SUDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF AGRICULTURAL STUDIES
DEPARTMENT OF AGRONOMY

Title
EFFECT OF IRRIGATION REGIMES AT VARIOUS PHYSIOLOGICAL GROWTH STAGES On SUGARCANE QUANTITY AND QUALITY YIELDS

BY
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A THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRONOMY.

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APRIL 2011
Dedication

To my parents without whom I would not be Here, May God sincerely bless them.
To my wives for sustenance and guidance

To my sons & daughters
First of all, praise is due to almighty ALLAH for his sustenance and guidance. Second, my sincere appreciation goes to my supervisor Dr. Ahmed Ali Mohamed Osman, for his guidance, invaluable advice and criticism. I am very grateful for the help and support of my co-supervisor Dr. Hassan Ibrahim Mohammed, who encourage me to conduct my PhD research on this topic. He showed a great deal of interest in reading, discussing and giving feedback on all aspects of my thesis. Hearty thanks for my supervisors.

I would like to give special thanks to the General Manager of Sudanese Sugar Company for funding and supporting this research, all the heads of the different sections for their friendly helps.

I am also deeply indebted to my close friends of Guneid Sugar Research Center staff for their uncountable and unlimited help only I can say God bless them.

I am very grateful acknowledge Dr. Ahmed. Obaid. Ahmed. (The manager of Guneid. Sugar Research Center(G.S.R.C) and Dr. Awad Al Hag M. for their great help and guidance, I particular have valued their advices.

I would like to give special thanks to the team of Agronomy and soil department in (G.S.R.C.) for their support all through the research and analysis.

I would like to give my sincere thanks and gratitude to my closely wives and my family for their help and support.
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<tr>
<td>AbuVI</td>
<td>small Canal from Abu XX to the field</td>
</tr>
<tr>
<td>Abu XX</td>
<td>Small Canal From the minor to The Number</td>
</tr>
<tr>
<td>ADE</td>
<td>Assistant Division Engineer</td>
</tr>
<tr>
<td>A.S.W.</td>
<td>Available Soil Water</td>
</tr>
<tr>
<td>B.D</td>
<td>Bulk Density</td>
</tr>
<tr>
<td>Ca</td>
<td>Calcium</td>
</tr>
<tr>
<td>C0</td>
<td>Centigrade</td>
</tr>
<tr>
<td>Cd</td>
<td>delivery coefficient = (0.693)</td>
</tr>
<tr>
<td>CEC</td>
<td>Concentrate of electric Conductivity</td>
</tr>
<tr>
<td>CWR</td>
<td>Crop Water Requirement</td>
</tr>
<tr>
<td>DSW</td>
<td>Deficit Soil Water</td>
</tr>
<tr>
<td>E</td>
<td>East</td>
</tr>
<tr>
<td>ETa</td>
<td>actual evapotranspiration</td>
</tr>
<tr>
<td>ETm</td>
<td>maximum evapotranspiration</td>
</tr>
<tr>
<td>ETC</td>
<td>crop evapotranspiration</td>
</tr>
<tr>
<td>ESW</td>
<td>Excess Soil Water</td>
</tr>
<tr>
<td>ET</td>
<td>Evapotranspiration</td>
</tr>
<tr>
<td>ET0</td>
<td>Reference Evapotranspiration</td>
</tr>
<tr>
<td>Ey</td>
<td>Harvested yield</td>
</tr>
<tr>
<td>FAO:</td>
<td>Food Agriculture Organization</td>
</tr>
<tr>
<td>F.C.</td>
<td>Field Capacity</td>
</tr>
<tr>
<td>Fe</td>
<td>ferric</td>
</tr>
<tr>
<td>F.O.P.</td>
<td>Field outlet Pipe</td>
</tr>
<tr>
<td>h</td>
<td>The distance between the weight and the centre of the plate</td>
</tr>
<tr>
<td>HYvs</td>
<td>High Yielding Varieties</td>
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<td>IWUE</td>
<td>The irrigation water use efficiency (ton ha-1mm-1),</td>
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Adequate Irrigation at 55% soil depletion.
Excess Irrigation at 110% saturation
Deficit Irrigation at 77% depletion
Potassium
Yield response Factor
Moment equal to weight (gm) multiplied by the distance (Cm(gram))
Magnesium
Nitrogen
North
Phosphor
Sucrose percentage
Part per million
Is the proportion of the total available water
permanent wilting point.
The discharge in litre per seconds. = (W×h)
Gravimeter rate content (gram of water./gram of soil)
volumetric water control (cm³ cm⁻³)
Readily Available Water
bulk density and the soil (gm⁻³)
density of water (gm⁻³)
Sudanese Sugar Company
Tillering stage of sugarcane growth (early growth stage)
vegetative stage of sugarcane growth (elongation or mid stage)
Maturity stage of sugarcane growth (late stage)
The seasonal irrigation water applied including rain (mm).
Total Available Water
Yield /Evapotranspiration
v/ v  volumetric value w/w \times B.D = \text{Volumetric}
Wd  mass of dry soil and container (g)
We  mass of container (g)
Wt  weight
WUE  Water use efficiency
Ww  Mass of wet soil and container (g)
w/w  gravimetric moisture control
W  The balance weight used for equilibrium
Ya  Actual yield Ym
Ym  Maximum Yield
Y  Yield
Zn  Zinc

\text{ABSTRACT}
The demand for food and energy is steadily increasing with increase of population growth rate. Irrigated agriculture assumed to make a major contribution to food security, all though it is the major consumer of water resources, unfortunately yields of irrigated crops is very low. At present, sugarcane is the most reliable food and feedstock and energy (bioethanol) production since its farming technologies are already in place in Sudan, and currently, the country is in deficient production of sugar. The scope for further horizontal irrigation development to meet sugar requirements in the coming years, is however, severely constrained by decreasing water resources and growing competition for clean water. While on a global scale, serious water shortages are developing in the arid and semi-arid regions as existing water resources reach full exploitation. The situation is serious (exacerbated) by the declining quality of water and soil resources. The dependency on water has become a critical constraint on further progress and threatens to slow down development, endangering food supplies and aggravating rural poverty. The great challenge for the coming decades will therefore be the task of increasing food production with less water, particularly in countries with limited water resources. For food Security and planning purposes, it is necessary to forecast crop yield before season end. With changing climate and environment worldwide water is becoming more scarce. In Arid and Semi-arid area the problem of water scarcity (less supply), and increasing demand (domestic uses, Agriculture, industry and urban uses) necessitated better irrigation management and proper scheduling. To improve water efficiency it is essential to develop water management tactics to overcome problems of improper water scheduling (over-under supply) for different crop growth stages.

The aim of this study is to investigate the way sugarcane crop react to stress irrigation, leading to practical guidelines to assist extensionists, farmers and decision-makers in optimizing water use for optimal crop production. Accordingly, field trials were carried out for two seasons (2007/2008) in Gunied Sugar plantation experimental farm located in Gezira State, in order to study sugarcane growth and yield response to excess/deficit irrigation imposed at each crop physiological growth stage. The experiment was a split-split plot design with factorial arrangement, completely randomized in 27 water treatments (adequate, excess and
deficit) for each one of three growth stages (tillering, vegetative and maturity) in three replicates. Deficit irrigation scheduling is one way in which farmers practicing irrigation farming, can cope with the pressure to reduce water used for crop production in order to release more water for other sectors in need of it. In this study deficit irrigation is investigated as a valuable and sustainable production strategy in dry regions with limited water resources. By limiting water applications to certain growth stage, this practice aims to maximize water productivity and to stabilize – rather than maximize – yields. The soil in the study area is characterized with its poor internal drainage resulting in water logging when over irrigated. Excess irrigation trials were conducted to a certain impacts of timing of efficient management practices as a cheap solution of the frequent problem of over watering.

Cultural practices followed are typical to those adopted by Gunied sugar plantation for variety Co6806. Data collected includes: level soil moisture depletion using gravimetric method, inflow rate measured with vane flow meter, yield components (plant height, thickness, number of tillers), yield parameters (cane yield as weight, sugar content and juice quality), and water performance indicators (yield response factor and water use efficiency). Statistical analysis of the data and discussion of obtained results reveals that:

Deficit irrigation at early stage of sugarcane growth produced higher cane yield and higher water use efficiency compared to other stages. In contrast, deficit irrigation at the late stage had a serious and drastic effect on final cane and sugar yields and hence, it may be regarded as the most sensitive stage. Although deficient irrigation imposed at vegetative stage produced lower cane yield compared to that of tillering stage, it resulted in the highest sugar content due to sugar recovery. Hence, deficit irrigation is recommended to be practiced at tillering stage, after well crop establishment, for optimum cane yield and high water use efficiency, and late application of deficit watering had to be avoided completely. Excess watering applied at the early stage produced the lower yields of cane and sugars compared to other stages therefore should be avoided, while excess watering imposed at the vegetative stage produced higher yields of cane and sugars compared to other stages. Therefore, acceptable level of over irrigation can be tolerated only at vegetative stage. This level need to be precisely determined by future studies. In addition more investigations need to be done on regular deficit irrigation at different soil moisture depletions at the early and vegetative stages of growth.
for maximum economical yields of sugarcane crop and an improved water use efficiency. Yield response factor was estimated as 1.13 for sugarcane crop, which match well with FAO value of 1.2. Using the estimated crop response factor, crop-water production functions for sugarcane crop in Sudan can be developed to derive the productivity of the applied. It can be inferred from the irrigation scheduling protocol of excess/deficit irrigation of this study that the past policies of water resource management which adopt irrigation practices consistent with an abundant and inexpensive water supply to avoid moisture stress to strive for maximum yield need to be replaced by those practices that consider deficit irrigation as a key strategy for increasing on-farm water productivity in water-scarce dry areas and the risk associated with deficit irrigation can be minimized through proper irrigation scheduling (avoiding water stress at growth stages sensitive to water stress).

**Key Words:** Deficit irrigation, yield formation,
نسبة للتغير في ظروف الطقس والمناخ في العالم أصبحت المياه شحيحة جداً في المناطق الجافة وشبه الجافة مشكلة كبيرة. مع ازدياد الطلب لها، (للاستخدامات الشخصية والزراعية والصناعية وظروف الحياة الأخرى) يفرض هذا الوضع تحسين إدارة وجدول مياه الري. تجوب ورقف كفاءة الري بنطاق امتثال معدات للتغيير على مشاكل إدارة مياه الري الناتجة من الحدود الحالية للري (زيادة معدلات الري أو تقليلها).

الهدف من القيام بهذه الدراسة هو معرفة سلوك المحمول عن التعرض لهرقات الري لكي نقود إلى خطوات عملية تساعد الأشخاص والمزارعين وتخفيض القرار في تحقيق أفضل كفاءة الري لافضل انتاج عالي. عليه تم القيام بهذا التجربة خلال موسمين (2008/2009) بمزرعة مركز بحوث السكر بالجبلide الجزيرة. بعرض دراسة استجابة مجموعات مياه الري لزيادة المغذيات الري وتحفيزها على مختلف مراحل الريف الفسيولوجي. بنيت التجربة على النظام التوزيع العشوائي للمعاملات المائية التي تم استخدامها ثلاثة معاملات مائية (ري عادي، رياضي وتقليل الري) لكل مرحلة من مراحل النمو الحيوى المختلفة (مرحلة النهضة، مرحلة الورك الخضرى ومرحلة النضج) في عدده 27 معاملة في ثلاثة مكررات.

ان جدولة معاملة تقليل الري هو أحد الطرق التي يمكن للمزارع تطبيقها تنتمي مع صعوبات تقليل استهلاك المياه مع تحقيق اعلى انتاجه ولتوفر أكبر كمية منها لاقساط تكون في حاجة لها.

في هذه الدراسة تطبق معاملة تقليل مياه الري تبين اها أقيم الاستراتيجيات الإنتاجية في المناطق الجافة محدودة مصادر المياه. اضافة مياه الري المحددة في ارق مراحل نمو المحمول يهدف إلى رفع الكفاءة المائية واستقرار الإنتاجية بخلاف تحقيق اعلى انتاجه.

تختص الدراسة التي تم اجراء التجارب عليها بوصف التصريف مما ينتج عنه ركود المياه عند تطبيق معاملة زيادة مياه الري عليه تم تحقيق هذه المعاملة بتسهيل زيادة معينه عن معدل الري الاعادى لمعرفة تأثيرها، كاسهل حل لمشكلة زيادة معدلات الري المتبعه في بعض المناطق.

لقد تم تطبيق المعاملات الفلاحية المتبعه في مشاريع السكر للصنف 060806. تم تجميع المعلومات والرقام (نسب الرطوبة في التربة باستعمال طريقة وزن النتر، نسبة رطوبة وجافه، مياه الري نمت معايزتها بواسطة جهاز قياس سرعة الري، معلومات الإنتاج والتي تشمل طول النبات، شكل النبات، عدد النباتات، انتاجية الفصل، وكمية السكر المنتج مع نوعية عصير الفصل. لتقريب بعض مؤشرات الاداء المحصولي تم حساب معامل تغيير الإنتاجية و كفاءة الري.

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التحليل الإحصائي للآرقام ودراسة انتاج المحصول عليها:

ان انتاج مياء الري في مرحلة التغريـع (مرحلة النمو الأولى) لمحصول قصب السكر لها تأثير مباشر في تـأثير انتاج القصب مع رفع كفاءة مياء الري مقارنة مع المراحل الأخرى. في المقابل تقليل مياء الري في مرحلة النمو (مرحلة النمو المحسوب الاخير) له تأثير ضئيل وكيـر على انتاج القصب وكمية السكر المنتج، عليه تعتبر مرحلة النمو هي المرحلة الأكثر حساسية لهذه الحالة. هـل من نـيل تقليل مياء الري في مرحلة النمو الخصري حقبة اقل انتاجه قصب مقارنة بتـأثير النقص الخصري إلا أنها حقبة اعلى كمية من السكر، وبـزيادة ذلك ارتفاع نسبة الاستخلاص. من هذه النتائج يوصى بتطبيق نظام تقليل مياء الري في محصول قصب السكر في مرحلة التغريـع (مرحلة النمو الأولى من النمو المحصول) بعد تكوين افضل محصول تم تطبيـصه لتسقيـم افضل إنتاجه اقتصاديه مع الحصول على اعلى كفاءة لمياء الري، كما يوصى بعدم تعرض المحصول لتقسيم مياء الري في مرحلة النمو الولى لعدم وجود أصلي.

أن زيادة معدل الري في مرحلة التغريـع (مرحلة النمو الأولى) حقبة اذي انتاجه لمياء الري والسكر والسكر المنتج مقارنة مع المراحل الأخرى بينما تطبيق زيادة معدل الري في مرحلة الـنمو الخصري حقبة اعلى انتاجه قصب وسكر مقارنة مع المراحل الأخرى، على أن زيادة معدل الري بنسبة مغفوله يمكن للمحصول تجعله فقط في مرحلة الـنمو الخصري. هذه النسبة تحتاج إلى فحص تفريـضها في دراسات مستقبلية، بالإضافة إلى ذلك مزيد من الدراسات بدوام القيام بها في مجال تطبيق نظام تقسيم مياء الري بإضافته على نسبة مختلفة من استيراده، وذلك في المرحلتين الولى من مرحلة التغريـع، و مرحلة الـنمو الخصري، لتحقيق اعلى انتاجه اقتصاديه لمياء الري ورفع كفاءة مياء الري.

لقد تم حساب معدل تغريـع الانتاجية 0.13 لمولص قصب السكر والذي ينطبق بـ 0.13 من مستوى الزراعه والثوبه العالميه (FAO) للمراحل مع مرحلة التغريـع، هذا الرقم المقدر لـتحمل معدل استفاعه المحصول كـمعلـم انتاجية لمياء الـنمو للسـكر في السودان يمكن اعتماده في مياء الانتاجية المطلقة.

يمكن أن تخرج من برونوكل جدولاً لـرير الري زيادة أو نقصاً في هذه الدراسة بأن سياسات إدارة المياء في السابق التي تـنطبق الززاعه والأغاثه العالمية (FAO) لا ينطبق على انتاجها كيمياء كمية من المياء باعتبار أن المياء متغيره ور جيـم لنـفتاذ زـراعة تعظـيسالحول لممـانع اعلى انتاجه، هذه السـياسات يمكن تغييرها باللامراءات التي ذكرت في هذه الدراسة والتي تعتبر نظام تقسيم الـري كـمفتاح استراتيجي لـربيع انتاجه مياء الـري داخل الحقول والمناطق الحافة، وسـتيت مياء الري كـما ان تجوز من التأثـر السلبي لـتقسيم مياء الـري يمكن استخدامه بـتطبيق أفضل جدوله ممكنه (الابعاد عن تقسيم تقسيم مياء الري في المراحل الحساسة من نمو المحصول).

المفتاح تقبل مياء الري، تحقيق انتاجه.