Sugarcane drip irrigation in saline and sodic soils under problematic water conditions

Yoram Krontal, senior sugarcane agronomist, Agronomy unit
Yann Hardy and Didier Martin, TPC Ltd, Tanzania

Abstract

Salt accumulation in irrigated soils can severely impair yields, irrigation efficacy and soil structure. Many farms are limited in expanding their growing area due to marginal soils, which raises the need to adapt irrigation methods for saline/sodic soils. The demonstrative case study of an estate called TPC Ltd is presented below.

TPC Ltd. is situated in a semi-arid region of Northern Tanzania with saline/sodic soils on about 3000 ha, which represent a third of the estate. The irrigation water quality is highly variable in terms of salinity and sodicity, depending on the source and season. Previous work suggested that soil reclamation was possible with overhead sprinklers, while reclamation with furrow irrigation proved unsuccessful. The consideration of subsurface drip irrigation is described below.

The trial consisted of five treatments: a) pre-planting overhead soil flushing, drip irrigation 1 l/h; b) pre-planting gypsum application and overhead soil flushing, drip irrigation 1 l/h; c) no pre-planting treatment, drip irrigation 1 l/h; d) pre-planting overhead soil flushing, drip irrigation 0.6 l/h; e) no pre-planting treatment, standard furrow irrigation (control). The trial was designed as a field observation of 1 ha per treatment with no replicates. Yield, soil chemical properties and dripper performance were analyzed for three years after planting.

Drip irrigated treatments maintained an average yield of 167 tons/ha for the three years, with no differences between the reclamation treatments, while furrow irrigated yields dropped from 140 t/ha in planted cane, to 86 tons/ha for the first ratoon and 66 tons/ha for the second ratoon.

Overhead flushing before planting was most effective at maintaining EC and SAR values within threshold values (EC 100-200 mS/m, SAR 5–10) throughout the trial. Low flow drippers (0.6 l/hr) were less effective at flushing salts. No drop of EC and SAR was noted in subsequent years under drip irrigation.

During the first year, some of the drippers - mainly low flow - showed sedimentation of organic matter and bicarbonate. Filtration method was replaced and recommendations for system maintenance were established. However, bicarbonates remain problematic due to low water quality. Injection of acid is recommended to dissolve precipitates.

Drip irrigation facilitated optimal cane growth though salts were not flushed from the soil. The efficacy of drip irrigation results from a high irrigation frequency, maintaining high soil moisture and matrix potential near optimal conditions, thus reducing water potential. For future application of drip irrigation in saline/sodic conditions it is recommended to use 1-2 l/h drippers and keep high soil moisture levels

Introduction

The accumulation of excessive salt in irrigated soils can reduce yields, irrigation efficacy and soil structure (Horneck et al., 2007). When soil salt concentration increases, cane growth is reduced, and the effect on yield is relative to the soil threshold level; the threshold level for sugarcane is between 1.7 and 2.0 dS/m (Copland et al., 2011). The expansion of agriculture to marginal soils, as in the case of sugarcane, raises the need to adapt appropriate irrigation methods for saline/sodic soils.

TPC Ltd. is situated in a semi-arid region of Northern Tanzania with saline/sodic soils on about 3000 ha, which represent a third of the estate. The irrigation water quality is highly variable in terms of salinity and sodicity, depending on the source and season.

Irrigation on TPC is mainly conducted through sprinkler and furrow irrigation and some drip irrigation in the non-saline soils. Previous work suggested that soil reclamation was possible with overhead sprinklers, while reclamation with furrow irrigation proved unsuccessful. (Noel, 2009, unpublished data).

Drip irrigation is considered an effective irrigation system that removes salts from the active root zone in trees (Burt & Isbell, 2005; Hanson et al, 2010). This is effective mainly due to a high irrigation frequency, keeping a high moisture level and reducing osmotic potential.

Previous work done in Swaziland by Nixon & Workman (1987) tested the impact of soil leaching in Sugarcane, by placing the drip line on the soil surface every inter-row or alternate inter-row; a good response was found only when the dripline was placed every inter-row.

However, since in sugarcane the drip line is installed subsurface at approximately 20cm depth, salts move not only downwards but also towards the soil surface.

Following is a field observational trial that evaluated growing sugarcane in saline/sodic soil using subsurface drip irrigation.

Objective

The following objective was set: Evaluate performance of drip irrigation in saline/sodic soils and poor water conditions:

- Is soil flushing prior to planting required when using sub-surface drip irrigation?
- Chemigation through drip system as a means of White Grub control
- The implications of managing drip irrigation

Materials and methods

Location: The field observational trial took place on TPC Estate, which is located near the town of Moshi in north Tanzania.

Climate: The region is characterized as semi-arid, with a yearly rainfall of 400-700mm and ET ~1500mm. The local climatic conditions are presented in the table below:

Table 1: Farm climate conditions (TPC met. Station, Sept. 1974 - Aug 2002)

	Min Temp	Max Temp	Humidity	Wind	Rad	ET_o	Rain
Month	°C	°C	%	km/day	MJ/m²/day	mm/day	mm
January	17.6	33.0	68	199	17.4	4.7	42
February	17.8	33.3	65	199	18.9	5.1	46
March	18.6	32.3	52	178	17.4	5.1	113
April	19.1	29.6	81	156	16.3	3.7	318
May	18.4	26.8	86	111	13.4	2.8	141
June	16.7	26.0	82	111	13.9	2.8	29
July	15.7	25.6	75	133	13.4	2.9	22
August	15.5	26.6	71	156	15.7	3.5	14
September	15.7	28.7	66	200	17.3	4.3	15
October	16.8	30.8	61	245	18.5	5.1	37
November	17.6	31.9	62	289	17.1	5.3	81
December	17.6	32.0	69	222	16.0	4.5	58
Total					195.3		916

Soil: the site soil is classified as saline/sodic loamy sand; Soil chemical properties are described in Table 2. The soil analysis shows that salinity was not a major threat, the soil had low Ca and Mg and high Na levels.

Table 2: Soil chemical properties taken from the trial location prior to initiation

Depth	pH	EC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	SAR
(cm)	1:2.5	(mS/m)	(me/l)			(me/ 100g)	
0 - 30	8.3	64.3	0.69	0.01	4.4	4.0	8.3
30 - 60	8.7	73.0	0.23	0.01	6.0	2.4	17.3
60 - 90	8.7	66.6	0.18	0.01	5.6	2.6	18.6

The threshold values are described in the table below:

Table 3: Desirable values.

Element	pH	ECe	Ca^{2+}	Mg^{2+}	^{+}Na	^{+}K	SAR
Unit	(1:2.5)	(mS/m)		(me/l)		(me/ 100g)	
from	7	100	2	1	2.5	1.5	4
to	9	200	4	2	5	5	8

Irrigation water source: the southern part of the estate is based on 2 water sources: the old intake (high-quality source) and the Kikuletwa River (low-quality). As the year progresses, the flow in the old intake decreases and water is added from the new intake at the Kikuletwa River in the south (saline water) and mixed in to make up for any missing volume to irrigate the furrow irrigated area in the southern part of the farm.

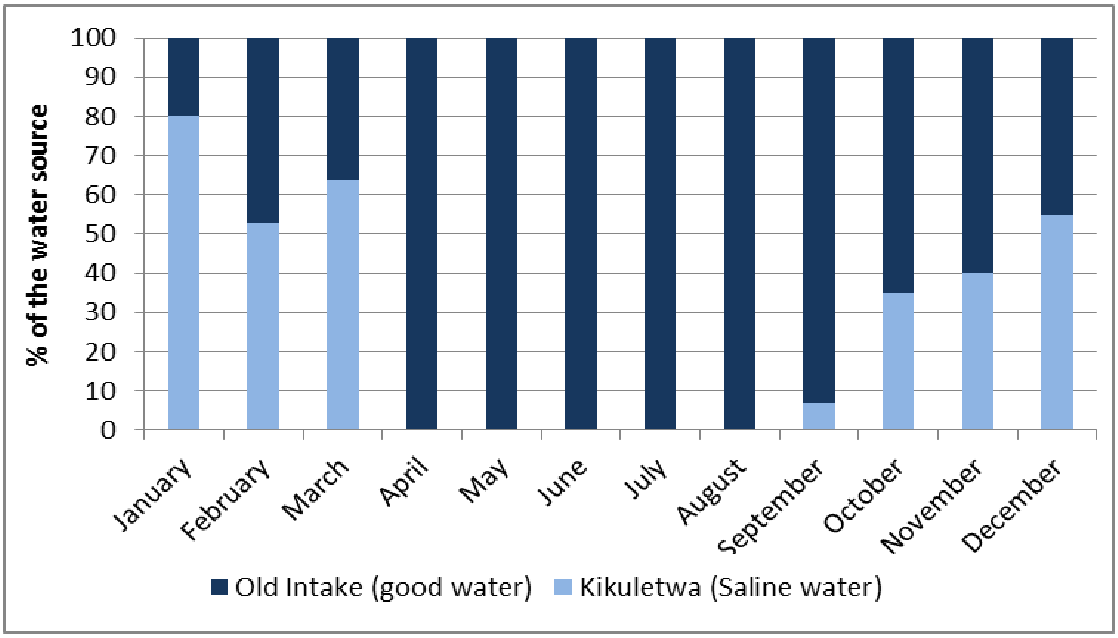


Figure 1: Water source mixture along the year

The chemical properties of the different water sources is shown in the table below

Table 4: Irrigation water chemical properties

Source	Type	pH	Ec	Ca_2^+	Mg_2^+	Na^+	K^+	CO_3^{2-}	HCO_3^-	SAR
		water	mS/m	me/l						
New Intake	River	7.8	20	0.5	0.4	0.9	0	0	2.4	1.3
Kikuletwa	River	8.4	134	1.5	3.8	8.3	0.5	0	12.2	5.1

Trial design: the field trial is designed as a field observation at a size of 1 ha per treatment with no replicates

Table 5: Trial treatments

	Treatments		Plot size
	Irrigation system	Prior to planting	(ha)
1	Furrow	Not flushed	1
2	DripNet PC 16150; 1.0 l/hr @ 0.3m	Not flushed 6 mm/day	1
3	DripNet PC 16150; 1.0 l/hr @ 0.3m	Not flushed	1
4	DripNet PC 16150; 1.0 l/hr @ 0.3m	Flushed	1
5	DripNet PC 16150; 0.6 l/hr @ 0.4m	Not flushed	1.6

Soil Reclamation and flushing: The flushing system was designed as a mobile MegaNet, 550 l/hr sprinkler system that uses the drip irrigation system by connecting to a bypass from the main line. After flushing, the sprinkler system is removed and the drip irrigation goes into operation. Should soil salinity and sodicity levels require repeating the flushing treatment, the sprinkler system can be reinstalled and activated. The system can be removed after flushing and installed in a different area; In this manner, one system can cover a significant area, following the harvesting and planting pattern.

Figure 2: Sprinkler flushing system

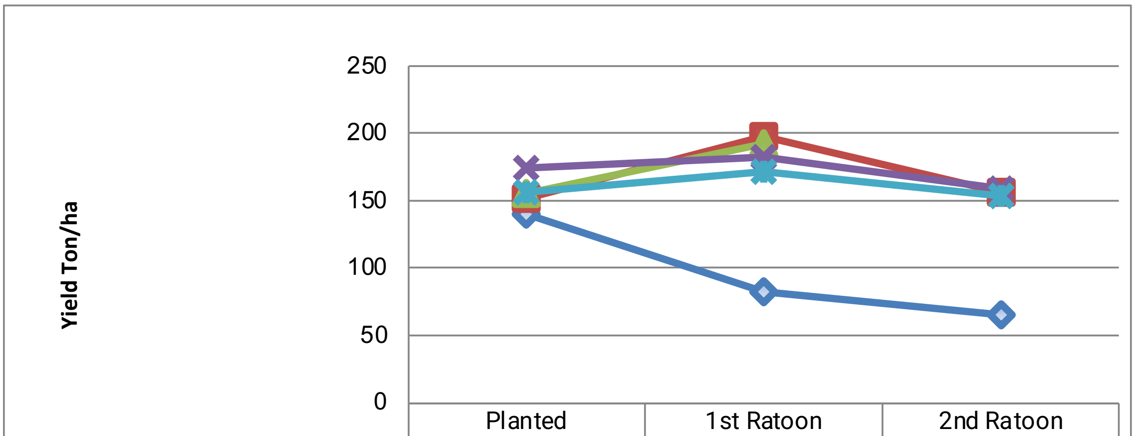
The crop: in March 2011, the cane variety N 25 was planted in a dual row configuration of 40cm x 140 cm. The drip line was placed in the center of the dual row 20 cm below the surface. The furrow treatment was planted at single row configuration of 150cm.

Irrigation was applied on a daily basis of 4mm/day and in the event of rain greater than 10mm, irrigation was suspended for 4 days. Nitrogen (fertigation) was applied through the drip system once a month till the 5th month.

Results

During the trial different aspects were analyzed: yield, soil reclamation, white grub control and dripper performance.

Yield: the first harvest took place when the cane was 10 months old. From the second year on, the cane was harvested at 12 months. At the 3rd harvest during loading, heavy rains caused a pause in the loading and the cane from treatments 3 was eliminated.



	Planted	1st Ratoon	2nd Ratoon
Furrow	140	83	66
Drip 1L - 6 mm/day	151	197	157
Drip 1L	155	193	
Drip 1L Flushing	174	183	159
Drip 0.6L	156	171	154

Figure 3: harvest results for 3 years

Furrow yield sums at 288 ton/ha (96 ton/average), while drip irrigation yield sums at 502 ton/ha (167/average), a 74% yield increase with drip. Among the drip treatments the differences are minor as compared to furrow irrigation. While the drip treatment maintained high yield during the 3 years, furrow irrigation yields dropped at a rate of 40%/year to a level where the crop needed to be renovated.

Effect on soil salinity: Higher levels of salinity were found in the low flow dripper, 0.6 l/hr. As the crop progressed the furrow irrigation showed increasing levels of salinity. The flushing treatment shows high levels for about 1 year and then a decrease, drip without flushing showed the lowest levels.

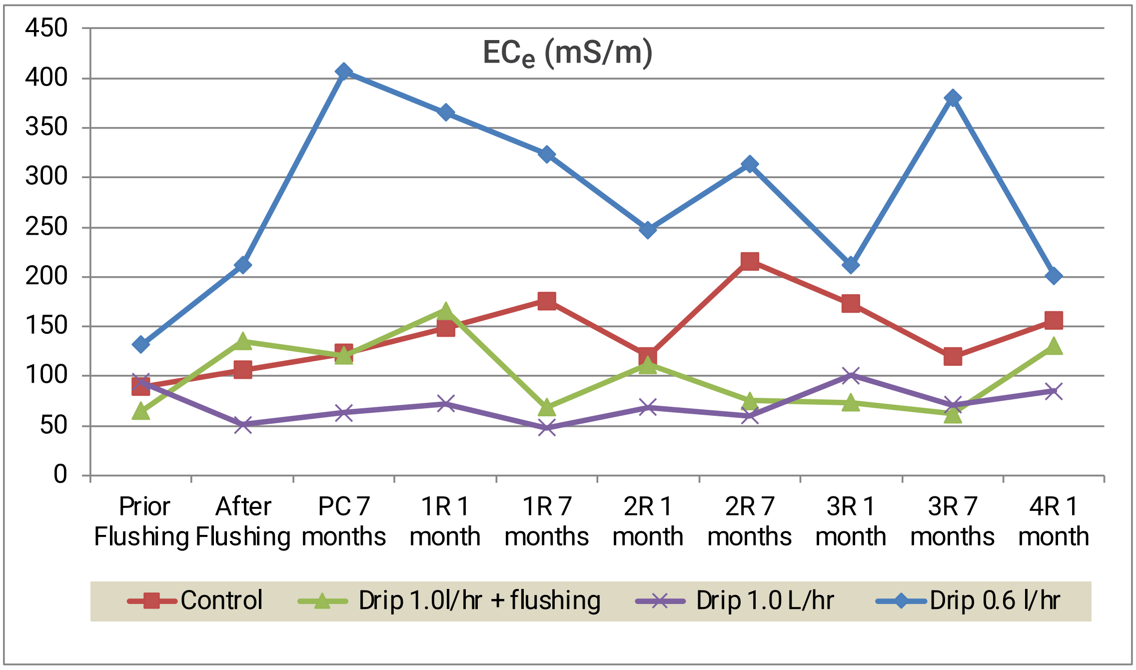


Fig 4: Soil solution electric conductivity in the various treatments

In the flushing treatment, SAR and EC are high during the first year due to release of cations into the soil solution, while in the furrow irrigation treatment SAR increases as the crop progresses. Better values found in the drip treatment without flushing.

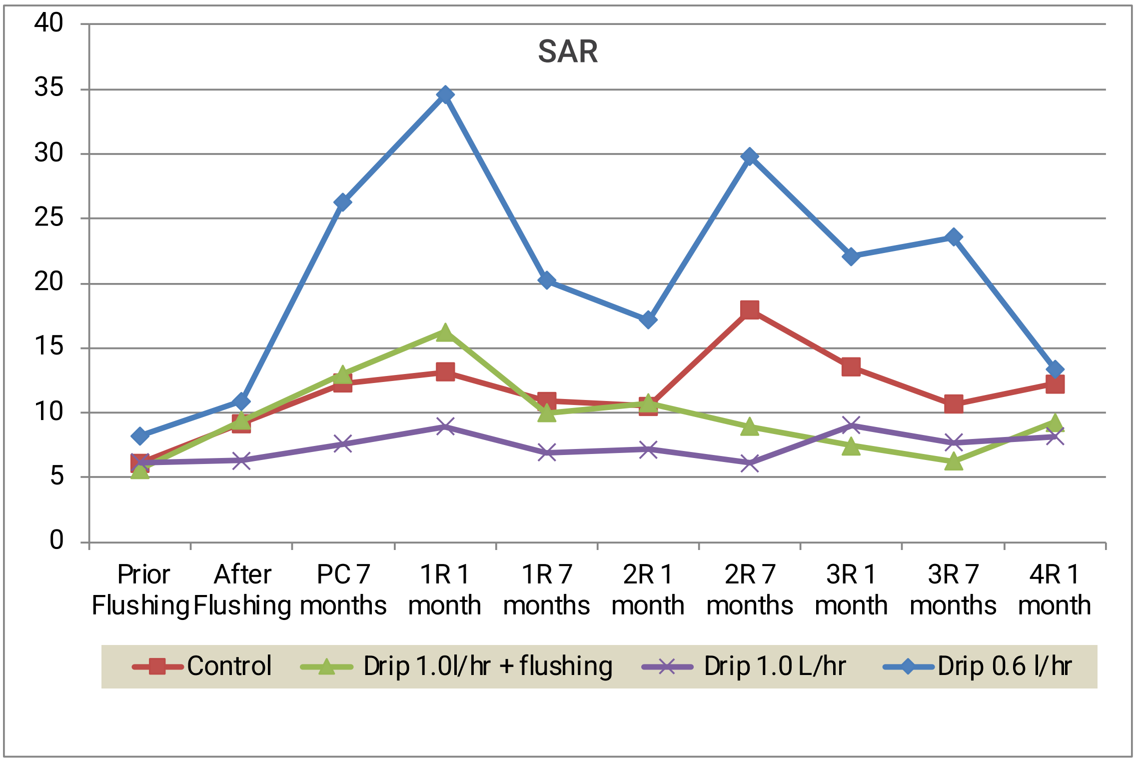


Figure 5: soil solution SAR in the various treatments

Although the soil analysis was aimed for salinity (soil solution) and not for soil fertility, the K levels under drip were lower by 0.3 meq/l compared to furrow, probably due to higher yields; fertilization recommendations for drip should be updated.

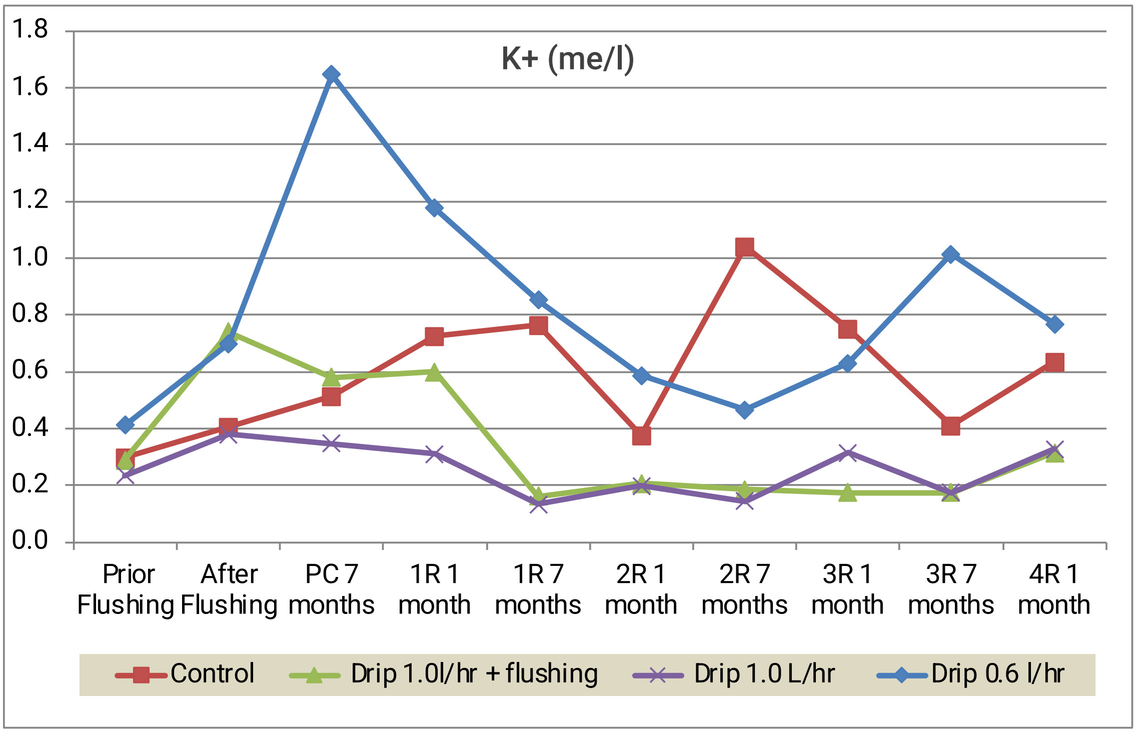


Fig. 6: soil solution K levels in the various treatments

System performance: towards the end of the first year, the system showed some serious performance problems: around 30 – 40% of the drippers showed sedimentation of organic matter and bicarbonate. As a result, significant flow reduction occurred and segments of cane began drying out. Dripper samples were taken to a laboratory where it was found that the sediment was composed of 65% mineral matter and 35% organic matter.

Fig.7: Segments of cane drying out due to drip clogging at the end of the first year

Fig. 8: Uniform cane development at 1st ratoon after system restoration, flow rates back to normal

As a result of the system's poor functioning, several steps were taken:

- The filtration system was replaced with a gravel filter instead of the simple screen filter that had been in use.
- Clogged segments of drip lines were replaced shortly after harvest.
- New recommendations for system maintenance were established, including flushing, peroxide, acid and pendemetelin injections, and performance monitoring.

Within a few months the problem was overcome. The system with the 1 l/h drippers is performing and the flow rate is back to normal values; with the 0.6 l/h the flow rate was recovered but is still at 85% of the normal rate, but the field and plant development are uniform.

Table 6: drip performance analysis prior and after treatments

Treat-ment	Dripper flow	1st Year		2nd Year		3rd Year	
	l/hr	Clogging rate	%	Clogging rate	%	Clogging rate	%
T2	1	0/4	0.00	0/12	0.00	4/16	0.25
T3	1	5/7	0.71	2/12	0.17	5/15	0.33
T4	1	0/6	0.00	1/12	0.08	0/16	0.00
T5	0.6	2/3	0.67	19/25	0.76	11/23	0.48

White grub control: toward the beginning of the fourth year, White Grub (cochliotis melolonthoides) infestation was observed. The grubs feed on the roots of the sugarcane plant, reducing growth and crop yield.

As the pest infected all the treatments, it was decided to treat the whole trial. For grub control 4l/ha ATTAKAN (SC Imidacloprid 350) was injected via the drip system.

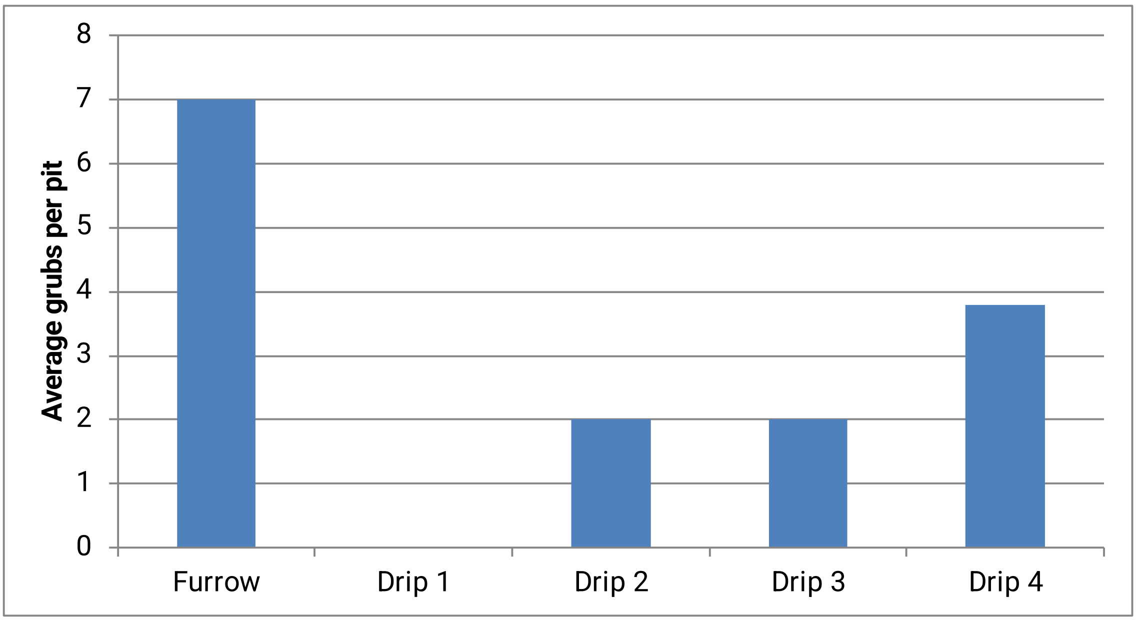


Fig. 9: White Grub levels at the various treatments after application

Grub counts showed that Attakan injection (liquid Imidachloprid) had a beneficial impact, with a dramatic drop in grub counts. It was concluded that injection of Imidacloprid for control of white grub should be done as a preventive measure soon after harvest.

Discussion

Subsurface drip in saline soil:

The soil Water Potential (ψt) is the sum of two potentials

$\Psi t = \Psi h + \Psi o$

ψo - The osmotic potential, and ψh = hydraulic potential.

While the hydraulic potential is the sum of pressure gravitation potentials: $\Psi h = \Psi p + \Psi g$

the osmotic potential is constant, results from the salts in the soil solution, and was apparently low, as shown by the soil analysis values. Applied daily, Drip irrigation kept the hydraulic potential high thus increasing plant water potential, and reducing the effect of the osmotic potential, so that the overall of both potentials stayed high in the SDI treatments thus allowing optimized water uptake and subsequently improved growth.

How to ensure high yields using subsurface drip in saline/sodic soil:

- Drip does not flush the soil, it keeps a small bulb with optimal conditions (high hydraulic potential)
- Irrigation must be applied daily to keep the high hydraulic potential
- In case of rain, up to 15mm irrigation should be applied to avoid backwashing of salts from surface into the root zone
- In the case of TPC, yearly rainfall of 500mm is sufficient to flush the soil
- In case of less rainfall, the flushing system should be applied when salinity increases

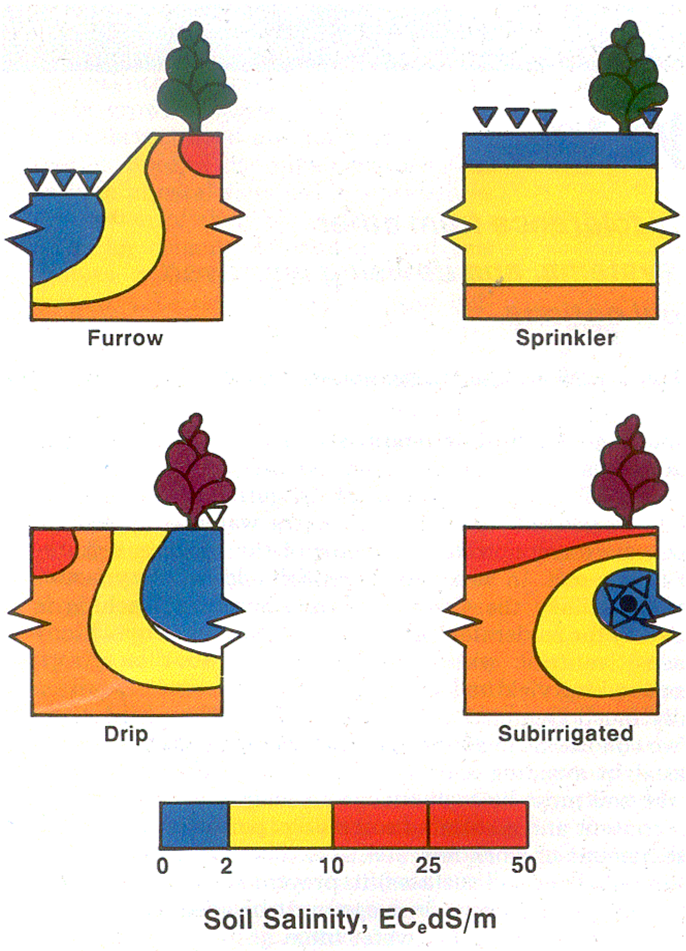


Fig. 10: Effect of soil salt flushing by different irrigation methods

The trial showed again the beneficial use of subsurface drip as a delivery system (besides water and fertilizers for: pest & diseases such as: White Grub, nematodes, borers, aphids.

Use for mill effluent or vinasse, and a vast variety of other products (under development), mycorrhizza.

Acknowledgments:

Jean Robert Lincoln – ALTEO Group Mauritius

Pierre Noel – TPC Estate

Sylvester Assenga – TPC Estate

Adaia Shiboleth – Netafim

References

Burt, C.M., Isbell, B. (2005). Leaching of Accumulated Soil Salinity under Drip Irrigation. Am Soc Agric Eng 48(6): 2115 – 2121.

Copland, M., Mayer, J. (2011). Good Management Practices Manual for the Cane Sugar Industry, PGBI Sugar and Bio Energy 271 – 310.

Hanson, B.R., May, D.M., Hopmans, J.W., and Simunek, J. (2010). Drip Irrigation as a Sustainable Practice under Saline Shallow Ground Water Conditions. 19th World Congress Soil Sci. Published on DVD.

Horneck, D.A., Ellsworth, J.W., Hopkins, B.G., Sullivan, D.M, and Stevens, R.G. (2007). Managing Salt- Affected Soils for Crop Production. PNW Extension Publication 601-E: 1-20.

Nixon, D.J. and Workman, M. (1987). Drip Irrigation of Sugarcane on a Poorly Draining Saline/Sodic Soil. Proc S Afr Sug Techno Assoc: 140 – 145.

Noel, P. (2009). TPC Salinity Reclamation Trial – Unpublished Data. (2009)