International Journal of Agricultural Policy and Research Vol.2 (1), pp. 026-032 January 2014
Available online at http://www.journalissues.org/ijapr/

ISSN 2350-1561

Original Research Paper

Drip irrigation as a potential alternative to furrow irrigation in sugar-cane production-A case of the Lowveld Estate, Zimbabwe

Accepted 18 November,2013

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This study was conducted to evaluate drip irrigation as a potential alternative to furrow irrigation in sugar-cane at Mupapa Settlement Scheme in Zimbabwe. The study addressed the water scarcity problem being experienced in the Sugar-cane Estates of Zimbabwe. It investigated the potential of using drip irrigation, which has higher water use efficiency. Twenty plots were arranged in a completely randomized design to determine fresh weight and sucrose content. The financial implications of the systems were evaluated using Net Present Value, Benefit Cost Ratio, and Internal Rate of Return. Yield and sucrose content results were analyzed using Genstat Package. The results showed a significant difference ($p<0.05$) in sugar-cane fresh weight and sucrose content between drip and furrow treatments. Drip had a lower fresh weight value of 114.5 t/ha compared to 134.95 t/ha for furrow systems in 2008. Sucrose values of 57.75t and 66.5t were obtained for drip and furrow, respectively in the same year. In 2009, there was a slight increase in fresh weight of 2.0t and 1.25t for drip and furrow systems, respectively. Sucrose content increased slightly by 0.15t for drip, and 0.2t for furrow system. For both treatments Benefit Cost Ratio was greater than zero and Net Present Value was positive, showing that they are profitable and viable projects. The Internal Rate of Return for drip project was 7.46% compared to a value of 26.66 % in furrow irrigation. Thus, more years are required to cover the initial costs incurred for drip irrigation.

Key words: Drip, Furrow, water scarcity, sugarcane, financial analysis, Zimbabwe

INTRODUCTION

Sugar-cane (*Saccharum officinarium*) is a tropical, succulent perennial C-4 plant that originated in New Guinea and gradually spread to Asia (FAO, 2013). It has a high affinity for water; requiring about 1300mm to 2000mm per year with the water requirements differing with different growth stages (FAO, 2013). The crop requires a well drained, well aerated, porous soil with pH of 6.5 and it is moderately sensitive to soil salinity (NETAFIM, 2009).

In Zimbabwe sugar-cane is mainly grown in the South - Eastern part, due to the suitability of the climate. Majority of Zimbabweans rely on sugar from this area and the sugar-cane estates that make use of this aids the country's economy. Apart from sugar, the main by-product, ethanol is also produced as bio fuel from the crop. The Southern region of Zimbabwe provides employment for thousands of people, thereby creating better livelihoods. Thus the area is very crucial and its viability and productivity is of importance not only to the residents but to the country as a whole.

However, the main challenge is that though optimum temperatures (32 to 38°C) are experienced, the area has one drawback of very low rainfall. Thus sugar-cane has to be grown under irrigation all year round. Currently, many of the fields are under furrow irrigation and some areas are being irrigated by overheard- portable sprinklers and centre pivot system. Furrow irrigation is one of the oldest methods and it is conducted by creating small parallel channels along the field length in the direction of predominant slope (Kemper, 1988). The high amounts of water used by the method often results in wastage of water due to tail water runoff, hence, contributing to low efficiencies (MSUES, 2007). As a result of the low efficiencies of furrow irrigation system, many farmers across the world have adopted irrigation systems with higher efficiencies such as drip irrigation. This move has been successful in crops like potatoes (Ghasemi-Sahebi et al., 2013) and maize (Humphreys et al., 2005) amongst others.

Drip irrigation is the frequent application of small quantities of water on, above or below the soil surface by surface drip, subsurface drip, micro sprayers or micro sprinklers (Frenken, 2005). Water is applied as discrete or continuous drops, tiny streams or miniature sprays through emitters or applicators placed along a water delivery line near the plant (NABARD, 2009). The drip system is characterized by low flow rate, long duration, frequent irrigation and application of water near or into the root zone of plants with low pressure delivery systems (Directorate of Sugar-cane Development, 2007). The method has gained popularity especially due to its high efficiency of about 90 % which also results in water savings of approximately 40 to 50 % (UNEP, 2009). Low cost drip kits have been developed and widely adopted in a fight to accommodate and help small farmers improve their water use efficiency.

Drip irrigation is still a new technology in Zimbabwe sugar-cane production. Not much research has been carried out in the country to evaluate the potential of drip system in sugar-cane production compared to surface and sprinkler systems. In some sugar-cane growing countries in Asia, successful stories of drip irrigation in sugar-cane have been cited. In a study by Sharmasarkar et al in 2001, they establish that sugar beet yield and sugar content were higher for drip irrigation than for furrow systems with average of 56 and 50.5 Mg ha^{-1} respectively. These results corresponded to another study by Sale in 2003, where he contrasts drip and furrow systems in sugar-cane production in Tamilnadu- drip yielded more (160 t/ha) than furrow (120 t/ha) and there was 29 % in water saving over flood irrigation. Blatchford (1996) also reports an increase in cane yield from an average of 92 to 116 tons cane/ha after converting from furrow irrigation to subsurface drip irrigation.

As the world faces the challenge of water scarcity and given that water demand is higher than the supply, action need to be taken to find ways to alleviate this. The Zimbabwe's Lowveld is no exception to water scarcity, as the area has been subjected to severe dry spells for the past decade causing alarm to residents, as the water levels of major supply dams have drastically reduced. This has resulted in the urgent need for immediate action for sustainable use of the few available water resources to enable more crops per drop. Considering the low efficiencies associated with furrow irrigation systems, there is need for adoption of new measures for water conservation. The drip irrigation has been proven in other countries as a water conservation measure, as well as a method of improving yields like in India (Kumar and Palanisami, 2010) Pakistan (Tagar et al., 2012). Focusing on this region, this study is a scalability to see the potential of drip irrigation in Zimbabwe. It compares the yields of the two irrigation methods as well as evaluates the economic merit of the systems.

MATERIALS AND METHODS

Site Description

The study was carried out at Mupapa Settlement Scheme, which is a sugar-cane out grower of Triangle Sugar Cooperation, in the South -East lowveld of Zimbabwe (430m altitude, 21° 01'S and 28°38'E). It falls under natural region IV of the agro ecological zones and receives annual rainfall of 625mm per year falling predominantly in the hot summer months of October to March (Anon, 2000). The area is subjected to severe dry spells, frequent seasonal droughts and very high temperatures of up to 40°C (FAO, 2005). Under the Zimbabwe soil classification the soils are classified under group 4P1. 2, which are siallitic soils derived from mafic gneisses (Thompson and Purves, 1978). The average soil depth is 80cm and the total available moisture is 90mm / m. The major crop grown in the area is sugar-cane and this is carried out under furrow and overheard irrigation.

Experimental design

The plots were arranged in a completely randomized design (CRD) with two treatments and ten replicates for each treatment. The plot sizes were each 100m* 100m. The trial plots were planted with sugar-cane (*Saccharum officinarium*) variety Natal 14. The sugar-cane was planted in August 2007 and harvested from the month of August through to September 2008. The crop was planted soon after land preparation and un-burnt certified seed cut into sets of 3 eyes was used. The sets were first dipped in bayleton and the knives were disinfected by dipping in microl solution after cutting every stalk. The sets were laid at the bottom of the furrow in two continuous parallel lines. After harvesting, the last year's crop was maintained and this was the first ratoon crop.

Irrigation set up and management

Siphon pipes of PVC material with a diameter of 63mm and a discharge of 3l/s were used for furrow irrigation. These were primed from a lined 21l/s canal. The drip set up followed the method used by Nyati (2004). Subsurface drip irrigation was done using standard layout, cane rows were spaced 1.5 m apart and a drip line (tape) was placed at 0.23 m below ground level under each cane row. A T-Tape - Typhoon 25- drip tape was used. The emitters were spaced 0.4 m apart, and delivered 1.6 L of water per emitter per hour. The drip system had two sand filters and one separate disc filter tank. In furrow irrigated plots, 40 mm of water was applied within 24 hours of planting. After planting in drip irrigated plots, water was applied in 3-hour pulses until the soil profile reached field capacity. Thereafter, irrigation in all plots was carried out based on evaporation data. The field was dried off prior to harvesting based on 3* TAM formula.

Crop management

All the management practices were carried out the same way across all fields. Fertilizer was applied at the same rate to all fields; 120kg/ha N, 60 kg/ha P and 120 kg/ha K. Weeding was done manually using hoes. Smut control was also manual; by pulling the smut at early stages, though it was very limited.

Data collection

Sugar-cane fresh weight determination

Harvesting was carried out manually using sharp long and short cane knives. This commenced four days after burning of the plots by an introduced veld fire. Sugar-canes from the different plots were tagged to facilitate no sugar-cane mixtures. Tags of furrow irrigation were numbered from F1 to F10, while tags from drip irrigated sugar-cane were numbered from D1 to D10. The sugar-cane was collected soon after harvesting and transported to the milling plant where it was weighed before crushing. Weighing of the sugar-cane was done using a weigh bridge. Sugar-cane from different plots was weighed separately and the results recorded in the field log sheet.

Sucrose weight determination

Fresh sugar-cane from each respective plot was dried using direct sunlight for a week. The dried sugar-cane was then crushed in the sugar cane crushing mill at Triangle sugar Cooperation. Sucrose content was determined using attenuated total reflectometry (ATR) spectroscopy (Cadet and Offman, 1997).

Sugar-cane fresh weight and sucrose weight data

The data on sugar-cane fresh weight and sucrose weight was analyzed using Genstat for Windows, version 8.1, statistical package.[1]The treatment differences were judged by LSD at 0.05 probabilities.

Financial analysis

Salient features of the investment results were used for financial comparisons between furrow and drip systems. The financial analysis tools used were net present value, benefit cost ratio, and internal rate of return. Data for financial analysis was analyzed based upon a projection of a 5 year period.

Net present value (NPV) determination

NPV is the sum of all the present values of all the cash flows, positive or negative that is expected to occur over the life of the project. NPV was calculated using equation 1 adopted from Khan (1993).

$$NPV = \sum \frac{Ct}{(1+r)^t} - I_c \quad [1]$$

Where,
C_t = Cash flow in year t.
t = number of the years of the investment
r = discount rate
I_c = Initial capital outlay.

NPV represents the net benefits over and above the compensation for time and risk. A project is considered viable when its NPV is positive.

Benefit cost ratio (BCR) determination

BCR means NPV per dollar of outlay. It can discriminate better between large and small investment. BCR was calculated using equation 2 developed by Dupuit in 1848 (MYSMP, 2010)

$$BCR = \frac{PVB}{Ic} \quad [2]$$

Where,
PVB = Present value of benefits.
I_c = Initial capital outlay

Internal rate of return (IRR) determination

IRR is the discount rate that makes NPV equal to zero. The

[1] GenStat for Windows is a general statistics package that offers a vast range of tried and tested high-quality statistical techniques backed up with publication quality graphics.
Numbers with the same letter are not significantly different.

Internal rate of return (IRR) is a rate of return used in

Table1. Results of fresh weight and sucrose content for the plant crop 2008

Treatment	Fresh weight (t/ha)	Sucrose content (t/ha)
Furrow	134.95[a]	66.5[a]
Drip	114.5[a]	57.75[b]
Mean	124.7	62.15
L. S. D	7.565	5.42

capital budgeting to measure and compare the profitability of investments (Main, nd). IRR was calculated using equation 3 adapted from Feibel (2003).

$$\sum \frac{Ct}{(1+r)^t} - I_c = 0 \quad [3]$$

Where C_t, t, r and I_c are as defined in equation 1 above

RESULTS AND DISCUSSION

Sugar -cane fresh weight

The results obtained in Table 1, showed that drip irrigated sugar-cane in all plots had a lower average weight of 114.5 tonnes and furrow irrigated sugar-cane had an average of 134.95 tonnes. The mean sucrose weight was higher for furrow with a value of 66.5 t/ ha than for drip system which had a value of 57.75 in 2008.

The results for the first ratoon crop followed the same trend as the plant crop. Drip irrigated sugar-cane in all plots had a lower average weight of 116.5 tonnes whilst furrow irrigated sugar-cane had an average weight of 136.2 tonnes/ha. The mean sucrose content was higher for furrow with a value of 66.7 tonnes than for drip system which had a value of 57.9 tonnes.

The results obtained showed that there was a significant difference ($p<0.05$) in mean fresh weight of sugar-cane and sucrose yield between drip and furrow irrigated sugar-cane for both years. There was a difference in fresh weight of 3.95 % and 3.9 % in 2008 and 2009 between drip and furrow irrigation systems. There was also a slight difference in sucrose content of 2.25 % and 2.2 % in 2008(drip) and 2009(furrow). In both cases drip system had the lower yield. The lower yields can be attributed to the fact that drip irrigation is still a new technology in Zimbabwe sugar-cane production, therefore, adaptation is the big problem. There was clogging of emitters, which resulted in low application efficiency and in turn disadvantaging the crop. Thus, the proper irrigation was carried out for furrow irrigated fields only and poor irrigation in drip irrigated fields, hence, the contribution to the low yields. The clogging of emitters affects the wetting pattern and amount of water applied to the crop; leading to deficit application not meeting the crop water requirement. Water deficit in sugar-cane results in less tillers, less stem elongation, as well as low sugar formation (FAO, 2013).

The findings from this study contradict those from studies conducted outside Zimbabwe. For example in a study carried out recently in Australia, they found drip irrigation to be more productive as compared to furrow irrigation. Their drip irrigation produced an extra 4.2 tons per hectare of cane on top of yield from furrow irrigation (Attard and O'Donnell, 2013). Locally, however it seems drip irrigation has so far failed to perform better under sugar-cane production. Earlier work on drip irrigation at the Zimbabwe Sugar Association Experiment Station (ZSAES) was abandoned, mainly because of emitters clogging of caused by poor water quality (Nyati, 2004).

Sugar-cane is a crop with high water demand grown in the lowveld area; which experiences very high temperatures, erratic rainfall and seasonal droughts, hence high evaporation losses. There is a possibility that these conditions may be overbearing for the low applications of drip irrigation resulting in under irrigation, stress of the plant and yield reduction (Broner, 2008). The high sucrose content from furrow irrigation may be due to a drying off period induced on the cane during the ripening period to enhance sugar formation (Reddy, 2006). In converse, Ahmednagar District, in Maharashtra where drip and furrow irrigation were compared, an increase of 27.66 in sugar-cane yield was observed in favour of drip (Waykar, 2003). Hamakua Sugar Company realized a benefit of 5700 more tones of sugar-cane on one acre in 1992 increasing their revenue by $2, 6 million per year (Toledo, 1999). Drip irrigation results in low applications of water but sufficient enough to meet the crop water requirements required for good crop stand. At the same time it gradually imposes a drought which helps retard the growth and elongation of internodes and favour sugar accumulation (Reddy, 2006). The Mahastra and Hamakua results were after a number of drip projects, since drip was a new technology for irrigators in this study. It could have been difficult to schedule their irrigation and apply the right amounts of water leading to inadequate irrigation, hence low yields. Thus, there is a possibility of improvement with more experience and training

The second harvest of 2009 shown in Table 2, resulted in a slight increase in fresh weight and sucrose content for drip irrigated plots of 2.0 tonnes and 0.15tonnes respectively. Thus, there was an increase of approximately

Table2. Results of fresh weight and sucrose content for the first ratoon crop 2009

Treatment	Fresh weight (t/ha)	Sucrose content (t/ha)
Furrow	136.2[a]	66.7[a]
Drip	116.5[b]	57.9[b]
Mean	126.35	62.3
L. S. D	7.585	5.435

Table 3.Financial Analysis results

Treatment	NPV	IRR	BCR
Furrow	13 946	26.66%	2.162
Drip	42 620	7.46%	2.52

2 % in fresh weight and 0.3 % in sucrose content. This again shows that with time, the adaptation of drip systems will improve with higher yield.

The financial results were projected for a period of five years as shown in Table 3. The results showed that the NPV was US$13 946 and US$42 620 for furrow and drip respectively and they were both positive. The NPV rule sugar- cane production under both drip and furrow systems have values greater than zero; therefore, they add value to the scheme. At any given time, there is a possible outcome that the business will realize enough cash inflows to counter cash outflows (Lin et al., 2000). Comparing the two values shows that, drip irrigation has a higher value than furrow. Hence, it is the more profitable project. As a result it would be better to invest in drip irrigation, as it will realize cash flows quicker than furrow irrigation.

The IRR for furrow irrigation was 26.66 % and it was greater than the cost of capital of 10%, whereas for drip it was 7.46% and less than 10%. Thus, the furrow irrigation project is very viable, because its expected returns far surpass the cost of capital, which is a risk, whereas it is very risky to undertake a drip irrigation project supporting sugar-cane production because the business is capital intensive (Pogue, 2004). This contradicted the study carried out by Sanchez et al. in 2009, where drip irrigation had an IRR of 15.4% higher than that of furrow of 14.5%. This can be explained by different regions. The capital costs required in one region can differ from another, which in turn will yield different values of the IRR. In this case, it is likely that the capital costs are lower in Mexico as compared to Zimbabwe. Looking at the trend in Zimbabwe and the fact that when a new technology is available the prices are considerably higher than normal, this could explain the high initial cost of drip system since it is not widely adopted in the country.

The results showed that BCR was 2.162 and 2.52 for furrow and drip systems respectively. Both values were greater than 1 which is good for both projects. Thus, the benefits are more than double the costs of the project; therefore, it's acceptable (MYSMP, 2010). In 2003, Shinde carried out a study in India and also obtained a BCR of 3.45 close to the one in this project.

According to the three financial criterion used by the research, it's viable to undertake a project in drip irrigation supporting sugar-cane production- except that the cost of capital is very high. Hence, it takes much time accruing benefits to cover the cost of capital. Attard and O'Donnell (2013), state that converting to drip irrigation can deliver significant long-term production and economic benefits. This means that in the long run drip irrigation has great potential to sustain sugar-cane production. Drip irrigation in sugar-cane has a payback period of 3 to 4 years after which the system becomes more economically viable (Waykar et al., 2003). In a study conducted by Sharmasarkar et al in Wyoming on sugar beet production, they conclude that the drip system investment cost decreased with plot size.

However, it should be noted that the three financial criterion used for the financial analysis was considered in their simplistic terms and have a number of weaknesses. The discount rates, which are composed of the risk free rates, the market rates and the project betas, and used in the NPV, BCR and IRR methods are rarely constant (Hill, 2010). This may lead to the need to use multiple discount rates combined with different economic situations which may lead to different results being observed under different experimental scenarios. Payback has the fundamental flaws of ignoring cash flows after the payback period and its disregard for the time value of money (Lumby et al., 2004). However, the financial analysis provides a basic point for evaluating the two irrigation methods.

Conclusions

There was a significant difference in the sugar-cane fresh yield and sucrose content of furrow irrigated and drip irrigated plots with the former having better results.

According to the financial analysis, both drip and furrow irrigation systems were viable projects except that drip will need more years to bring net returns.

RECOMMENDATIONS

It is recommended to implement drip irrigation as a long term project in order to fully enjoy the benefits. This will facilitate the investment to bring back returns on investment since the project is capital intensive. The yields of drip irrigation were affected by clogging of emitters, which resulted in poor water distribution and in turn affect production. Pre screening and good filtering of irrigation water is therefore recommended, so as to reduce incidences of blockages and clogging. The authors recommend continuous study of effects of emitter spacing on the yield of sugarcane to come up with the most appropriate spacing for sugar-cane under the Lowveld conditions.

ACKNOWLEDGEMENTS

The authors would like to thank the personnel from MSS for providing them with data and their commitment to the project.

REFERENCES

Anon (2000). Zimbabwe Sugar Association Experiment Station Research Report 1998- 2000. Chiredzi, Zimbabwe.

Attard S, O'Donnell D (2013). Drip irrigation on sugarcane in the Burdekin region. Queensland Government

Blatchford F (1996). Drip irrigation on farm 41, Hippo Valley Estates. In: Proceedings of the 2nd Zimbabwe Sugar Seminar. 1-10

Broner (2008). Irrigation Scheduling, Colorado State University Extension.

Cadet F, Offmann B (1997). Direct Spectroscopic Sucrose Determination of Raw Sugar Cane Juices. J. Agric. Food Chem. 45 (1): 166–171.

Directorate of Sugarcane Development (2007). Micro Irrigation in Sugarcane, Government of India, Ministry of Agriculture, Indian Institute of Sugarcane Research.

FAO (2005). Aquastat; FAO's Information System on Water and Agriculture, Zimbabwe

FAO (2013). Crop Water Information: Sugarcane. Natural Resources and Environment Department

Feibel BJ.(2003). Investment Performance Measurement. New York: Wiley. Frenken, K. (2005) Irrigation in African figures- AQUASTAT Survey-2005(PDF). Food and Agriculture Organization of the United Nations.

Ghasemi-Sahebi F, Farid E, Mehdi R, Iman P (2013). comparison of Tape Drip Irrigation and Furrow Irrigation systems on Base of Water Use Efficiency and Yield of Potato in West of Iran. Int. J.Biol.1 (5):52-62

Hill Robert A (2010). The Capital Asset Pricing Model, Ventus Publishing.

Humphreys L, Fawcett B, O'Neill C, Muirhead W (2005). Maize under Drip, Sprinkler and Furrow Irrigation. IREC Farmers' Newsletter. No. 170

Kemper WD, Trout TJ, Humphreys AS, Bullock MS (1988). "Mechanisms by which surge irrigation reduces furrow infiltration rates in a silty loam soil". Transactions of the ASAE 31 (3): 921–829.

Khan MY (1993). Theory & Problems in Financial Management. Boston: McGraw Hill Higher Education.

Kumar DS Palanisami K (2010). Impact of Drip Irrigation on Farming System: Evidence from Southern India. Agric. Econ. Res. Rev. 23(7-12) :265-272.

Lin Grier CI, Nagalingam S V (2000). CIM justification and optimisation. London: Taylor & Francis. 36.

Lumby S, Jones C (2004). Corporate Finance – Theory and practice 7th edition, Thomson

MSUES, Mississippi State University Extension Service (2007). Irrigation Systems Selection, MSUCares.

MYMSP, My Stock Market Power (2010). Benefit Cost Ratio: fundamental analysis, LLC. 16192 Coastal Highway Lewes, Delaware 19958

NABARD, National Bank for Agriculture and Rural Development (2009). Model Bankable Projects: Minor Irrigation, India

NETAFIM (2009). BIOENERGY: Sugarcane: Drip Irrigation.

Nyati CT (2004). Cane and ERC yields of ten sugarcane varieties irrigated by subsurface drip at the Zimbabwe Sugar Association Experiment Station, Proc S A, Sugar Technology Association (78): 261-262.

Pogue, M.(2004). Investment Appraisal: A New Approach. Manag. Auditing J. 19 (4):565-569.

Reddy SR (2006). Agronomy of field crops, ANGR Agricultural University, Kalyani Publishers, New Delhi, India.

Sale YC, Waykar KR, Shinde HR, Kasar DV (2003). Effect of drip irrigation on water saving, yield and profit in sugarcane in Tamilnadu, Indian Sugar 53 (4): 251-259.

Sanchez T, Vasquez P, Rivera E (2009). Evaluacion Financiera de dos sistemas de riego, goteo y gravedad en el cultivo de caÃƒÂ±a de azucar en Zapotiltic, Jalisco, Mexico, Revista Mexicana de Agronegocios

Sharmasarkar FC, Sharmasarkar S, Held LJ, Miller SD, Vance GF, Zhang R (2001). Agro economic Analyses of Drip Irrigation for Sugar beet Production, Agron J. 93:517-523.

Tagar A, Chandio FA, Mari IA, Wagan B (2012). Comparative Study of Drip and Furrow Irrigation Methods at Farmer's Field in Umarkot. World Academy of Science, Engineering and Technol. 69.

Thompson JG, Purves ED (1978). A guide to the soils to Rhodesia. Rhodesia Agric. J. Technical Handbook No. 3.

Cite this article as :Ndeketeya A, Rusere F, Svubure O, Gwatibaya S, Mashonganyika J (2014).Drip irrigation as a potential alternative to furrow irrigation in sugar-cane production-A case of the Lowveld Estate, Zimbabwe. Int. J. Agric. Policy Res. 2(1):026-032.