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Effect of Various Levels of Potash Application Through Drip Irrigation on Yield and Quality of Sugarcane

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Abstract

Water and nutrients are the most crucial inputs for sugarcane cultivation and their application through micro irrigation systems is highly important as a means of increasing land, water and fertilizer use efficiency. An experiment studying the effects of various levels of potash application through drip irrigation on yield and quality of sugarcane using the variety Co 86032 over three crop seasons (2003-2004, 2004-2005 and 2006-2007) is reported. Application of nitrogen and potash fertilizers through drip irrigation not only saved 30 percent of nitrogen (N) and potassium (K) fertilizer, but also increased yield by 19.1 percent and more than doubled water use efficiency, as compared to the control using the recommended application of chemical fertilizers and conventional irrigation. The total quantity of irrigation water applied under conventional irrigation was 26,560 m^3 ha^{-1} compared to only 14,560 m^3 ha^{-1} under drip irrigation, resulting in 45.2 percent reduction in water use. The cane yield obtained in the control was 142.82 mt ha^{-1}, while with 70 percent N and K fertilizers through drip irrigation and 100 percent P through soil application the cane yield was 170.08 mt ha^{-1}. Agronomic efficiency of K fertilizer with 30 percent saving of N and K fertilizers was 1.43 mt cane kg^{-1} K_2O as compared to 0.84 mt cane kg^{-1} K_2O in the control. The optimal treatment yielded savings of 30 percent N and 15 percent of K (as compared to the control), and increased the net income by more than Rs. 18,000 (approx. USD 400) per hectare.

Keywords: Drip irrigation, paired planting, long furrow irrigation, water use efficiency, fertilizer use efficiency, water saving.

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Project location in India.

Introduction

Sugarcane is a major cash crop in India responsible for the overall socio-economic development of the farming community. It is cultivated on 5.15 million hectares providing an annual sugarcane production of 340 million mt (2008-2009). Average productivity is thus relatively low, at 66 mt ha^{-1}. Production of the crop is mainly located in the states of Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka and Gujarat. Currently India consumes about 18.5 million mt of sugar but to meet the demands of an increasing population, there will be a need to produce 28 million mt of sugar by 2015.

It is believed that improper water management and imbalanced nutrition are the main constraints to increased productivity. Improving the application of these two inputs certainly raises sugarcane yields. Consequently, there is an urgent requirement to increase sugarcane production through modern and precise methods of cultivation, including fertigation.

Sugarcane is a long duration crop which produces huge amounts of biomass, requiring large quantities of water,

Experimental plot at the Vasantdada Sugar Institute fields. Photo by IPI.

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which typically are supplied through 25-30 irrigation cycles per crop season. It has been estimated that the total water requirement of sugarcane crop varies from 20,000 to 30,000 m^3 ha^{-1} $year^{-1}$ and it is estimated that 12,000 to 13,000 m^3 of water is required for a sugarcane crop of 12 months duration if used efficiently. The crop requires 400 m^3 of water to produce one metric tonne of total dry matter and 200 m^3 of water to produce one metric tonne of cane. Irrigation management in sugarcane is therefore of prime importance to raise crop yield and sugar production.

The K requirement of sugarcane is 1.32-1.44 kg K_2O mt^{-1} of cane (IFA, 1992). K applications are usually made together with N because of the more efficient utilization of N by the crop in the presence of K. However, late application of K up to six months into the growth of the crop has also been found to improve sugar recovery.

Potassium application raises milleable stalk yield, percentage sugar in the cane and degrees Brix (°Bx), a measure of the percentage of sugar in the juice. K deficiency impairs sucrose transport from the leaf into the stalk. There is a positive interaction between N and K, the lowering of the sugar content caused by high rates of N being ameliorated by an adequate supply of K. Excessive dosages of K (i.e. over and above optimal rates) may exert a negative influence on apparent sucrose percentage in cane (pol percent cane) and may promote an increase in the ash content of the juice, since K is the major constituent in the ash. The main effect of excess K is to depress the recovery of sucrose during milling by maintaining a certain amount of sucrose in solution (Ng Kee Kwong, 2002). The unfavorable effects of K, however, should be anticipated only when excessive rates are used; on low potassium soils, improvement in cane quality is to be expected.

Erratic and uncertain monsoons which lead to poor recharging of the groundwater table and over depletion of groundwater due to overuse of irrigation, have led to water becoming the most limited and costliest input in agriculture. There is an acute shortage of irrigation water, especially during the summer season, resulting in a decline in cane yield. Fertilizer use efficiency is also low under conventional irrigation.

Table 1. Treatments for the fertigation experiment.

Treatments	Irrigation method	$N\text{-}P_2O_5\text{-}K_2O$	No. fertilizer application	Application method
		kg ha^{-1}		
T1	Long furrow	340-170-170	4	A
T2	Drip	340-170-170	4	A
T3	Drip	240-170-196	13	B
T4	Drip	240-170-170	13	B
T5	Drip	240-170-145	13	B
T6	Drip	240-170-120	13	B
T7	Drip	240-170-95	13	B

Notes:
A = All fertilizers applied directly to soil.
B = N and K applied in fertigation; P as single super phosphate (SSP) in two soil applications.

Adoption of drip irrigation in sugarcane offers an opportunity for placing fertilizer in a soluble form at the root zone of the crop along with the irrigation water, thus increasing water and fertilizer use efficiency. Fertigation ensures that essential nutrients are supplied precisely at the area of most intensive root activity according to the specific requirements of sugarcane crop and type of soil, thereby resulting in higher cane yields and sugar recovery.

This paper describes the results of a three-year experiment conducted at the experimental farm of the Vasantdada Sugar Institute (VSI) in Pune, Maharashtra State. The results from three farmers' fields located in different districts, using two selected treatments, are reported in an appendix. The application of N and K fertigation were tested with five levels of K to better understand the potential of the fertigation system to achieve a higher water and K use efficiency. The objectives of the research project were as follows:

1. To study the effect of different levels of K through drip irrigation on yield and quality of the sugarcane crop.

2. To study fertilizer and water use efficiency with different levels of fertilizer application.

3. To analyze the cost benefit ratio with different levels of fertilizer application.

Materials and methods

The work was carried out at the VSI's experimental farm beginning in 2003 using the plant cane (Variety – Co 86032) and was continued for the first ratoon crop and second plant cane. The experiment was set up in a random block design (RBD) with four replications. Total plot size was 58 x 58 m, with individual plots of 8.5 x 13.5 m.

Soil analysis was carried out before planting the crop. The soil of the experimental plot was non-calcareous with a pH around 8. The electric conductivity (EC) in different plots varied from 0.35 to 0.45 dS m^{-1}. Organic carbon was in the range of 0.59 to 0.95 percent. Available phosphorus was estimated by using the Olsen method and was in the range of 4.38 to 6.97 ppm, while 1 N Ammonium Acetate Extractable Potash was more than 400 ppm in all the treatment plots (Table 1).

T1: Recommended dose (for Maharashtra State) of chemical fertilizers ($N\text{-}P_2O_5\text{-}K_2O$ of 340-170-170 kg ha^{-1}) in four splits under conventional irrigation (soil application), N in four splits i.e. at planting and then every 45 days after planting, P_2O_5 and K_2O in two splits at planting and after 120 days of planting on earthing up.

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T2: Recommended dose (for Maharashtra State) of chemical fertilizers ($N-P_2O_5-K_2O$ of 340-170-170 kg ha^{-1}) in four splits under drip irrigation (all fertilizers applied in soil application).

T3: 70 percent of recommended dose of urea + 115 percent recommended dose of KCl in 13 equal splits through drip irrigation + recommended dose of single super phosphate (SSP) in two splits by soil application.

T4: 70 percent of recommended dose of urea + 100 percent recommended dose of KCl in 13 equal splits through drip irrigation + recommended dose of SSP in two splits by soil application.

T5: 70 percent of recommended dose of urea + 85 percent recommended dose of KCl in 13 equal splits through drip irrigation + recommended dose of SSP in two splits by soil application.

T6: 70 percent of recommended dose of urea + 70 percent recommended dose of KCl in 13 equal splits through drip irrigation + recommended dose of SSP in two splits by soil application.

T7: 70 percent of recommended dose of urea + 55 percent recommended dose of KCl in 13 equal splits through drip irrigation + recommended dose of SSP in two splits by soil application.

The irrigation schedule of the furrow irrigation treatment was based on Irrigation Water/Cumulative Pan Evaporation (IW/CPE) = 0.75, and in drip irrigation treatments the irrigation quantity was applied based on a climatological approach i.e. monthly average evaporation, pan coefficient and crop coefficient as per crop growth stages. Under furrow irrigation the average irrigation interval was 18, 14 and 9 days in the rainy (June to September), winter (October to January) and summer (February to May) seasons respectively. Under drip irrigation, the estimated irrigation quantity was applied daily to maintain the moisture content close to the field capacity of the soil. The total quantity of irrigation water applied under conventional long furrow irrigation was 26,556 m^3 per hectare, and under drip irrigation system was 14,563 m^3 per hectare (54.84 percent of the conventional method).

Table 2. Growth observations at harvest (pooled data of two plant and one ratoon crop).

Treatments	$N-P_2O_5-K_2O$	Milleable height	Girth	No. of internodes
	kg ha^{-1}	-------------*cm*-------------		*No.*
T1	340-170-170	271.35	8.55	22.83
T2	340-170-170	300.57*	8.44	25.02*
T3	240-170-196	300.84*	8.93*	25.00*
T4	240-170-170	299.62*	8.64	24.58*
T5	240-170-145	305.74*	8.86*	24.19*
T6	240-170-120	300.56*	8.97*	24.83*
T7	240-170-95	277.69	8.33	23.91
SE ±		2.99	0.08	0.38
CD at 5%		8.82	0.23	1.13

*Statistically significant data as compared to other treatments.

Results and discussion

Based on three years data (two plant crops and one ratoon crop), the results of the experiment are discussed below:

Growth observations at harvest

Growth observations including milleable cane height; number of internodes and cane girth were recorded at the time of harvest and pooled data are presented in Table 2. The milleable cane height at harvest varied from 271 to 305 cm between treatments. Significant differences between both milleable cane height and number of internodes with the respective controls were found in all the treatments except in T7 (240 and 95 kg N and K_2O ha^{-1}, respectively). Cane girth in this treatment (8.33 cm) was the lowest, possibly due to the lowest K level applied among all treatments.

Yield and CCS at harvest

Cane yield significantly changed in response to the irrigation method and fertigation. A significant increase in yield and commercial cane sugar (CCS) was achieved by using drip system (T2) instead of flood (T1), despite a large decrease in water used (Fig. 1; Table 3). T1 and T2 differ only in the irrigation system used and amount of water. These results demonstrate the high wastage of water in the flood system (T1).

Treatments T3-T7 all use N & K in the fertigation system, as compared to basal application to soil in T1 and T2. From the pooled results given in Table 3, it

Table 3. Cane and CCS yield, water quantity applied, and water use efficiency of sugarcane with different irrigation and nutrition treatments (pooled data of two plant and one ratoon crop).

Treatments	$N-P_2O_5-K_2O$	Cane yield	Milleable canes at harvest	CCS at harvest	CCS yield	Quantity of water applied	Water use efficiency
	kg ha^{-1}	*mt ha^{-1}*	*No. ha^{-1}*	*%*	*mt ha^{-1}*	*m^3 ha^{-1}*	*kg cane m^3*
T1	340-170-170	142.82	111,293	13.71	19.60	26,556	5.4
T2	340-170-170	163.88*	122,141*	14.11	23.12*	14,563	11.3
T3	240-170-196	170.32*	136,815*	14.01	23.88*	14,563	11.7
T4	240-170-170	169.43*	130,026*	14.30	24.22*	14,563	11.6
T5	240-170-145	175.50*	133,869*	14.06	24.67*	14,563	12.1
T6	240-170-120	170.08*	129,813*	14.11	24.00*	14,563	11.7
T7	240-170-95	148.25	117,666	13.95	20.67	14,563	10.2
SE ±		2.12	2,333	0.15	0.36	-	-
CD at 5%		6.24	6,864	N. S.	1.08	-	-

*Data is statistically significant.

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can be seen that the cane yields obtained in treatments with fertigation through drip irrigation are superior to the control, T1 (all fertilizers as basal, with flood irrigation) and T2 (split of nutrients applied to soil and use of drip system). Moreover, the use of N and K in fertigation allowed a 30 percent reduction in the N and 15 percent of the K (T5) applied.

Highest yield of cane (175.5 mt ha^{-1}) was obtained with T5 (drip and fertigation, with 70 and 85 percent of the N & K as compared to farmers' practice, T1). A further reduction in K application (T7, 55 percent of farmers' practice) caused yield reduction and was not significantly higher than the control (T1).

CCS at harvest was higher in all drip-irrigated treatments, but not significantly (Table 3). However, with the additional cane yield, CCS yield was significantly higher in all the drip irrigated treatments, except T7 (with the lowest K level), and responded well to the amount of K applied (Fig. 1). These results show that in terms of gained income, which is strongly related to the CCS yield, farmers can achieve the highest income with treatment T5, which is significantly higher than the control.

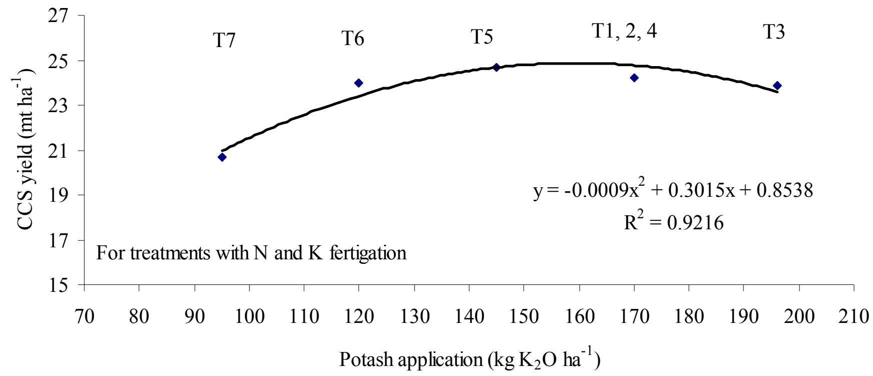

Fig. 1. CCS yield after potash application.

Water use efficiency

Water use efficiency more than doubled with the use of the drip system, from 5.4 to 12.1 kg cane m^{-3} (Table 4). This astonishing finding demonstrates the significant benefit in using water saving technologies. The economic benefit can be seen as either enabling farmers to double the cane area for the same amount of available water, or use and pay less for the same land. This value is still not calculated, but we are certain that policymakers should attribute the required added economic benefit to drip systems.

Economics

The average pooled costs of cultivation of sugarcane, including the drip irrigation system for three crop seasons in treatments T1 - T7 (based on return of cost of system in five years), were Rs. 86,549, 100,666, 100,657, 100,315, 101,085, 99,969 and 96,105 respectively (Table 4). Considering the yield levels in these treatments and

Table 4. Water use efficiency and profitability of sugarcane production under water and nutrient savings via the use of drip fertigation (pooled data of two plant and one ratoon crop).

Treatments	$N-P_2O_5-K_2O$	Water applied	Cane yield	Water use efficiency	Cost of cultivation$^{(\dagger)}$	Gross income	Net income(§)	B:C ratio(‡)
	kg ha^{-1}	*m^3 ha^{-1}*	*mt ha^{-1}*	*kg cane m^{-3}*	*Rs. ha^{-1}*		*Rs. ha^{-1}*	
T1	340-170-170	26,556	142.82	5.4	86,549	142,820	56,271	1.65
T2	340-170-170	14,563	163.88*	11.3	100,666	163,880	63,214*	1.63
T3	240-170-196	14,563	170.32*	11.7	100,657	170,320	69,663*	1.69
T4	240-170-170	14,563	169.43*	11.6	100,315	169,430	69,115*	1.69
T5	240-170-145	14,563	175.50*	12.1	101,085	175,500	74,415*	1.73
T6	240-170-120	14,563	170.08*	11.7	99,969	170,080	70,111*	1.70
T7	240-170-95	14,563	148.25	10.2	96,105	148,250	52,145	1.54
SE ±		-	2.12	-	-		1,782.8	0.021
CD at 5%		-	6.24	-	-		5,244.1	0.064

Notes:

- Selling price 1 mt cane = Rs. 1,000; Farm gate costs of N, P_2O_5 and K_2O (as urea, SSP and muriate of potash (MOP) were 10.87, 18.75, and 7.67 Rs. per kg nutrient.
- Including cost of drip system: cost of drip irrigation system is based on the life of five cropping seasons, i.e. Rs. 60,000 ha^{-1} in five years equates to Rs. 12,000 + interest at 12 % = Rs. 16,320 yr^{-1}. This cost has been added to treatments T2 to T7.

$^{(\dagger)}$ The cost of cultivation is the total expenditure made from land preparation to harvesting of the crop including the cost of drip irrigation system (Rs. 16,320 yr^{-1} ha^{-1}).

$^{(§)}$ Net income = Gross Income - Cost of cultivation.

$^{(‡)}$ Benefit Cost Ratio (B:C) is the ratio between gross income and cost of cultivation.

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sugarcane price at Rs. 1,000 per metric tonne, the income in treatments T1 to T7 worked out to be Rs. 142,820, 163,880, 170,320, 169,430, 175,500, 170,080 and 148,250 respectively, leaving a net income of 56,271 to 74,415 Rs. ha^{-1}, depending on the treatment (Table 4). Net income was significantly higher in all the treatments with drip irrigation, except T7. Net profit significantly increased over the control by Rs. 18,144 (approx. USD 403) ha^{-1} (Table 4).

According to our results, switching from flood to drip irrigation generates an additional Rs. 7,000 yr^{-1} just with the increased yield. Clearly, once water use is charged, this additional profit will increase.

The cost benefit ratio in treatments T1 to T7 was 1:1.65, 1:1.63, 1:1.69, 1:1.69, 1:1.73, 1:1.70 and 1:1.54 respectively (Table 4). The cost benefit ratio under drip irrigation systems i.e. in treatments T2 to T7 were worked out on the basis of the actual cost of the system in the market. However there is provision for a subsidy up to 50 percent for the drip irrigation system. In addition to increased yield under the drip irrigation system, there was water saving of 45.16 percent in drip treatments T2 to T7, as compared to the control i.e. conventional long furrow irrigation with recommended dose of chemical fertilizers.

Conclusions

Sugarcane is a major cash crop in India, yield and crop quality being critically dependant on supply of water and nutrients. Experiments carried out over three seasons are reported here in which drip irrigation was compared with conventional irrigation with recommended doses of chemical fertilizers. The results demonstrated that by using drip irrigation it was possible to achieve more than two-fold higher water use efficiency, and at the same time reduce fertilizer requirement and raise crop yield and quality. Cane yields of sugarcane increased by 19.09 percent with CCS values raised by 22.47 percent. This was achieved in addition to a 42.5 percent water saving using 30 percent less N and K fertilizer. The consequent cost benefits of drip irrigation to the farmer are economically assessed and are of major importance.

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The paper "Effect of Various Levels of Potash Application Through Drip Irrigation on Yield and Quality of Sugarcane" appears also at:

Regional Activities/India

Appendix: Demonstration plots

Three demonstration plots were laid out at three farmers' fields in Ahmednagar, Sangli and Latur districts, Maharashtra State. Two treatments were demonstrated:

T1: Conventional irrigation with a recommended dose of fertilizers (340-170-170, N, P_2O_5 and K_2O, respectively).

T2: 70% N, 70% K_2O through drip irrigation in 13 equal splits and 100% P_2O_5 through soil application (240, 170 and 120 N, P_2O_5 and K_2O, respectively).

The (pooled) results of these farm demonstrations are presented in the table below, and are comparable to the results obtained at the VSI farm.

Treatment	Germination	Tiller ratio at earthing up	Milleable cane height	Number of internodes	Cane girth	Plant population	Cane yield	CCS	CCS yield	Quantity of water applied	Water use efficiency
	%		*cm*	*No.*	*cm*	*No. ha^{-1}*	*mt ha^{-1}*	%	*mt ha^{-1}*	*m^3 ha^{-1}*	*kg m^{-3}*
T1	73.16	5.96	247.67	22	9.85	90,357	88.24	12.25	10.82	26,370	3.3
T2	74.12	6.49	262.67	23.33	10.09	94,627	111.53	12.41	13.84	14,844	7.5