcon, Israel) as per schedule with recommended

dose of NPK as 250:115:115 kg/ha. In water soluble fertilizer treatments, urea (46:0:0), urea phosphate (17:44:0) and MOP (0:0:60) were used for fertigation. In treatment of N fertigation (T<sub>7</sub>), all the 'N' was applied through urea in 12 equal splits at an interval of 15 days whereas P and K were applied through soil. In treatments T<sub>8</sub> and T<sub>9</sub>, the nutrients were applied through soil as per conventional practice.

The single eye bud setts (var COM 265 or Phule 265) were planted twice during December 2007 and 2009 and harvested during the November 2008 and 2010, respectively. The first ratoon was allowed from the 2 fortnight of November 2008 and was harvested during the month of November 2009. Planting was done in paired row (0.75-1.50 × 0.30 m) with 0.75 m row to row, 1.5 m pair to pair and 0.30 m plant to plant spacing. Adequate plant protection measures were adopted as and when required. The drip irrigation system was installed to meet out crop water requirement and for fertigation of water soluble fertilizers. In drip system water was applied on alternate day while in surface irrigation, 80 mm depth of irrigation was applied at 75 mm of cumulative pan evaporation. The spacing between two adjacent laterals and emitters within plot was 2.25 m and 0.75 m, respectively.

The uptake of nutrients was worked out by multiplying dry matter accumulation to N, P and K concentration at important growth stages as tillering (0-90 DAP), earthing up (90-180 DAP), grand growth (180-270 DAP) and harvest (365 DAP). Sugarcane plant samples from different treatments were analyzed for N, P and K content by adopting standard methods (Perkinson and Allen 1975). The soil samples were collected periodically (90, 180, 270 days after planting and at harvest) for measuring nutrient availability at a distance of 0, 15, 30, 45, 60 and 75 cm laterally and vertically from emitters (average availability) for each treatment (Singh *et al.* 1999).

The economics parameters of sugarcane fertigation, viz. net seasonal income, benefit: cost ratio, net extra income over surface and water productivity of drip fertigation as influenced by different treatments were worked out. The total cost of cultivation was computed by adding the seasonal cost of drip irrigation with operational cost. The b:c ratio was calculated by dividing the gross seasonal income with total cost of cultivation. Critical difference (CD) test was used to determine whether differences exist between certain comparisons. The probability level for determination of significance was 0.05 (Panse and Sukhatme 1985).

#### RESULTS AND DISCUSSION

##### *Yield contributing characters*

The germination percentage was 92% in all the treatments and not differed significantly indicating a common and uniform germination existed and thus the treatments were compared unbiasedly. The data pertaining to number of tillers/ha indicated increasing number of tillers with age of crop from 60 to 120 days after planting (DAP) and decreasing trend afterwards upto 180 DAP (Table 1).

Table 1 Periodical no. of tillers/ha and millable canes/ha as influenced under sugarcane fertigation (Pooled mean of 2008-2010)

Treatment	Number of tillers			No. of millable canes/ha
	60 DAP	120 DAP	180 DAP	
100% fertigation (A)	73 638	159 511	78 413	77 627
80% fertigation (A)	71 764	158 123	74 186	73 067
60% fertigation (A)	69 694	156 718	72 560	72 160
100% fertigation (B)	73 712	159 608	78 400	77 867
80% fertigation (B)	71 815	158 311	74 288	73 253
60% fertigation (B)	69 734	156 825	76 610	75 200
100% CF (NTD)	71 994	158 176	75 216	75 013
100% CF +DI	70 931	157 390	73 882	73 253
100% CF +SI	68 856	156 297	71 719	62 960
CD (P=0.05)	892	648	685	NS

The 100% fertigation schedule B recorded significantly more no. of tillers/ha than any other treatments at 60, 120 and 180 DAP. The number of tillers/ha reduced substantially with every successive reduction in fertigation dose. The 60% fertigation (schedule A and B) showed lowest number of tillers/ha. However, it was on par with conventional method of irrigation and fertilizer application. Sufficient supply of nutrients in appropriate splits during growth stages and continuous availability of soil moisture throughout the growth period of sugarcane increased number of tillers in drip fertigation (Tan *et al.* 2009). The number of millable canes/ha among the treatments did not differ significantly.

#### Yield of cane

The cane yield data pooled over three years (2007-2010) was found to range between 133.42 tonnes/ha to 187.75 tonnes/ha among various treatments (Table 2). Among all the treatments significantly superior yield of 187.75 tonnes/ha was recorded in 100% fertigation through schedule B (26 splits as per crop growth stages); however, it was on par with cane yield under 100% fertigation schedule A (178.59 tonnes/ha) and 80% fertigation through schedule B (168.80 tonnes/ha). The uniform moisture status in root zone and more availability of nutrients resulted into more uptake of water and nutrients and in turn produced more biomass. Veeraputhiran *et al.* (2012) also observed significantly higher cane yield under fertigation.

The cane yield (156.25 tonnes/ha) obtained under drip

irrigation with 100% conventional fertilizers applied through soil was found on par with 60% fertigation using schedule B (156.71 tonnes/ha). It emphasized that fertigation using WSF can save fertilizer dose of sugarcane up to 40%. The cane yield obtained under N fertigation through drip (165.90 tonnes/ha) indicated that on account of incurring slightly more cost, yield of sugarcane can be increased sizably than no fertigation through drip. The surface method of irrigation produced lowest cane yield (133.42 tonnes/ha). The reasons of low yield in surface irrigation might be water stress between two irrigations. The results are in conformity as reported by Dalri and Cruz (2008).

The sugar yield has also showed similar trend with highest yield under T<sub>4</sub> (22.00 tonnes/ha) and was statistically on par with T<sub>1</sub> (19.68 tonnes/ha) and T<sub>5</sub> (18.14 tonnes/ha). It was due to better and adequate supply of required quantity of water and nutrients at the right time and at right place. The study revealed increase in sugar yield with increasing fertigation levels which is supported by the work of Mahendran and Dhanalakhmi (2003). The (CCS %) were also improved under drip fertigation but the difference was non-significant (Table 1). Application of fertilizers as per growth stages had a positive effect on CCS as values were improved to 11.2% in drip fertigation schedule B from 9.3% over conventional method.

#### Nutrient availability

The periodical availability of nutrients as per fertigation level (Averages of schedule A and B) and method of fertilizer application for sugarcane was studied (Fig 1 to 4) and discussed in following sections.

#### N availability

The N availability (Fig 1 and 2) was increased with crop duration and found highest at 270 DAP but afterwards it decreased due to withdrawal by plant. At harvest, the availability of N in root zone was found more in 100% (190.0 kg/ha) amongst all water soluble fertilizer treatments (T<sub>1</sub> to T<sub>6</sub>). The availability decreased with lower dose (187.2 kg/ha in 80% and 185.6 kg/ha in 60%). When method of fertilizer application was compared (Fig 2), the water soluble fertilizers (100% as per schedule B) resulted in higher availability of N (191.6 kg/ha) in soil followed by treatment 100% fertigation schedule A (188.4 kg/ha) and N fertigation (188 kg/ha) as compared to conventional fertilizers (172.6 kg/ha). The N availability was also found more when only

Table 2 Yield of cane as influenced by fertigation levels (Pooled mean of 2007-2010)

Treatment	100%	80%	60%	100%	80%	60%	100%	100%	100%	CD (P=0.05)
	WSF(A)	WSF(A)	WSF(A)	WSF(B)	WSF(B)	WSF(B)	CF (NTD)	CF +DI	CF +SI	
Cane yield (t/ha)	178.59	164.41	149.19	187.75	168.30	156.71	165.90	156.25	133.42	21.07
CCS %	11.1	10.6	9.5	11.2	10.9	9.9	10.2	10	9.3	NS
Sugar yield (t/ha)	19.68	17.18	13.92	22.00	18.14	15.31	16.40	15.48	12.52	4.10
Increase in yield* (%)	35.26	24.02	12.13	41.77	27.26	17.96	25.30	17.61		

\* Increase in yield over T<sub>0</sub>, WSF-Water soluble fertilizers, CF-Conventional fertilizers, NTD-Nitrogen through drip, DI-Drip irrigation, SI-Surface irrigation, A, B- Fertigation schedules

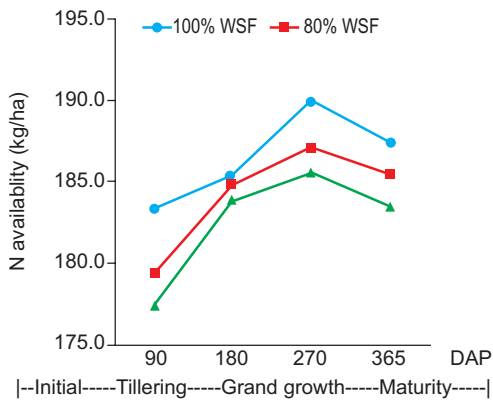


Fig 1 N availability as per fertigation level

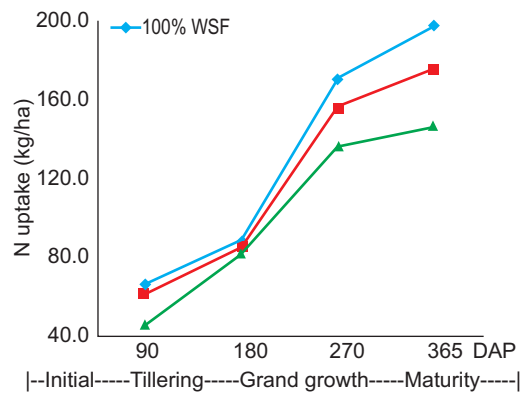


Fig 5 Cumulative N uptake as per fertigation level

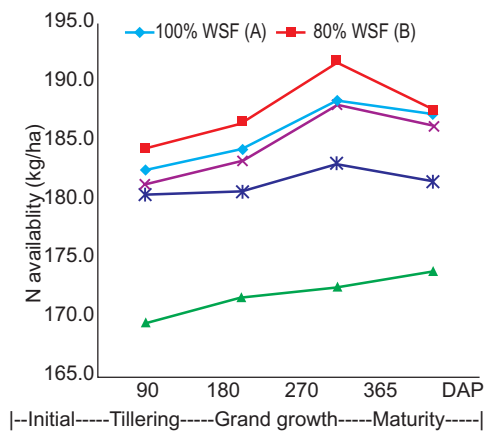


Fig 2 N availability as per fertilizer application method

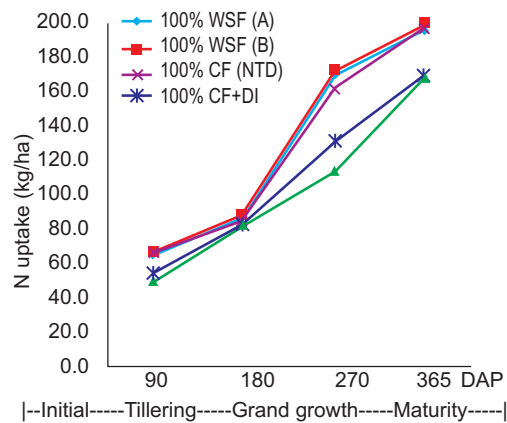


Fig 6 Cumulative N uptake as per fertigation method

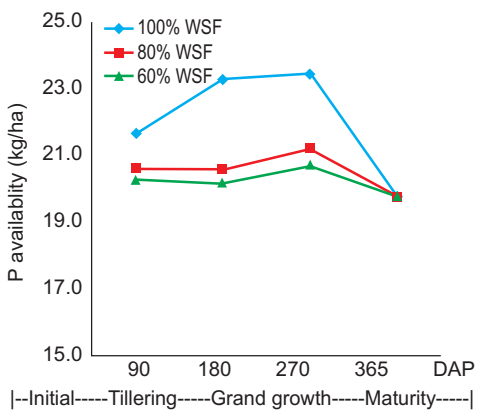


Fig 3 P availability as per fertigation level

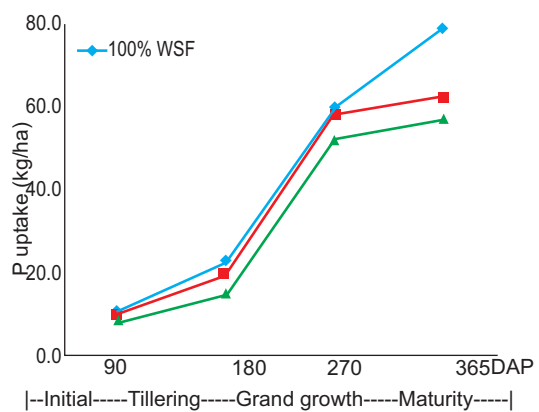


Fig 7 Cumulative P uptake as per fertigation level

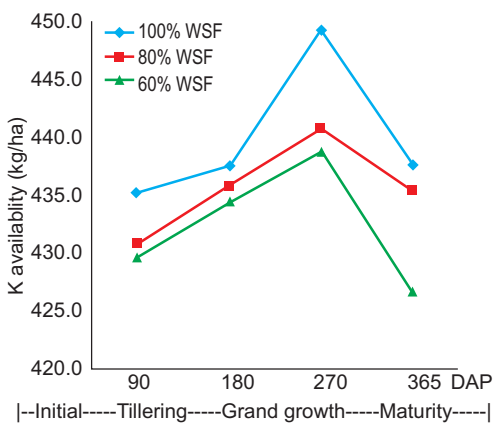


Fig 4 K availability as per fertigation level

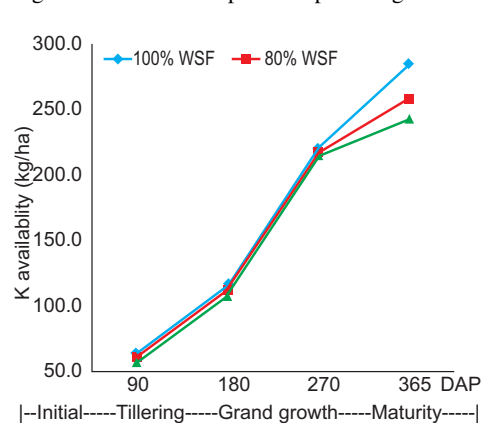


Fig 8 Cumulative K uptake as per fertigation level

drip irrigation (183 kg/ha) were used. The tendency of nitrogen to leach and evaporate was minimized by applying 'N' in more splits through drip in a specified wetted zone which resulted in improved 'N' availabilities in fertigated and drip irrigated treatments. The adequate quantum of water just beneath the drippers increased the nitrogen availability in root zone.

#### *P availability*

The phosphorus availability was also increased up to 270 DAP and reduced afterwards (Fig 3). The maximum availability of P was found in 100% WSF dose (23.5 kg/ha) and decreased with decreased fertilizer levels, i.e. 60% WSF (20.7 kg/ha). The availability of phosphorus to the crop is a problem in clay soils due to its fixation, but fertigation @ 100% through schedule B resulted into more availability of P (24.4 kg/ha) in soil as compared to conventional fertilizers (17.3 kg/ha). Frequent application of fertilizer in more splits in specified area of root zone resulted in increased 'P' concentration and more availability of phosphorus as compared to conventional fertilizers.

#### *K availability*

Similar trend was also found in K availability (Fig 4). The K availability at 270 DAP was found lowest in 60% WSF (438.8 kg/ha) as compared to 100% (449.3 kg/ha) and 80% (440.9 kg/ha). The water soluble fertilizers through schedule B resulted into more availability of K in soil (454.6 kg/ha) as compared to conventional fertilizers (412.6 kg/ha). The schedule A also resulted into more K availability (444 kg/ha) in soil as compared to N through drip (433.3 kg/ha), drip without fertigation (432.7 kg/ha) and conventional method (Fig 6). The favourable soil moisture concentrations proved beneficial for K availability in the soil. Bangar and Chaudhari (2004) also observed significantly higher nutrient availability under drip fertigation at higher quanta of N, P and K.

#### *Nutrient uptake*

Nutrient concentration in sugarcane at different growth stages were significantly influenced by levels of fertilizers and methods of application (Fig 5 to 8).

#### *N uptake in sugarcane*

It is observed that levels of water soluble fertilizer (averages of two schedules) had significantly increased N uptake by plant (Fig 5). The cumulative N uptake was found increasing with age of crop. The application of 100 per cent RD of WSF showed higher uptake at harvest (197.9 kg/ha), however, it was at par with 80 per cent (175.9 kg/ha). The fertigation resulted into more concentration of nutrients readily available in soil and optimum availability of water in soil increased nutrient uptake. The rate at which uptake of 'N' took place was more in tillering and grand growth stage.

There was significant difference between the N uptake by plant under various methods of application (Fig 6). The

application of WSF in 26 splits as per growth stages (Schedule B) resulted into improved 'N' uptake during all growth stages. The split wise N fertigation through drip also showed significantly more N uptake by sugarcane at different growth stages than conventional method of fertilizer application. The uptake of nitrogen was statistically on par in 100% fertilizers applied in 26 splits through drip (199.7 kg/ha), uniform splits of 100% fertilizer (196.2 kg/ha) and N fertigation (197.7 kg/ha). The nitrogen uptake in conventional method was lowest because of moisture stress (168.5 kg/ha).

#### *P uptake in sugarcane*

The maximum phosphorus uptake (79 kg/ha) throughout crop growth period was observed in 100% fertigation applied in 26 splits which was significantly superior to rest of the treatments (Fig 7). It was followed by 80% fertigation (62.5 kg/ha at harvest). At lower levels (60% fertigation), the uptake of P was low (57 kg/ha at harvest). The uptake of 'P' was found to be at lowered rate during maturity stage. When the methods of fertilizer application were considered, the more uptake of P (79.9 kg/ha) was observed in drip fertigated treatments (100% as per schedule B) due to more splits of fertilizer applied as per crop growth stages at particular location and solubility in the presence of uniform moisture as compared to conventional method (56.5 kg/ha).

#### *K uptake in sugarcane*

Potassium uptake was found significantly more in 100% fertigation (285.2 kg/ha) than rest of the levels, i.e. 80% (258.9 kg/ha) and 60% (242.8 kg/ha). The best performance of WSF fertilizers (100% schedule B) in terms of K uptake (286.1 kg/ha) was observed which might be due to frequent and adequate application as compared to conventional method. The 'K' uptake pattern in all the application methods was almost identical during tillering stage; however variable pattern was observed during grand growth and maturity stage. The application of WSF through schedule A and B resulted into significantly improved 'K' uptake than all other fertigation treatments. 'K' usually get lost easily in conventional practices through leaching. The positive to drip fertigation may be due to avoidance of deep percolation losses to greater extent. The uptake of K were statistically at par in N fertigation (254.3 kg/ha), drip with straight fertilizer (255.1 kg/ha) and conventional method (250.2 kg/ha) as method of K application was not different in these treatments. These results have close conformity to those reported by Ng Kee Kwong and Deville (1994) that water soluble fertilizer application help in better nutrient uptake and development of plant.

#### *Cost economics*

The three years pooled data of net seasonal income, benefit: cost ratio and net extra income over surface as influenced by different treatments is presented in Table 3. The seasonal fixed cost of drip system for 0.75 m - 1.5 m - 0.30 m paired row planting for sugarcane was estimated as

₹ 18 904/ha considering the depreciation cost, interest on capital investment and cost towards repairs and maintenance. It is revealed from Table 3 that more cost of cultivation/ha was incurred in fertigation treatments because of high market cost of water soluble fertilizers. The seasonal cost of surface irrigation treatment was lowest (₹ 53 521/ha). The prevailing market price for sugarcane was ₹ 1 200, 1 800 and 2 000 per tonne (₹ 1 667/tonne, average of three years) in 2008, 2009 and 2010, respectively.

#### Net seasonal income and B: C ratio

The higher net seasonal income of ₹ 226 195/ha was obtained when 100% WSF was applied through drip as per schedule B which was on par with uniform splits (₹ 208 311/ha), 'N' fertigation (199 869/ha) and 80% fertigation using schedule B (₹ 196 864/ha). The lowest net seasonal income of ₹ 159 949/ha was obtained under conventional method. The conventional method of irrigation resulted highest B:C ratio (4.68) as the cost involved is less followed by N fertigation (4.25) and 100% fertigation using schedule B (4.15), however, the difference was non-significant. All the water soluble fertigation treatments resulted into lower B: C ratio mainly due to very high (3-5 times more) costs of water soluble fertilizers than conventional fertilizers. Raskar and Bhoi (2001) reported higher seasonal income accrued under fertigation was masked by straight fertilizer owing to the high cost of water soluble fertilizer.

#### Net extra income and payback period

The fertigation using 100% WSF using schedule B (T<sub>4</sub>) resulted into ₹ 66 246/ha as maximum net extra income over surface method. The net extra income of ₹ 22 471/ha was estimated due to drip irrigation over surface method of irrigation. It indicated that, all capital investment on drip unit can be reimbursed within one year (Table 3), if drip along with fertigation is used for sugarcane; whereas, about 2.7 years will be required to recover the capital expenditure

Table 3 Economics of sugarcane (₹/ha) as influenced by different treatments (Pooled data of three years)

Treatment	Seasonal cost	Net seasonal income	B:C ratio	Net extra income over control	Payback period (Years)
100% WSF(A)	84 258	208 311	3.74	48 362	1.24
80% WSF(A)	80 174	190 851	3.76	30 902	1.94
60% WSF(A)	76 100	167 820	3.60	7 871	7.62
100% WSF(B)	84 258	226 196	4.15	66 246	0.91
80% WSF(B)	80 174	196 864	3.78	36 915	1.63
60% WSF(B)	76 100	179 782	3.69	19 833	3.03
100% CF (NTD)	70 945	199 869	4.25	39 920	1.50
100% CF +DI	70 945	182 420	3.93	22 471	2.67
100% CF +SI	53 521	159 949	4.68		1.24
SE (±)		10 800	0.28		
CD (P=0.05)		31 200	NS		

if fertigation is not used.

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