IRRIGATION SYSTEM EVALUATION

BAK GRIFFITHS AND NL LECLER

Zimbabwe Sugar Association Experiment Station
Private Bag 7006, Chiredzi, Zimbabwe

Abstract

Evaluation of irrigation system performance facilitates objective analysis of the typical as opposed to the potential performance of various types of irrigation systems and the respective management criteria, appropriate for local conditions. This information can also help with the selection of one system over another given local constraints. The impact that the application uniformity of a system can have on crop yield and irrigation efficiency, is further motivation to undertake system evaluations.

Rationale and summarised procedures for the evaluation of pumping plants, overhead sprinklers, sub-surface drip (SSD), centre pivot and furrow irrigation systems are presented. Results from in-field distribution evaluations of seven floppy sprinkler and 27 SSD systems are tabulated. The floppy sprinkler coefficient of uniformities (CU) range from 66-84% with the distribution uniformities (DU) ranging from 59-78%. The SSD distribution uniformity (DU) values range from 33-94%, with the statistical uniformity (SU) values ranging from 53-98%.

When all the different types of irrigation systems have been evaluated in the area, an invaluable database would have been collected. Growers will have a benchmark to measure their systems against in the future, and the repetitive nature of certain management and design variables which may be detrimental to system performance, may eventually be rendered obsolete.

Keywords: irrigation, system, evaluation, performance, uniformity, sugarcane, Zimbabwe

Introduction

In the present irrigation market there are a variety of irrigation systems accessible to the grower. The typical as opposed to the potential performance of these systems and the respective management criteria, under local conditions, can be major factors in the choice of one system over the other. Also, the fact that one grower can achieve higher sugarcane yield per unit of water used compared to another, in the same area, needs investigation.

Reasons for differences in performance could be a combination of environmental conditions, scheduling, system performance/design and management. It is with this in mind that the sugarcane industry in Zimbabwe has established a Mobile Irrigation Performance Unit (MIPU). This unit, together with *ZIMsched* (Lecler, 2000) can provide information/data to quantify and explain these performance differences. This information is extremely important if improvements are to be made to irrigation management practice and/or design, and to facilitate objective selection of appropriate irrigation systems.

An irrigation system evaluation involves taking in-field measurements and then using scientific and engineering principles to assess these measurements in the light of performance standards. The objectives of evaluating the performance of an irrigation system are listed below:

- to determine if the system is working according to grower assumptions/design specifications in terms of the amount of water applied, and to thereby provide a basis for improved irrigation scheduling,
- to determine how much variation there is in the amounts of water applied and whether or not the measured variation will have a significant impact on crop yields, deep percolation (drainage) and runoff losses, fertiliser use efficiencies and production costs,
- to determine the causes of the variation in applied water and investigate and recommend cost effective remedial action,
- to assess whether or not the conveyance system is sized within design norms that are based on a fair balance between capital and operating costs,
- to check the efficiency with which power is being used,
- to produce recommendations to improve on any aspects that will lead to more effective use of water and energy.

The information from an evaluation should help a grower reduce input costs, increase returns and, if necessary, provide motivation for a designer to implement remedial measures if a design is not up to standard.

In this paper, rationale and procedures for the evaluation of the pumping plant, overhead sprinkler, sub-surface drip (SSD), centre-pivot and furrow are summarised. Results from the evaluation of floppy sprinkler systems and SSD systems in the south east lowveld of Zimbabwe are also discussed.

Performance measurement: Uniformity

The first requirement for the efficient operation of an irrigation system is uniform water application. Pitts (2001) notes that a highly uniform water application does not ensure high efficiency since water can be uniformly under or over-applied. However, it is noted that a highly efficient system along with good crop yields requires uniform water applications.

Solomon (1998b) states that the phrase 'irrigation uniformity' refers to the variation or non-uniformity in the amounts of water applied to locations within the wetted area. Uniformity is related to crop yields through the agronomic effects of under and over-watering. Insufficient water leads to high soil moisture tension, plant stress and reduced crop yields. Excess water may reduce crop yields due to leaching of plant nutrients, an anaerobic rooting environment, increased disease or failure to stimulate growth of commercially valuable parts of the plant.

Irrigation uniformity is also linked to the efficiency with which agricultural resources are used. In the case of excess water being applied, several water related resources are lost, such as, the excess water itself, the energy used in pumping the water, fertilizers and other agro-chemicals being leached or washed away and the waste of other agricultural inputs for the anticipated high yield which does not materialise. Due to the fact that irrigation uniformity relates to crop yield and the efficient use of resources, engineers regard it as an important factor to be considered in the selection, design and management of irrigation systems (Solomon, 1998a).

The impact that uniformity can have on the yield of various crops, including sugarcane, is shown in Table 1. Although the equation used to calculate the relative yield for sugarcane in Table 1 is simplified, it still provides an overview of the general effect of irrigation uniformity on crop yields (Solomon, 1998b). The reduction in yields resulting from poor uniformities can result in a significant loss of revenue. Research using deterministic crop and irrigation simulation models, for example, *ZIMsched* (Lecler, 2000) to further refine estimates of the effects of uniformity on crop yields and irrigation efficiency is being undertaken at the Zimbabwe Sugar Association Experiment Station.

The band of uniformities which can be expected for various adequately designed and managed irrigation systems, is shown in Table 2. The American Society for Agricultural Engineers (ASAE) give criteria for acceptable statistical uniformities for drip systems and also state that the statistical uniformity should be 80 % or greater before fertilizer injection is recommended. (ASAE, EP458, 1998). Reinders (1996) states that although a slight decrease in uniformity over time with an irrigation system is expected, field data from MIPUs has shown there is no direct correlation between uniformity and the age of an irrigation system.

Methodology

Evaluations have a basic goal which is common to all irrigation systems. Measurements must be taken to ascertain the actual amount of water which is applied to the crop, as opposed to the potential. If a pressurised system is being used, the energy usage to get the water to the crop, and the effect that the hydraulics may have on water delivery must also be investigated. A summary of the evaluations for the different systems follows.

Pumping plant and conveyance

The flows from the pump and the respective outlet pressures, motor voltage and ammeter readings are recorded to determine the pump and motor efficiencies. The pump efficiency combined with the motor efficiency gives the pumping-plant efficiency. The evaluation procedure and equations used are taken after the Nebraska Performance Standards for irrigation pumping plants (University of Nebraska, 1982) and Van Niekerk (1999).

Table 1. Impact of uniformity on yield (after Reinders, 1996 and Solomon, 1998b).

Uniformity		Yield in tons/ha		Relative yield
Coefficient of uniformity CU[1](%)	Distribution uniformity DU[2](%)	Maize	Bananas	Sugarcane
95	92	-	-	1.00 (150)[a]
90	83	-	-	0.99 (148.50)
80	66	6.80	38.30	0.97 (145.50)
75	59	6.30	35.50	0.95 (142.50)
70	52	6.00	32.10	0.93 (139.50)
65	45	5.15	28.05	0.90 (135)
60	39	4.20	23.04	0.86 (129)

1- Calculated using Christiansen (1941)

2- Calculated using Burt *et al*. (1997)

a - The figures in the brackets show what effect the uniformity has on a field which starts at 150 tons of cane, and the uniformity decreases.

Table 2. Potential field uniformity values for moderately well designed and managed irrigation systems (*adapted from* Burt, 1995; Clemmens and Dedrick, 1994; English, 2000; and Solomon, 1998a).

Irrigation system	Potential field DU (%)	Potential field CU (%)
Furrow	65 - 87	78 - 91
Hand-move sprinkler	70 - 86	81 - 91
Solid-set sprinkler	73 - 86	83 - 91
Centre-pivot	78 - 90	86 - 94
Sub-surface drip	86 - 90	-

The relationships in Figure 1 show that low overall pumping plant efficiency increases power consumption and thus pumping costs, and vice versa.

New pumping plants should be tested to confirm operating specifications because, if they are not operating as expected, it is possible to make corrections or adjustments while the equipment is still under warranty. The pump installer should be held responsible for ensuring that the pump performs properly. Tests on older pumping plants should be done every few years, and a cost analysis must be made to determine the economic feasibility of repair versus continued operation with the current pump if operating efficiency is low (Longenbaugh and Duke, 1980).

Hanson *et al.* (1996) state that technology such as variable frequency drives for electric motors have the potential to adjust the pump performance to match operating conditions by reducing motor and pump RPM. However, the initial cost is high and a plant should be operated for at least 500 to 1000 hours a year to receive any benefit.

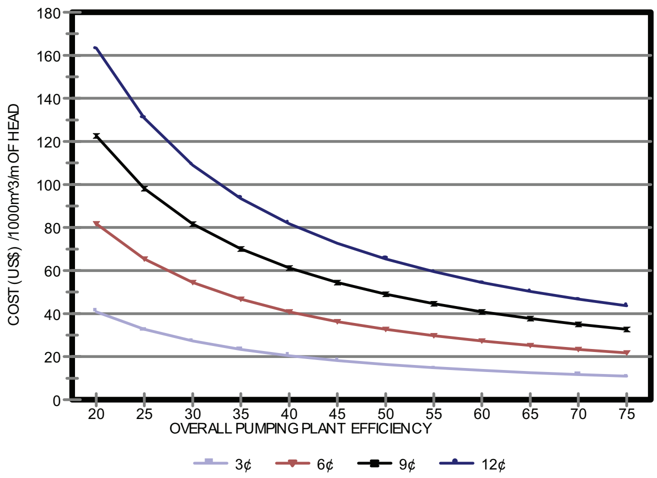

Figure 1. Variation in pumping plant performance for various electrical charge rates, ranging from 3c/kWh to 12c/kWh (currency US$), *after* Longenbaugh and Duke (1980).

With pressurised conveyance systems, losses due to friction in pipes, fittings and valves must be kept to a minimum, at the same time keeping the economics of the project in mind. Ideally a proper economic optimisation should be undertaken, comparing capital and running costs for various pipe sizes. From an evaluation perspective, pressure losses greater than 2 m per 100 m length of pipe and flow velocities outside the range of 1 to 1.5 m/s, indicate the need for further investigation and possible justification (Burt, 1995; Reinders, 1996). Pressure can also be lost due to worn pump impellers, incorrect design of the pump intake, leaking and/or blocked pipes, and faulty and/or leaking valves.

Conveyance with an un-pressurised system will be affected by the loss of water along the route taken, which is very dependent on whether or not the canals are lined or earthen. Cipolletti weirs to measure inflow and outflow along a section of earthen canal provide a practical means to quantify the drainage losses. Modified broad-crested weirs, a style of long throated flume, are the preferred method to measure flows and associated water losses in concrete lined feeder canals (Clemmens and Replogle, 1980).

Overhead sprinklers

With sprinkler irrigation the design parameters which may affect uniform water application include: incorrect spacing and/or orientation of sprinklers, mis-matched standing times, flow hydraulics and nozzle wear. Rain-gauges are positioned in a grid system in order to check the uniformity of water distribution. Pressures need to be measured at the sprinkler, together with the flow. Special measurement tools are used to quantify the wear of the nozzle, which as King *et al*.(1999) state, is extremely important. Worn nozzles will:

- increase droplet sizes,
- decrease overall system discharge pressures,
- upset the sprinkler spray patterns,
- decrease the uniformity of water application,
- increase pipe friction losses,
- change the pump operating point and efficiency, and thereby
- contribute to increased pumping costs to the grower in addition to any yield reductions.

Details of the procedures involved in evaluating sprinkler systems are explained adequately in Simpson and Reinders (1999), which use internationally recognised performance standards. Software that can be used includes Spinkmod (Allen, 2001), which can be used to check the hydraulic design of the scheme and Catch3D (Allen 2001) which can be used to calculate the uniformities due to different sprinkler layouts/spacings, wind and operating pressures.

Sub-surface drip

Pressures and flows are two important aspects in SSD irrigation which can affect uniformity adversely. Thirty reference points are chosen in the field, five emitters along each of six laterals where the emitter flow is measured. If the flow uniformity is below 80% then it is advised that pressures be taken along the lateral. The pressures either side of the delivery valve to the field are read so as to compare against design criteria.

When the pressure variations down the laterals are combined with the flow variation from emitters, these readings can be used to quantify whether emitter flow variation is due to hydraulics or emitter blockages. If emitter blockages are found to be a major problem, methods to help prevent the situation worsening further are recommended and depend on the water quality and causes of the blockages. Water samples are taken for analysis and when necessary, samples of blocked drip emitters are also collected for analysis. The causes of the blockages can include poor design leading to inadequate flushing velocities, incorrect filtration, poor water sources and pump intake arrangements, and/or inadequate or inappropriate water treatment and routine maintenance. The flushing velocities in the drip laterals are measured using an in-line flowmeter.

The evaluation procedure which is followed is based on ASAE EP 458, (1998), Burt and Styles (2000) and USDA (1997). These contain filtration specifications and water sampling and testing guidelines. Software available from the Irrigation Training and Research Center (ITRC, 2000) can also be used for the calculation of system performance parameters.

Centre-pivot

A radial line of rain-gauges is laid out along the entire length in order to determine the uniformity. Individual sprinklers are selected and flows are measured, to check against the flow required at those positions for the given system capacity. The outer-edge water application intensity is measured with an electronic rain-gauge. Time and distance measurements are used to assess the accuracy of the system controller settings. A key aspect of centre-pivot performance is the adequacy with which the application rate of the pivot is matched to the infiltration rate of the soil, taking into consideration the effect of soil capping from water droplet impact. This is measured during an evaluation using a specialised infiltrometer apparatus (ARC-ILI,1984). This apparatus can also be used to determine and check design specifications, including:

- the maximum size of pivot, for a
- given wetted bandwidth of sprinkler,
- soil type and
- peak daily crop water requirement.

The evaluation procedure used is taken after ANSI/ASAE S436.1 (1998) and USDA (1997). Software from ITRC (2000) and CpED (Heermann, 2000) can be used to check both design and uniformity.

Furrow

This type of irrigation pre-dates all the other systems in use today, but it is still the most difficult irrigation system to evaluate accurately. This is due to the multitude of factors which affect the hydraulics of furrow irrigation, such as, stream size, soil characteristics, resistance to flow, slope, furrow shape, length and intake opportunity times, and the in-field variability of all of these.

The process of evaluation itself is quite simple but readings must be accurate. The process can be very time consuming when a large number of furrows are selected in order to account for in-field variability. The representativeness of evaluation data can also be questioned when there is a large amount of variation in operator input. Therefore, a large number of evaluations are needed, often repeated on the same field during a season, in order to gain confidence in the results. Inflow is measured using a calibrated syphon and head measuring device. The rates of advance and recession are noted at specific points along the furrow and the time of cut-off is recorded. Outflow is measured with a calibrated flume. A dumpy level is used for surveying the field slopes. Evaluations are taken after FAO 45(1989) and Burt (1995). The data collected allows for the calculation of the infiltration parameters using both the 'two-point' method (Elliott and Walker, 1982) and the 'advance' technique using Infiltv5 (Durack, 2001)

These parameters can be used in simulation software, *viz*. Sirmod II (Walker, 1999) and/or SRFR (Strelkoff *et al.*, 1998) in order to calculate the corresponding uniformity and efficiency parameters. This software can be used to predict irrigation performance, for example, system uniformity and application efficiency, given certain gradients, soils, field dimensions, in-row or inter-row planting. This prediction capability may facilitate the modification of furrow irrigation operational guidelines and, if necessary, layouts/design, so that performance is comparable to more marketed irrigation systems. An area of concern, however, is the accuracy of the calculated infiltration parameters and their representativeness over the field, but with use, the procedures involved will be refined to give accurate values.

Raine ([1] personal communication), Tilley and Chapman (1999) state that the software which is currently used in Australia (Sirmod II) is used mostly for showing growers the benefits of management practices and has been very effective in this regard.

Results

Floppy sprinkler

Seven evaluations at four floppy sprinkler schemes were carried out, readings were taken to represent the best and worst hydraulic cases. All tests were carried out in the early morning under low wind conditions. The sprinkler spacings used on all systems was 12 by 14 m. Results from the analysis for floppy sprinkler systems are shown in Table 3.

Sub-surface drip

Twenty-seven evaluations were carried out at nine SSD schemes. Where possible, in-field measurements were made on the fields closest and furthest from the pump. There are two different designs prominent in the area. System A has the

[1] Raine, S R, (2001). Principal Scientist. National Centre for Engineering in Agriculture. University of Southern Queensland, Toowoomba, Qld 4350, Australia. E-Mail: raine@usq.edu[1]

Table 3. Results from floppy sprinkler evaluations.

Field	Average application rate in test block (mm/h) [b]	Average pressure in floppy sprinkler test block (kPa)	Distribution uniformity (DU,%)	Coefficient of uniformity (CU,%)
1	3.3	208	59	66
2	4.1	215	57	73
3	3.5	276	65	76
4	3.5	281	61	72
5	3.6	286	66	70
6	3.8	286	68	76
7	- [c]	333	78	84
Mean	**3.6**	**269**	**65**	**74**

b - Design specified application rate is 4.2 mm/h for 12 by 14 m spacing at a pressure between 200 to 400 kPa.

c - Discrepancy in time interval noted, needs to be re-evaluated.

submain feeding the laterals from one side with the flushing manifold separate, and System B is where the submains also serve as the flushing manifolds, with the laterals being supplied from both ends. The results of evaluations, differentiated according to the type of design are shown in Table 4 and Table 5 respectively.

Discussion

Floppy sprinkler

The variation in a typical water application, represented by the evaluation event, can be shown graphically to the grower as shown in Figure 2. Such diagrams are useful to growers and evaluators as they help with the visualisation of the uniformity results.

Results from the analysis for floppy sprinkler systems have highlighted:

- a definite correlation between pressure and uniformity, thus the need to find the optimum operating pressure and spacing,
- the need for correct filter specifications to be adhered to,
- that well designed and installed floppy system performs well (DU, 78% ; CU, 84%),
- possible advantages of being able to create a cooler more humid microclimate. According to some experts this is an important issue, and contributes to higher application efficiencies (USDA, 1983). The cooling effect could facilitate enhanced growth when surrounding ambient temperatures are above the upper threshold for optimum cane growth,
- Coefficient of uniformities (CU) generally ranging from 66-84%, Distribution uniformities (DU) ranging from 59-78% (>80% for CU and >70% for DU is considered good).

Sub-surface drip

With drip irrigation it is suggested that the grower is also presented with a graph. This will be very representative of irrigation events due to the repetitive nature of non-uniformity in SSD and the decreased impact of environmental factors on uniformity. Graphs show the amount of water the field is being given, and can be referenced, with the use of *ZIMsched* (Lecler, 2000), to the amount of water the sugarcane crop needs. Graphs also help growers to gain a visual understanding of what is happening to the water distribution in-field. Together with the graph, recommendations to improve the water distribution are supplied. The uniformities should, however, still be calculated by the evaluator, as these values can be used for benchmarking this type of irrigation system under the local management and environmental conditions.

An example of a graph which can be used to visually explain the impact of uniformity and application variation is shown in Figure 3. This graph is for a single evaluated field. The lower graph represents the measured application rate (MAR) as opposed to the specified design application rate (DAR). The more level the MAR line is, the more uniform the water distribution within the field. Where the MAR line crosses the DAR line, this value is taken away from 100% and will give the percent of the field which receives the required amount of water.

Table 4. System A: Results from sub-surface drip evaluations (submain feeds laterals from one side, flushing manifold is separate).

Field	Age of system (years)	Measured application rate (mm/h)	Design application rate (mm/h)	Distribution uniformity (%)	Statistical uniformity[3] (%)	Absolute error between measured and design submain pressures (kPa)	Flushing velocity (m/s) [d]
1	<1	2.03	1.89	93	95	25	-
2	<1	2.47	1.89	91	93	5	-
3	<1	2.31	1.89	94	97	-	-
4	<1	2.35	1.89	94	98	-	-
5	<1	2.26	2.26	94	97	-	-
6	<1	2.39	1.89	94	97	-	-
7	2	2.65	2.33	91	93	28	0.38
8	2	1.96	1.94	87	90	12	0.46
9	2	1.89	1.89	88	89	10	0.25
10	2	1.96	1.94	89	92	15	0.24
11	3	1.66	1.83	81	83	11	0.23
12	3	1.73	1.83	80	80	11	0.36
13	5	1.29	1.44	71	76	16	0.41[e]
14	5	1.55	1.44	50	64	69	0.48[e]
Mean	**-**	**-**	**-**	**86**	**89**	**19.9**	**0.35**

3 - Calculated using ASAE EP458 (1998)

d - Recommended flushing velocity, 0.3 - 0.5 m/s

e - Flushing manifolds recently redesigned

From the example it can be seen that 23% of the field shown realises the specified design application rate.

The upper graph, however, is the one that the grower will be most interested in. This shows how well a four hour daily irrigation time replenishes average peak daily crop water requirements. The average peak daily crop water requirement is based on evidence from research trials that supports the use of a full canopy pan factor of 0.85 and >25 years of weather data that gives an average daily summer A-Pan value of 7 mm (Lecler, 2000).

If the 10% variation in flow rule is then allowed with regard to the tolerated deviation in design application, the area receiving

Table 5. System B: Results from sub-surface drip evaluations, (Submains also serve as flushing manifolds, as laterals are fed from both ends).

Field	Age of system (years)	Measured application rate (mm/h)	Design application rate (mm/h)	Distribution uniformity (%)	Statistical uniformity (%)	Absolute error between measured and design submain pressures (kPa)		Flushing velocity (m/s)	
						Submain		Submain	
						A	B	A	B
1	3	2.38	2.60	33	53	39	56	0.26	0.39
2	3	2.41	2.60	71	76	17	31	0.28	0.60
3	3	-	-	-	-	35	38	0.35	0.13
4	3	-	-	-	-	22	24	0.40	0.25
5	3	-	-	-	-	55	64	0.45	0.24
6	4	1.28	1.17	92	91	19	15	0.20	0.27
7[f]	4	1.00	1.22	75	79	43	37	0.09	0.16
8[f]	4	-	-	-	-	37	31	0.15	0.23
9	4	2.49	2.38	82	86	24	22	0.16	0.18
10	4	2.50	2.38	67	71	28	14	-	-
11	4	2.34	2.33	75	75	16	15	-	-
12[f]	4	1.69	2.07	79	83	13	22	-	-
13[f]	4	1.72	2.27	80	78	21	34	-	-
Mean	**-**	**-**	**-**	**73**	**77**	**28**	**31**	**0.26**	**0.27**

f - Modification to the original SSD design has been performed by the farmer.

adequate water, for a four hour irrigation, increases to 78%. A good benchmark irrigation time for the system shown, for the months of October-January, for a full canopy crop is therefore 4 - 4.5 hours/day.

This concept can be applied on a weekly or monthly basis for each field that is evaluated. The grower can then visually note, from the graphed data, how the SSD within a field has performed.

Results from the analysis of drip systems have shown:

- relatively good yields under appropriate management and operation

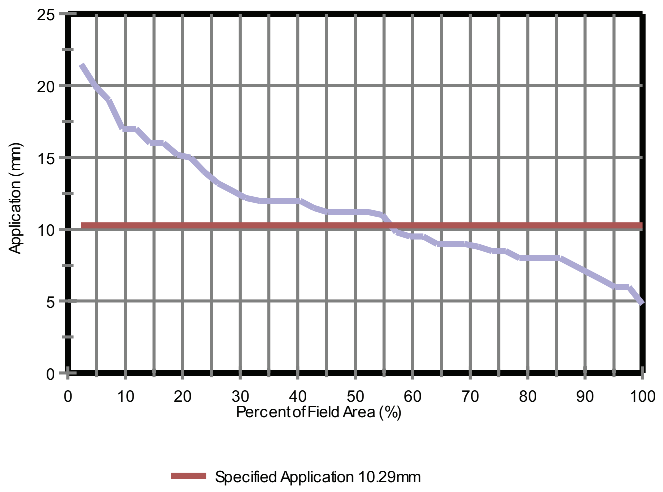

Figure 2. Graph to show in-field variation of the water application under floppy sprinkler.

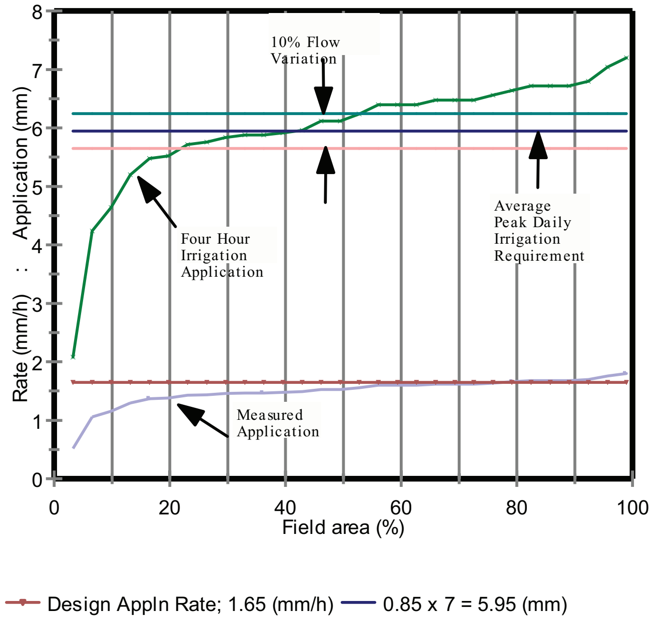

Figure 3. Graph to show in-field variation of water application for a four hour irrigation event with SSD irrigation.

- all newly installed systems have a statistical uniformity (SU) above the recommended 90% value
- uniformity does decrease with the age of the system, notably when preventative maintenance was not practised
- that there was a difference in the performance parameters, dependent on which of the two different design approaches was used
- inadequate water quality diagnosis and incorporation of appropriate remedial measures at the design and pre-implementation phase, especially with regard to oxidation and settlement of iron
- non-existent chemical compatibility tests, such as the simple 'jar test', before certain types of chemigation are practised
- inadequate chemigation injection designs, resulting in poor distribution of fertilizer during injection
- inadequate flow velocities during flushing, resulting in accelerated system deterioration
- incorrect management due to missing or non-existent operational guidelines, leading to abnormal pressures during operation, which in turn lead to lower or higher than expected application rates and premature emitter clogging
- the need for specialised personnel to carry out adjustments to original SSD designs
- generally distribution uniformity (DU) values ranging from 33-94%, and statistical uniformity (SU) values ranging from 53-98% (>80% for these parameters is considered good).

Recommendations

Floppy sprinkler

Despite the flow control mechanism, it is apparent from the results shown in Table 2 that there is a correlation between the pressure at the floppy sprinkler, and the DU. The MIPU recommends that the design operating pressure for any new floppy system, be at least 250 kPa at a 12 x 14 m triangular spacing, as compared to 200 kPa that was previously considered adequate by Hiemstra (1998). Adjustments to existing systems would include installing correctly sized 500 micron filters, which in typical circumstances would have the effect of slightly increasing the average operating pressures as they require less frequent cleaning than the 140 micron filters that were typically installed, and which were causing excessive pressure losses due to infrequent cleaning. The economics of increasing pipe sizes and/or pumpsets/impellers to increase the uniformity needs to be further investigated on a case-by-case basis. More research on the effects of uniformity on sugarcane yields for given environments, including soils, needs to be undertaken in order to facilitate the economic analyses.

Sub-surface drip

An intensive management approach is needed for SSD. This should include an extensive pressure and flow monitoring programme and regular maintenance of the equipment. Some systems have been found to be lacking an accurate system pressure gauge. Thus valves at the fields have not been set correctly, which impacts on the uniformity of the flow down the laterals and the irrigation application amounts. Certain pressure regulator valves have small filters, some of which had not been cleaned for many years, with the result that the valves had not been functioning properly.

Because water quality varies throughout the year, the MIPU has also recommended that growers submit water quality samples every month, so remedial action can be taken if necessary. Chlorination and acidification have been recommended as remedial and/or preventative, measures. The simple 'jar test', which entails checking for undesired precipitants in a small water sample before committing to treating the whole system has been invaluable. For example, a farmer was planning to use a certain grade of phosphoric acid that he had in stock but this was shown to be unsuitable when combined with his water, after the jar test revealed undesirable precipitants.

Some growers have had the system flushing manifolds redesigned, to concur with design standards. Where it is found that the initial design was not up to standard, the designer is expected to institute remedial measures.

Of the two different designs used in this area, System A, which keeps the supply submain and the flushing submain separate, gave a better overall evaluation result than System B. This could be due to a number of reasons, *viz*.

- the complexity of the design for System B is such that the submain must also serve as the flushing manifold. Therefore, either the submain will be over-designed, and thus impact on the economics and application rate of the system, or the design flushing velocities will not be attainable, which will lead to premature system deterioration due to emitter clogging
- the operation of this type of drip system requires more intensive management, which was not realised from the implementation phase
- the average age of this system type is older than System A, consequently factors which would have compounded system deterioration have been allowed to accumulate for a longer period.

Conclusions

Although the MIP Unit is still in the process of development, its use in quantifying the performance of current irrigation systems used in the Zimbabwean sugarcane industry, is of great value. This is true for both the grower and system designer, as the grower can be assured of a system which is performing to what was expected, and the designer knows, quantitatively, that a competent system was supplied.

When all the different types of irrigation systems have been evaluated in the area, an invaluable database would have been collected. Growers will have a benchmark to measure their systems against in the future, and the repetitive nature of certain management and design variables which may be detrimental to system performance under local conditions, can eventually be rendered obsolete.

In addition, the typical uniformities associated with the different types of irrigation systems can be used to provide a crucial input to methodologies for determining potential irrigation efficiencies, and help facilitate objective decisions regarding the selection of systems to suit particular environments.

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