SUGAR CANE IRRIGATION: A REVIEW

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ABSTRACT

Irrigation technology and water management are progressing in the Proserpine, Mackay and Burdekin areas of Australia. Water application represents 15% of the cost of cane production. Thus farmers are trying new equipment including the drip tape, the linear move and the centre pivot together with new irrigation scheduling tools. Measures have been taken to reduce significantly potential pollution hazard from surface run-off or irrigation tail water.

Drip irrigation is gradually gaining ground in many cane producing countries. The high initial capital outlay coupled with rigorous management restrict further expansion of this system. Some studies are addressing the movement of water as well as root activity under drip irrigation.

The major breakthrough for the overhead method is the centre pivot (or linear move) equipment. The lower investment cost and the less stringent management make this equipment more farmer-friendly. However, the application of chemicals including nutrients remains an unclear aspect of the equipment.

Surface irrigation is improved through the surge flow technique or the use of lay-flat tubes with adjustable outlets. Inspite of this, its water application efficiency remains low.

Crop growth models and the introduction of new moisture monitoring equipment are contributing to increased water use efficiency. However, there are quite a number of issues that have been identified and which need the attention of equipment manufacturers as well as irrigation research scientists.

Keywords: Drip irrigation, centre pivot, australia, water use efficiency, sugar cane.

INTRODUCTION

This paper is a report on the irrigation workshop which took place in Australia. It consisted of field visits and technical sessions. The irrigation experience in Australia was shared through a two-days visit to farmers, project areas and the research station in the regions of Proserpine, Mackay and Burdekin. In those three districts rainfall varies to a large extent and most of the cane land needs supplementary irrigation. The heavy downpours occur during the summer period and effective rainfall is often at 50% of the total amount. In these districts, particularly in the Burdekin area (30%) sodicity is a problem apart from duplex soils and poorly drained areas. In order to improve water use efficiency and to protect the environment from off-farm pollution (viz. The Great Barrier Reef), an increasing number of farmers are introducing ring tanks or dams to collect tail water and surface run off during rainfall events.

The Australian cane farming system could be referred to as the “gentleman farmer” type. The farmer and his family participate in the administrative and technical aspects as well as cultural operations of the farm. Some operations are contracted out. Although the Burdekin area is one of the most productive cane areas in the world, growers are still looking forward to decreased cost of production and/or increased productivity via the introduction of new equipment or improved crop husbandry and farm management. Thus a close collaboration between the research station via an efficient extension service was evident. Quite a number of growers had introduced the mini-evaporation pan, the enviromscan and were monitoring crop growth in order to assess...
properly the readily available water of their fields and increase then on their water use efficiency. New irrigation equipment such as lighter fold-away spray booms, the linear move, the centre pivot and the drip tape are being tried. Green cane trash blanket is felt to be suitable for the mobile gun equipment but not for surface irrigation. Water management is taking a new direction with growers taking over the operation and management of the water delivery system from the source up to the farm gate.

Water reforms in Australia include the above as well as cost recovery in water pricing. Thus irrigation schemes in Mackay and Proserpine districts have set their water prices at about AUS 60 per ML and it includes a capital contribution. The annual requirement for many schemes is estimated at approximately 10 ML/ha. In the Burdekin area, water is considered as an important cost component which is close to 15% (AUS 400/ha or AUS 3/tonne of cane) of the total cost of producing cane.

The highlights of the technical sessions are presented below.

**DRIP IRRIGATION**

Drip irrigation was introduced in the 1970's in Hawaii, Australia and Mauritius. In those days the amount of know-how was low and basic research scanty. In Hawaii the increasing cost of labour, the attending problems of disposal of factory waste water and the increase in yield obtained with drip were enough reasons for a fast conversion from furrow to drip irrigation. Improvements in tubing technology, settling ponds and various types of filters pushed some companies such as Hawaiian Commercial and Sugar Company to convert 100% of their cane land to drip.

Although drip is present in most cane growing countries around the world and the technology has been introduced for over a quarter of a century, there are still quite a number of basic aspects to be tackled apart from applied ones concerned with the operation and the management of a drip system for sugar cane. The following issues were mentioned and some results were presented during the workshop: irrigation scheduling methodology, i.e. quantity to be applied and frequency; the problem of saline and sodic soils, wetting pattern under drip and leaching of nutrients; the optimum placement of drip tubes in cane fields; the economics of a drip system.

Very often farmers are confronted with the decision to shift from one method of irrigation to another one, say from surface to drip. Thus, it is agreed that such a shift at least for growing areas in the Burdekin District (Australia) has been slow in view of: the low cost of water (29 AUS/ML), a reasonable return being enjoyed as compared to other crops, the cost/benefit of drip yet to be demonstrated, and the varied results as well as problems encountered on the initial trial sites which were too small. Up to now there are still some constraints to be overcome. Among the constraints, the high initial investment costs coupled with the fact that the block of fields concerned have already been levelled and prepared for efficient surface irrigation. In Australia as in many other countries the strict and rigorous management of a drip system is not convenient to cane growers, particularly during the learning phase.

It is felt that the numerous advantages of drip should be demonstrated to cane growers. Further expansion of drip is expected with the increasing cost of water coupled with penalties or fines which could be imposed for run off water or leaching of nutrients into underground water.

In Australia and many other parts of the world, growers have to make the best use of a limited water supply. This is directly related to water use efficiency (WUE), wetting pattern under drip, drainage or leaching as well as irrigation scheduling. On-farm trials as well as research projects led by appropriate institutions are dealing with these aspects with the project known as CRC for Sustainable Sugar Production. Field experimentation to assess the two dimensional flow of water under drip, root growth and root activities within or around the “wet bulb” and the uptake of nutrients are not common being not only costly but tedious also. However, it was very comforting to see some new pieces of equipment and software which are now available at reasonable costs. One example is the software package “HYDRUS-2D” which allows the analysis of water and nutrient flow in two dimensions under a drip system. It can be used in conjunction with another modelling software called SWIM.
In order to provide recommendations for scheduling water application, measurements of soil moisture have been assessed up to 1 m within the soil profile for various soil types. This was possible with the use of neutron probes, Time Domain Reflectometry (TDR) probes and an Environscan system.

OVERHEAD IRRIGATION

Overhead irrigation received less attention during the technical session of the workshop. The review presented by this author pointed out that the advent of plastic pressure pipes and polyethylene pipes to be used with static or mobile machines contributed to the use of overhead equipment such as mobile gun travellers. The use of medium or low pressure sprinklers such as the drag-line very often depends upon the cost of energy and labour. The drag-line has gained popularity in African countries and since the 1980’s in Mauritius. However, in the latter case the lack of labour and its high cost restricts the use of such a system to a few areas only. The system has some inconvenience when lodging occurs during the grand period or boom-stage of growth of the crop. The main lines and some laterals have to be buried when cane is harvested and/or loaded mechanically.

The boom sprinkler system has been in use in a few countries but is gradually being replaced by improved equipment. The travelling sprinkler (Hose-coiler) has been tried in many countries with varying success due to poor adaptation to soil conditions and operating costs. The need of tractors to move the machines may represent an additional cost if the system has not been designed properly. The centre-pivot (or linear move) system has been considered as the most recent breakthrough. Although its water application efficiency, coefficient of uniformity and incremental yield can be as high as for the drip system, there are some disadvantages and limitations which prevent a wider use. The irrigation of corners for rectangular blocks is yet to be resolved through the provision of reliable “corner systems”. In countries where land is not a limiting factor, this may not be an important constraint. Further, the use of such systems are not recommended for soils with very low infiltration rates, on heavy clays such as dark magnesium clays or black cotton soils. The system can be used on slopes up to 15% and has to be well anchored in countries exposed to tornadoes or cyclones. The management of a centre-pivot is less demanding than that of a drip system. This factor coupled with the lower investment cost are responsible for the faster adoption of that system by cane growers in Mauritius.

Overhead irrigation is practised in Cuba over 50% of the irrigated area (384 000 ha). Cane yield increases obtained vary from 25 to 40 tonnes/ha. A significant decrease (from 7.2 to 4.2 million tonne sugar) in sugar production over the last decade is attributed to the reduction in the area under irrigation.

SURFACE IRRIGATION

Surface irrigation inspite of its poor water application and water-use efficiency is practised over large areas around the world. It is agreed that it is the most suitable method for heavy soils or areas where water is cheap and the cost of energy is high. In Australia about 60% of the area under cane is irrigated by this method. Over the last three decades various improvements have been introduced to address issues such as water losses in conveyance channels, soil erosion, drainage of sodic soils, application efficiency and tail water effects on the environment. Application efficiency in the Burdekin Delta is estimated to be near 40%. Increasing furrow length from 300 to 700 m has reduced the efficiency from 73 to 42%. There has been changes in management practices such as minimum tillage, shifting from wide “U” to narrow “V” shaped furrows on freely draining alluvial soils. These, together with the use of concrete or improved conveyance systems have contributed to the increase in the current irrigation efficiency. This situation could be improved significantly for the highly permeable soils by shifting to overhead systems. The price of water is about AUS 18/ML for the Burdekin cane growers whilst for the Burdekin River Irrigation Area (BRIA), it is AUS 39/ML at the farm gate. A higher furrow irrigation efficiency has been noted recently for the cracking clay and sodic duplex soils in the BRIA. The growers are now practising tail-water recycling not only to increase application efficiency but also to reduce the amount of nutrient and pesticide residues leaving the farm. Gypsum is currently used to improve the sodic soils and for long term sustainability growers are advised to wash away or leach out sodium that may accumulate within the root zone. To increase the amount of water entering such soils, basin irrigation has been tried but it did not increase cane yield significantly. In Egypt it has been demonstrated that a significant saving
in water could be achieved with proper furrow irrigation as opposed to wild flooding. This was accompanied by an increase in cane yield of the order of 25 tonnes/ha.

There are various ways of improving the conveyance of water to the irrigated furrows and to monitor the delivery rate for each furrow. A new system was presented under the trade name of “Flexiflume”. The lay-flat tubing is made of polyethylene and adjustable outlets are fitted to correspond to irrigation furrows. The tubing diameter varies from 86 to 425 mm and the maximum working pressure ranges from 1.1 to 0.14 bars. The tube can be installed by means of a tractor and retrieved prior to harvest. Being a new system, no information was given for its average life span in cane fields. Irrigating duplex soils is a common problem on the African continent. Salinity and sodicity on such soils which have a high content of montmorillonite clay contribute to the poor infiltration rate and low cane yield. Nearly 60% of cane land in Swaziland is furrow irrigated. Furrows are 220 m long on a slope of 1:200 and water is applied at 4.3 L/sec. The use of phosphogypsum in the furrows at planting and on the surface in ratoon crops has brought down the electrical conductivity of the soil from 150 to 50 m Sm⁻¹ over a period of 3 years. This was accompanied by an improved infiltration rate and a higher sugar yield of the order of 3 tonnes/ha.

WATER USE EFFICIENCY AND IRRIGATION SCHEDULING

Water use efficiency (WUE) was reviewed prior to presentations and discussions on scheduling methods and optimising the use of a limited water supply. WUE was defined as the ratio of cane yield to the seasonal net water use. Other scientists define it as the marketable unit of a crop per unit of water consumed in evapotranspiration. WUE for different countries may be obtained from the slope of the relationships between cane yield and water use. Care should be exercised for countries which harvest their crop at the age of 21 to 26 months (Hawaii & Kenya). WUE, according to available data varies from 3 to nearly 20 t/ha/100 mm. In Australia a bench mark WUE for sugar cane is about 12.2 t/ha/100 mm. When gross water use is taken into consideration, then the apparent WUE is less than those mentioned above. This is due to low irrigation efficiencies. The high variability in WUE is attributed to inaccurate measurements of effective rainfall, net amount of irrigation water, variations in soil properties and cultural practices, water use by different cane varieties etc.. The term Irrigation Water Use Efficiency (IWUE) commonly used by irrigation planners is defined as the ratio of cane yield to the total amount of irrigation water used. Another term related to the irrigation method and the level of management is the Irrigation Efficiency (IE) defined as the ratio of the volume of water used by the crop to the volume of water pumped or delivered to that crop area.

As WUE is related to final yield and evapotranspiration (ET) then factors which influence crop growth and ET will eventually affect it, i.e. micro-climate, soil moisture holding characteristics, soil fertility, cane variety, salinity and the irrigation method/system. Sugar yield is the product of cane yield and the recoverable sucrose percentage in the cane. Thus maximum sugar yield depends not only on a proper management to achieve high cane yields but also on an effective drying off or irrigation management during the ripening period (8 to 12 weeks prior to harvest). Hence sugar yield to water relations are further complicated and influenced by local conditions. Two known relations are:

1. Tonnes sugar/ha = 1.35 (Et mm/100)-1.32
2. Tonnes sugar/ha = 2.37 (ET mm/100)-8.93

There is a need to quantify the response of dry matter accumulation and its partitioning (into sucrose and non-sucrose) to soil water for management and other purposes.

WUE is used generally by agronomists, engineers, economists and farm managers for such purposes as: water resources planning, estimates of cane yield for a mill area; water requirement for a given level of production and the calculation of the economic response to irrigation.

In order to promote WUE via efficient distribution systems, Australia has been implementing an integrated package of measures designed to provide a clear, integrated and productive approach to the allocation and management of water resources. This is an interesting innovation as it increases the competitive pressure and
accountability to distributor systems. It will provide the impetus for water distribution authorities to become more customer focussed and eventually self-funding. Effective benchmarks will be established to measure efficiency within the supply systems.

When water is a costly resource or a scarce one, then proper irrigation scheduling is of primary importance. Recent developments in various countries such as Swaziland, South Africa, Australia and Mauritius in the modelling of cane growth have led to specific crop models. From these a number of scheduling techniques have evolved and are targeted at a range of management levels. The response of the sugar cane plant to water deficit varies with the three main phases of development, i.e. tillering, elongation and ripening. Thus in Mauritius a higher yield can be achieved by irrigating an area below crop satisfaction rather than irrigating part of the area at 100% crop satisfaction and leaving the remaining as rainfed. In Australia the research programme, as for Mauritius, is designed to supply growers with information about the risks and benefits of the various irrigation options. The APSIM model (from Australia) is being used to make recommendations for the strategic use of limited irrigation water.

Irrigation scheduling is being refined with modern soil moisture measuring devices and information technology. Still, there is a need for simple devices for those who cannot afford such sophisticated devices. It was interesting to know that a simple device has been tested both in Australia and Colombia - the mini-pan. The Colombian device is a 20 L capacity plastic bucket. The maximum storage capacity is defined by the height of the overflow orifice near the rim and two marks indicate the need to irrigate whenever the water level approaches them. The distance from the orifice to the lower marks are determined by the soil water holding characteristics of the area and the crop age. The mini-pan has been field tested and proved to be an effective irrigation scheduling device.

Irrigation practice must now take into account of offsite impacts. Drainage water, excessive leaching, tail-end water as well as excessive pumping from boreholes may lead to irreversable effects on the environment, inspite of the fact that the soil itself can act as a filter. In the Ord river project (Australia) cane yield is far from the potential expected whilst the electrical conductivity of the soil has increased significantly over the last three years. In the Burdekin district, farm management strategies are now available to reduce off-farm run-off. A recycling pit is used to collect tail-water or the water is deliberately contained within the irrigated blocks. Nutrient outflows have been kept to a minimum except after rainfall events which follow fertilizer application. Herbicides such as Diuron and Atrazine can be detected for short periods only. In Australia and in some other countries over pumping from boreholes may lead to salt water intrusion from elsewhere (e.g. the sea).

CONCLUDING REMARKS

All three methods of irrigating cane are in use in cane producing countries. The choice of a method and the appropriate equipment depends upon technical and non-technical considerations. However, very often the estate agronomist or the farm manager is not consulted at the design stage and this often leads to system failure or poor efficiency. Further, the lack of training as well as operation and maintenance manuals have also contributed to the poor performance of equipment, particularly for drip irrigation.

There is a need for information on the use of waste water via either a drip or a center-pivot system. There is little information on the application of fertilizers through these systems. The life expectancy of drip tubes or drip tapes should be given due consideration without forgetting that their disposal after a crop cycle can become an environmental issue.

Gradually new instruments are being produced to monitor soil moisture and software or models are becoming available for irrigation scheduling or simulation studies. Still, it seems that we need to fine-tune our knowledge of the response of the sugar cane plant to soil moisture. In this area the critical level of soil moisture potential beyond which cane elongation is significantly reduced should be determined particularly for rocky or porous soils (with high infiltration rate). In many countries our estimation of the effective rainfall is still a poor one as well as the volume of soil with active roots.
Some attention is given now and then to the small planters’ sector of the industry. Thus the mini-evaporation pan for irrigation scheduling is a laudable effort as in some countries the small growers’ share of the total production may be a very significant one.

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RIEGO DE CAÑA DE AZÚCAR: UN REPASO

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RESUMEN

La tecnología de riego y el manejo de agua se están desarrollando en las regiones de Proserpine, Mackay y Burdekin de Australia. El uso de agua representa un 15% del costo de producción de la caña. Por eso los cultivadores están tratando nuevo equipo como la línea de goteo, el movimiento lineal y el pivote del centro, junto con nuevas herramientas planificadores de riego. Se han tomado medidas para reducir significantemente el riesgo potencial de contaminación de corrosión de la superficie o agua residual de riego.

El riego por goteo se hace poco a poco el más favorecido en muchos países productores de caña. El alto capital inicial junto con manejo riguroso restringen la expansión de este sistema. Algunos estudios se dirigen hacia tanto el movimiento de agua como la actividad de raíz bajo el riego por goteo.

Un gran adelanto en el método de goteo elevado es el equipo pivote de centro (o movimiento lineal). El costo más bajo de inversión y el manejo menos restringido hacen este equipo más favorable con los cultivadores. Sin embargo, el uso de los químicos incluso los nutrientes todavía es un aspecto poco claro.

El riego de la superficie es mejorado mediante la técnica de flujo oleado o el uso de tubos puestos en la tierra con salidas ajustables. A pesar de eso, su eficiencia de uso de agua es baja.

Modelos del crecimiento de la cosecha y la introducción de nuevo equipo controlador de la humedad están contribuyendo a la aumentada eficiencia del uso de agua. Sin embargo, hay bastante asuntos que se han identificado y que necesitan la atención de los manufactureros de equipo así como los científicos investigadores de riego.

Palabras claves: riego por goteo, pivote de centro, Australia, eficiencia de uso de agua, caña de azúcar.
UNE REVUE DE L’IRRIGATION DE LA CANNE À SUCRE

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RÉSUMÉ

Les techniques d’irrigation et la gestion de l’eau ont progressé dans plusieurs régions de l’Australie (Proserpine, Mackay et Burdekin). Dans le coût de production de la canne, l’eau représente 15%. Ainsi, les fermiers, essaient de nouveaux équipements tels que la gaine du goutte à goutte, la rampe frontale et la rampe pivotante aussi bien que de nouveaux outils pour la gestion de l’irrigation. Des mesures sont prises pour réduire d’une façon significative les risques de pollution à partir de l’écoulement des eaux de pluie ou d’irrigation.

La superficie sous goutte à goutte augmente dans beaucoup de pays producteurs de canne à sucre. L’investissement initial élevé et la gestion rigoureuse limitent l’étendue de ce système, où des études sont en cours sur l’écoulement de l’eau ainsi que le développement radiculaire.

Un récent développement majeur dans l’irrigation a été l’introduction des rampes frontales ou pivotantes. Les fermiers préfèrent ces équipements, car ils sont moins onéreux et leur gestion moins rigoureuse. Cependant, il faudrait que l’application des produits chimiques incluant les engrais, au moyen de ces équipements, soit perfectionnée.

L’irrigation de surface a été améliorée avec le ‘surge flow’ ou l’utilisation des tubes en polyéthylène avec des vanettes ajustables.

La modélisation ainsi que de nouveaux équipements pour mesurer l’humidité dans le sol ont contribué à une efficacité accrue de l’utilisation de l’eau. Malgré cela, plusieurs contraintes ont été identifiées et requièrent l’attention des fabricants aussi bien que les chercheurs dans ce domaine.

Mots clés: irrigation goutte à goutte, rampe pivotante, ‘surge flow’, l’efficacité de l’utilisation de l’eau, canne à sucre