AGRICULTURAL WATER CONSERVATION GRANT

FINAL REPORT

to the

TEXAS WATER DEVELOPMENT BOARD
Contract No. 2004-358-005

December 2005

Texas Water Resources Institute
make every drop count

Agricultural Water Quality Grant
Final Report

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Contract No. 2004-358-005

Overview

In January 2005, the Texas Water Resources Institute (TWRI), in conjunction with the Texas Water Development Board (TWDB), administered a request for proposals. From that RFP 10 projects were selected for funding. They are listed below.

TWRI continues to interact with project leaders on a regular basis and offers support to these teams on an as-needed basis.

This report briefly describes the water-savings that may be achieved through the results or progress of each project. The final technical reports submitted by each principal investigator are attached.

Listing of Funded Projects

1. James Bordovsky, Texas Agricultural Experiment Station at Plainview. “Equipment Installation for the Evaluation of Crop Row Direction and Offset Distance from Subsurface Drip Irrigation.” $10,000.

2. John Jifon, Texas Agricultural Experiment Station at Weslaco. “On-Farm Volumetric Measurement of Irrigation Water Use as a Best Management Practice Tool for Water Conservation in Drip Irrigated Vegetables.” $10,000.

3. Allen Knutson, Texas Agricultural Experiment Station at Dallas. “Implementing Biological Control of Saltcedar in the Upper Colorado River Watershed.” $9.577.

4. Leonardo Lombardini, Texas A&M University Horticulture Science Department. “Irrigation Scheduling in Pecan Orchards Using a Soil Water Balance Model.” $9,732.

5. G.J. Michels, Texas Agricultural Experiment Station at Bushland. “Biological Control of Saltcedar at Lake Meredith, Texas.” $6,776.

6. Genhua Niu, Texas Agricultural Experiment Station at El Paso. “Determining Plant Water Use and Crop Coefficients of Selected Nursery and Landscape Plants.” $9,425.

7. Genhua Niu, Texas Agricultural Experiment Station at El Paso. “Impacts of Drought on Salinity Tolerance of Landscape Woody Plants Irrigated with Reclaimed Wastewater.” $9,425.

8. Bobby Stewart, West Texas A&M University. “Seeding Dryland Grain Sorghum in Clumps to Decrease Tillering and Increase Grain Yield.” $9,500.

9. Giovanni Piccinni, Texas Agricultural Experiment Station. “On-Farm Research to Evaluate Irrigation Scheduling Tools to Increase Yield and Control Diseases.” $10,000.

10. John Sij, Texas Agricultural Experiment Station at Vernon. “Managing Water Resources of the Seymour Aquifer Using Subsurface Drip Irrigation.” $10,565.

Progress/Activities

1. *James Bordovsky, Texas Agricultural Experiment Station at Plainview. “Equipment Installation for the Evaluation of Crop Row Direction and Offset Distance from Subsurface Drip Irrigation.”*

Overview
The overall goal of this project is to quantify the extent to which the physical distance between subsurface drip irrigation systems and the rows in which crops are grown may affect cotton germination, nutrient uptake, and crop yield, as well as water use efficiency.

Opportunity for Water Savings
This project sought to quantify the effects of planting rows of cotton perpendicular or parallel to subsurface drip irrigation lines on water use efficiency, cotton germination and yield. In this study, subsurface drip irrigation (SDI) was installed on 4.4 acres at the Texas Agricultural Experiment Station research facility at Halfway on the High Plains. The first crops will be planted in 2006 and data will be collected on water use efficiency, soil moisture, soil compaction, and plant growth. Research results are expected to provide insights agricultural producers can use when they consider converting to more efficient drip irrigation systems, including determining the extent to which planting crops parallel or perpendicular to drip laterals may increase profitability for agricultural producers. In addition, the research may yield insights into how SDI may benefit the germination of crops by promoting soil wetting.

2. *John Jifon, Texas Agricultural Experiment Station at Weslaco. “On-Farm Volumetric Measurement of Irrigation Water Use as a Best Management Practice Tool for Water Conservation in Drip Irrigated Vegetables.”*

Overview
The overall objective of this study is to determine if affordable water meters can be used to accurately measure the amount of water used for irrigation and to calculate water use efficiency. By establishing such a methodology, comparisons can be made about the volume of water use as well as the amount of water that can be saved from the use of drip versus furrow irrigation systems.

Opportunity for Water Savings
Portable, reusable, totalizing water meters were used to estimate crop water use and potential water savings that can be achieved by switching from furrow- to drip-irrigation to grow onions in the Lower Rio Grande Valley. Monitoring the volume of on-farm water use provides key data needed to fine-tune irrigation schedules, allows comparisons to be made that can quantify changes in water use and resulting water savings, and can increase the profits of irrigators by reducing production costs. Results from studies of commercial onion fields in Sullivan City, TX (Hidalgo County) show that 0.9 acre-feet of water can be saved annually when drip irrigation is used instead of furrow irrigation. In addition, the use of drip irrigation instead of traditional furrow irrigation methods does not reduce crop yields. Only about 10 percent of the 11,000 acres of onions now grown in the Lower Rio Grande Valley utilize drip irrigation. If the use of drip irrigation of onions became more widespread, the potential water savings could total as much as 8,000 acre-feet annually.

3. *Allen Knutson, Texas Agricultural Experiment Station at Dallas. "Implementing Biological Control of Saltcedar in the Upper Colorado River Watershed."*

Overview
The overall goal of this project is to establish nursery sites for rearing large numbers of a specific species of beetle that can be used to biologically control water wasting saltcedar in the Upper Colorado River watershed. These studies are concentrated along Beals Creek near Big Spring, Texas.

Opportunity for Water Savings
Saltcedar infests roughly 500,000 acres of stream banks and water courses in Texas. Studies have shown that, along the upper portion of the Pecos River Basin in Texas, 1 acre of dense saltcedar can consume up to 7 acre-feet of water per year. Recent estimates suggest that there are roughly 16,000 acres of saltcedar-infested acreage near three West Texas reservoirs (Lake Thomas, Lake Spence, and Lake Ivie) and it is projected that an additional 6,000 acres along the Upper Colorado River are plagued with saltcedar. The Colorado River Municipal Water Authority suggests that saltcedar annually consumes enough water to meet the needs of the City of Odessa (7 billion gallons). This study reared and released 5,200 beetles at 18 sites along two saltcedar-infested water courses near Big Spring in the summer of 2005. As a result, additional beetle populations may be established in the summer of 2006. As a result of this project, several recommendations have been developed about how beetles should be released and established in order to increase the population of these insects to a level that they can cause significant damage to saltcedar stands. If a sufficient population of saltcedar beetles can be established over time, these insects may have the potential to reduce saltcedar and thus produce significant water savings.

4. *Leonardo Lombardini, Texas A&M University Horticulture Science Department. "Irrigation Scheduling in Pecan Orchards Using a Soil Water Balance Model."*

Overview
The overall goal of this project is to introduce an alternative method for scheduling irrigation in pecan orchards through the use of a soil water balance model. Validating the model in pecan orchards will allow this methodology to be used in different regions with varying climate conditions and to conserve water.

Opportunity for Water Savings
This project sought to model the soil-water balance in experimental pecan orchards on the Texas A&M University campus in College Station, TX. The goal was to utilize monitoring data about soil-water content to develop a system to schedule irrigation based on actual plant and soil needs. In the project, researchers gathered weather data and utilized neutron probes to measure soil-water content before and after irrigation events. The effect of irrigation on pecan trees was also monitored. Information on crop and soil water needs was modeled through the SALUS model developed by Bruno Basso of the University of Basilicata in Italy in 2000. Previous studies using SALUS have shown that the water use of some crops can be reduced by 30 percent if irrigation is applied precisely, based on monitored water needs. Similar water savings might result when SALUS is applied to pecans, but this has to be proven through field research. In 2006, the researchers will apply three different irrigation regimes (rainfall with no additional irrigation, irrigating trees at regular intervals, and irrigating trees based on soil-water content data). These studies will determine the amount of water savings that may accrue if irrigation is precisely scheduled based on monitored data of plant and soil water needs. This project should benefit pecan growers in much of Texas who are struggling with the challenge of growing orchards under water-limited conditions. Because water supplies are a major threat facing pecan growers, developing strategies to more effectively manage water will help orchard owners remain competitive.

5. *G.J. Michels, Texas Agricultural Experiment Station at Bushland. "Biological Control of Saltcedar at Lake Meredith, Texas."*

Overview
The overall goal of this study is to determine if the deployment of the saltcedar beetle (*Diorhabda elongata*) can be a successful biological control agent to manage saltcedar populations near Lake Meredith and in the Canadian River watershed and thus conserve water.

Opportunity for Water Savings
This study monitored the establishment, growth, and movement of saltcedar beetles deployed near Lake Meredith in the Texas High Plains. In addition, data was recorded about such factors as soil types, ground cover, vegetative abundance, and the types of woody plants that grew adjacent to the saltcedar. Results show that the beetles successfully survived the winter in the region. By June 2005, saltcedar showed light herbivory damage and defoliation because the beetles preyed upon these plants. In, this project reached a key milestone when beetle populations were successfully established at Lake Meredith. In 2006, project leaders will

continue to monitor the increase and spread of these beetles and the extent to which they damage saltcedar. This project has the potential to reduce dense stands of saltcedar, which have been reported to consume as much as 200 gallons of water per plant per day. Regardless of the amount of water saltcedar actually consume the fact remains that controlling saltcedar will yield water savings. If the populations of beetles near Lake Meredith increase, significant defoliation of saltcedars can be expected to begin within the next 1 to 3 years, thus producing water savings.

6. *Genhua Niu, Texas Agricultural Experiment Station at El Paso, and Raul Cabrera, Cynthia McKenney and Wayne Mackay, Texas Agricultural Experiment Station at Dallas. "Determining Plant Water Use and Crop Coefficients of Selected Nursery and Landscape Plants."*

Overview
The overall goal of this project is to determine the water use and crop coefficients of selected landscape plants. The study will compare the differences in water use and crop coefficients that result when these species are grown in El Paso and Dallas. The project will also investigate water use trends in plants grown in containers versus plant species grown in landscapes.

Opportunity for Water Savings
This study shows that water use of landscape plants can be accurately estimated from container-grown plants, provided that the growth index and leaf area can be quantified. Information from this study can be used to reduce the amount of water applied in landscape irrigation, if plants are grouped according to similar water use and if irrigation is scheduled according to plant needs.

7. *Genhua Niu, Texas Agricultural Experiment Station at El Paso. "Impacts of Drought on Salinity Tolerance of Landscape Woody Plants Irrigated with Reclaimed Wastewater."*

Overview
The overall goal of this study is to evaluate the relative salinity tolerance and water use of selected shrubs and tree species under well-irrigated and drought-stressed conditions. The project will also analyze how these species take up sodium and chloride ions and translocate them into parts of the growing plant.

Opportunity for Water Savings
Results showed that lacebark elm is the most salt-tolerant of the seven trees and shrub species that were evaluated in this study. Lacebark elm did not suffer any foliar damage due to salt it grew by as much as 44 percent in a three-month evaluation. Russian olive and Desert willow grew by as much as 30 percent but suffered some leaf injury. On the other hand, sand plum, sand cherry, and black cherry showed severe defoliation and did not grow significantly. Results of this project may be useful as water suppliers consider reusing municipal effluents which may have higher levels of salinity than traditional water supplies.

8. *Bobby Stewart, West Texas A&M University. "Seeding Dryland Grain Sorghum in Clumps to Decrease Tillering and Increase Grain Yield."*

Overview

The rationale behind this project is to investigate, through field research, whether growing grain sorghum in clumps has the potential to increase yields under water-short conditions. Previous studies suggest that growing grain sorghum in clumps may produce fewer tillers and less vegetative growth early in the season, thus leaving more water in the soil that can be used in the critically important grain-filling period.

Opportunity for Water Savings

Field research was carried out on the Texas High Plains in 2005 to determine if growing grain sorghum in clumps producers fewer tillers and increases grain yields, compared to plants grown in traditional furrows. The research involved monitoring the grain sorghum crop as well as measuring the ratio or red to far-red light (R: FR) to obtain data about crop growth and water use trends. Results suggest that the number of tillers decreases when grain sorghum plants are grown in clumps. When the number of tillers decreases, more grain filling occurs and a higher harvest index is generated. Because of this project, agricultural producers in the High Plains and Rolling Plains are showing increased interest in growing grain sorghum using this dryland strategy. In sum, the project indicates that growing grain sorghum in clumps may be a viable way to practice dryland agriculture in the region. If widely adopted throughout the region, the project has a significant potential to promote dryland agricultural production method on the Texas High Plains, thus helping preserve the Ogallala Aquifer.

9. *Giovanni Piccinni and Kenneth White, Texas A&M University Agricultural Research and Extension Center at Uvalde, and Thomas Gerik, Blackland Research and Extension Center at Temple. "On-Farm Research to Evaluate Irrigation Scheduling Tools to Increase Yield and Control Diseases."*

Overview

The goal of this project is to reduce the production costs of crops grown in the Rio Grande region by improving irrigation efficiency in stressful environments (i.e., where heat and drought stress occur) while controlling diseases such as aflatoxin and common root rot. The research will identify irrigation scheduling and farm management tools and educate growers about how to these methods to deal with factors that stress corn crops.

Opportunity for Water Savings

This project focuses on evaluating research findings from Texas Agricultural Experiment Stations throughout Texas to determine if the use of potential evapotranspiration (PET) data in farm settings can result in more efficient irrigation applications, thus conserving water resources. The project consists of computing evapotranspiration data to assess the growth and development of irrigated crops now being grown in the Edwards Region. The CropMan computer model is then used to evaluate irrigation management and crop production practices that achieve water conservation without adversely affecting crop yield and profitability. In this project, CropMan was calibrated using various formulas for crop evapotranspiration (ETc). Comparisons were made between ETc values derived from the use of in-ground weighing lysimeters and ETc values developed by using various formulas. Preliminary data suggest that 50,000 to 60,000 AF of water could be saved each year if all the agricultural producers in the Edwards Aquifer region implemented irrigation scheduling based on PET data.

10. John Sij, Texas Agricultural Experiment Station at Vernon. "Managing Water Resources of the Seymour Aquifer Using Subsurface Drip Irrigation"

Overview

The overall objective of this project is to research and demonstrate how subsurface drip irrigation systems have the potential to conserve water and increase yields and profits for agricultural producers at sites in the Rolling Plains where groundwater resources are limited. The project will install, test, and monitor subsurface drip irrigation systems being installed at the Chillicothe Research Station. Research results will be demonstrated to agriculture producers in the region through demonstrations, field days, and Extension efforts.

Opportunity for Water Savings

This project prepared a subsurface drip irrigation research site at the Texas Agricultural Experiment Station Chillicothe Research Station. The site will be used to conduct research into the extent to which deficit irrigation may enhance water-use efficiency and conserve groundwater resources.

Previous research results from subsurface drip irrigation plots at the Texas Agricultural Experiment Station in Munday showed that the volume of irrigation water applied could be cut by 50 percent if irrigations were based on potential evapotranspiration data. Research results also suggest that reducing irrigation by 50 percent would negligibly reduce crop yields (by 20 percent). These findings suggest that deficit irrigation, when combined with conservation tillage, could extend the usable life of groundwater resources in the Seymour Aquifer.

Equipment Installation for the Evaluation of Crop Row Direction and Offset Distance from Subsurface Drip Irrigation Laterals

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Background and Objectives

Past research has shown that well designed and managed subsurface drip irrigation (SDI) systems are more water efficient that LEPA and spray irrigation systems, particularly at low irrigation capacities (Bordovsky and Lyle, 1998, Bordovsky and Porter, 2003). However, maintaining crop rows in SDI fields at precisely the same relative location to underground water supply lines, year after year, is very difficult. Crop row position relative to buried drip laterals directly affects seed germination as well as plant development, particularly in areas of limited irrigation capacity. The effects on cotton production of crop row to drip tape location in alternate-furrow SDI installations has not been determined. In addition, planting perpendicular to buried drip tape laterals occurs in some areas of the South Plains, simplifying the use of SDI systems in certain situations. Crop response and the effects of long-term tape deterioration resulting from planting crops perpendicular to drip tape laterals is not known. The overall objectives of this research are to:

1) Quantify the effects on cotton germination, yield and WUE of planting row distances (horizontal, not depth) from drip tape laterals at two irrigation levels; and,
2) Quantify the effects on soil compaction, cotton germination, yield and water use efficiency of plant row orientation relative to drip lateral direction (perpendicular vs. parallel) at two irrigation levels.

This project assisted in the development and installation of appropriate test equipment for this research.

Description of SDI Installation

This project was conducted at the TAES research facility at Halfway. It involved the installation of 4.4 acres of SDI with sets of drip tape laterals oriented both parallel and perpendicular to the final crop row direction (Figure 1). The SDI field was surveyed (topographic) using mobile GPS survey equipment. From this map, drip tape lateral positions and corresponding GPS tractor guidance files were created using ArcView® 9 software. The guidance files were loaded onto a Trimble AgGPS Autopilot® aboard a John Deere 7420 4WD tractor. Drip tape was installed with this equipment in a non-listed (flat) field (Figure 2). The drip tape offsets were planned and installed according to the experimental treatments. All drip supply manifolds and flush lines were installed, connected, pressure checked, and flushed (Figures 3 and 4). The concrete base for a control center/filter station has been constructed (Figure 5). An abandoned irrigation well located on the research farm was cleaned and test pumped, and a submersible pump and motor were installed to provide a water source for this field experiment.

The field experiments will be a two factor-split plot design. The main factor will be irrigation capacity with treatments of approximately 2.5 and 4.0 gpm/acre. The sub-factor will be plant row orientation or location relative to drip tape position. The seven sub-factor treatments will be parallel-planted row offsets to SDI tape laterals of zero, 5," 10," and 15" (treatments 1-4) and perpendicular planted rows relative to SDI laterals with lateral spacings of 30," 45," and 60" (treatments 5, 6, and 7). Planted rows will be 30" apart with plot sizes of 8 rows by 90 ft in the parallel lateral treatments and 8 rows wide by 30 ft in perpendicular lateral treatments. The field is divided into four blocks providing four replications. The irrigation system is composed of 8 SDI zones.

The first crop year will be planted in 2006. Plantings will be conducted using a GPS guided tractor to provide planned offset distances from SDI tape laterals. Data collection will include plant population at germination, volumetric soil moisture, soil compaction (across and along drip tape), lint yield, and WUE. Opportunity for root pattern and fertilizer placement studies will exist in the future.

Anticipated Results

Seed germination in dry years and soil compaction around drip tape have caused problems or reduced yields in two of the past three years at the TAES research site at Halfway/Helms (Bordovsky, 2004). In general, documenting crop response relative to drip tape position and orientation will help address management problems and provide information for economic decisions concerning conversion to more efficient drip irrigation systems. This project will also help determine the value of precision-guided tractors in terms of water conservation and production efficiency on the South Plains. Specific benefits of this experiment include improved management by determining the economic loss (or gain) of crop row placement "offset" from optimum position relative to drip tape laterals, and of increasing planting flexibility by planting cotton perpendicular versus parallel to SDI laterals.

References

Bordovsky, J.P. and W.M. Lyle. 1998. Cotton irrigation with LEPA and subsurface drip systems on the Southern High Plains. Proceedings of the 1998 Beltwide Cotton Conference, San Diego, CA, 409-412.

Bordovsky, J.P. and D.O. Porter. 2003. Comparison of spray, LEPA, and subsurface drip irrigated cotton. Paper No. 032008. American Society of Agricultural Engineers International Meeting, Las Vegas, Nevada. Pp. 1-11.

Bordovsky, J. P. 2004. Subsurface drip irrigation design and management for cotton production. Project 02-210 TX. 2003 Annual Report to Cotton Incorporated. 13 pp.

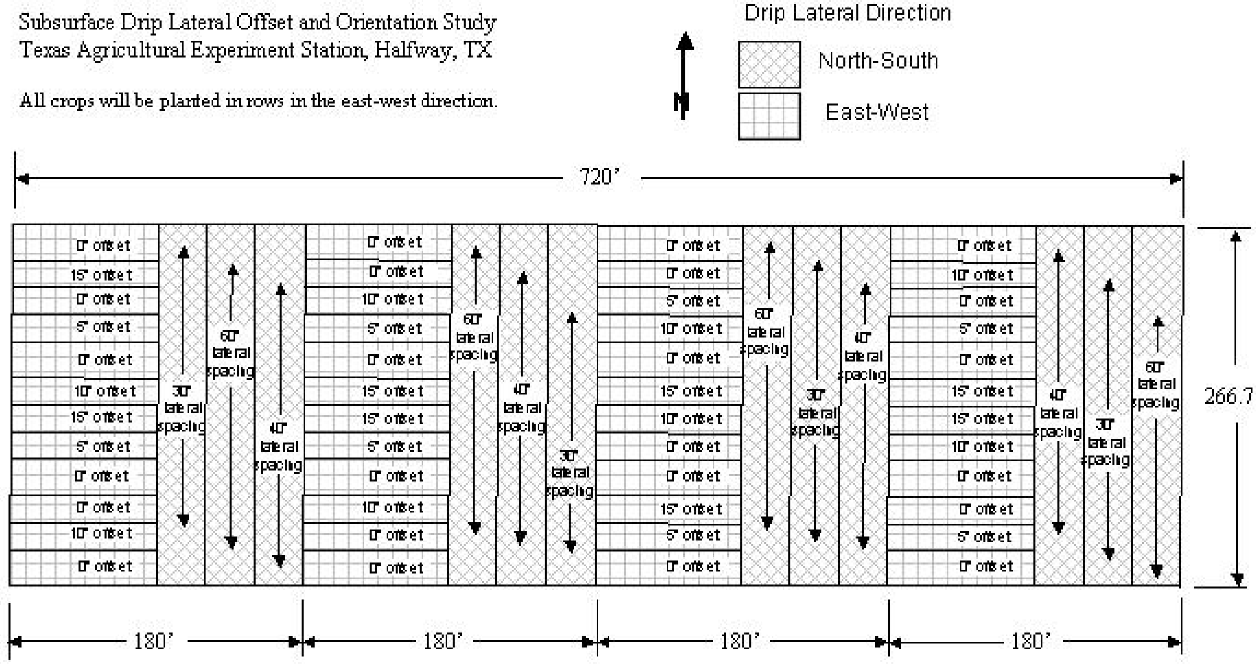

Figure 1. Plot map for drip lateral offset and orientation study, TAES, Halfway. Installation was conducted in 2005. The first crop experiments will be in 2006.

Figure 2. Installation of SDI laterals with GPS guided tractor, Joe Mustian, Doug Nesmith, and Cody Mull, TAES, 2005.

Figure 3. Opening ditches with a Cleveland trencher for water supply and flush manifold connections to SDI laterals.

Figure 4. SDI drip lateral connection to water supply manifolds, TAES, 2005.

Figure 5. Concrete base for SDI water filter and zone valve control station, TAES, 2005.

On-Farm Volumetric Measurement of Irrigation Water Use As A Best Management Practice Tool For Water Conservation In Drip Irrigated Vegetables

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Project Goal

To use affordable totalizing water meters to accurately measure irrigation water inputs and get a better estimate of the amount of water that can be saved through the use of drip irrigation compared to furrow irrigation. This project is part of a wider effort to improve on-farm water conservation and crop water use efficiency (WUE) in vegetable production systems in the Lower Rio Grande Valley through site-specific irrigation scheduling approaches.

Project Location

Sullivan City, Hidalgo County, TX: Cooperator: Valley Onions, Inc, Duda Farms: 2004
Edinburg, Hidalgo County, TX: Cooperator: Valley Onions, Inc, Duda Farms: 2005
Rio Grande City, Starr County, TX: Cooperator: Tetra Fruit & Vegetable Company: 2005
Weslaco - Hidalgo County, TX - Texas Agricultural Experiment Station: 2004, 2005

Summary

Information on how much water can be saved by adopting on-farm water conservation technologies is scarce due to a lack of accurate records of crop water use. In this study, we used portable, reusable and affordable totalizing water meters to estimate crop water use and the amounts of water that can be conserved by switching from furrow- to sub-surface irrigation of onions in the lower Rio Grande region of Texas. Results obtained from commercial onion fields in Sullivan City (Hidalgo County), indicate that about 0.9 acre-feet of water could be saved by using subsurface drip irrigation instead of furrow irrigation. We estimated that the current practice of furrow irrigation uses about 2.2 acre-feet of water for onion production. These water savings were obtained without compromising productivity. This translates to nearly 8,000 acre-feet of potential water savings in onion production for the Lower Rio Grande Valley given that only about 10 percent of the 11,000 acres of onions currently grown in the Valley are drip irrigated. Volumetric monitoring of on-farm water use provides the most accurate means for documenting on-farm water use, fine-tuning irrigation scheduling, and quantifying the success of water conservation when best management practices are implemented. Volumetric flow-metering, when used in conjunction with other water conserving strategies, can increase growers' profit margins by reducing production costs. Converting from furrow to drip irrigation of major vegetables grown in the Valley could conserve a significant amount of water and actually increase productivity.

Furrow irrigation is used on onion crops at Sullivan City in Hidalgo County, Texas.

Introduction

The adequacy of water supplies continues to be a major concern for agricultural production in most of Texas particularly in the Lower Rio Grande Valley, which is the most important vegetable production region in the state. Drought vulnerability is particularly high for vegetable crops because they are harvested, marketed and consumed fresh. A uniform supply of moisture throughout the growing season is therefore essential for vegetable production. Major Valley vegetable crops such as muskmelons, onions, and cabbages can require up to 20-30 inches of water depending on weather, soil, and management factors (Dainello, 1996). With less water available for irrigation, improved water management techniques are needed to optimize yields. Irrigation scheduling for vegetable production in the Valley is largely based on empirical assessments of factors such as days since the last irrigation or crop and soil symptoms. Such approaches can cause drought stress during periods between irrigations and anoxia due to excessive irrigation. Water requirements for major vegetable crops grown in the Valley are highly variable, partly because accurate records of water used in irrigation are not available. Compared to furrow irrigation, subsurface drip irrigation is an efficient means of delivering water to the crop root zone with minimal losses. It is also ideally suited for monitoring irrigation water input by use of various measuring devices. In order to quantify the potential water savings and water use efficiency of drip compared to furrow irrigation, it is essential to obtain accurate data on the amount of water supplied.

Objectives

The main objective of this project was to determine the potential water savings in drip- compared to furrow-irrigated onions. Affordable totalizing water meters were used to accurately measure irrigation water inputs. Total water use was compared with crop evapotranspiration for the season. We also compared water use in a typical commercial production field with results from fields that were irrigated based on crop evapotranspiration.

Procedures

The first phase of this study was conducted during the 2004-2005 onion growing season in commercial-scale onion fields in Sullivan City (Hidalgo County; soil type, Reynosa silty clay loam; about 32 acres) and Weslaco (Hidalgo County; Raymondville clay loam soil; about 5 acres). The cooperating grower in Starr County was Duda Farms.

The second phase was planted in the fall (October) of 2005 at three locations: Rio Grande City (Starr County; Lagloria silt loam), Edinburg (Hidalgo County; Hidalgo sandy clay loam) and Weslaco. This report includes data from the first phase only.

Onions (cv. Texas Grano 1015Y) were direct-seeded in double rows, spaced 10 inches apart on 40-inch wide raised beds with drip tape (T-Tape, T-Systems Int. Inc., San Diego, CA) installed at a depth of 6 inches. The drip tape had emitters spaced 12 inches apart and a flow rate of 0.45 gal/minute/100 ft. At Sullivan City and Weslaco, furrow-irrigated plots were also established.

This subsurface drip-irrigated commercial onion field is in Sullivan City in Hidalgo County.

Irrigation scheduling in the commercial fields (Sullivan City, Rio Grande City and Edinburg) was managed entirely by the grower and was based largely on empirical assessments such as days since the last irrigation or crop and soil symptoms. Weather conditions were also monitored and recorded at these sites. At the Weslaco sites, irrigation scheduling was based on soil moisture monitoring and crop evapotranspiration (ET_c) using crop coefficients from the United Nations Food and Agriculture Organization (FAO) and reference ET_o data from a local weather station. At one of the Weslaco sites (Center), irrigation was managed so the drip- and furrow-irrigated plots would receive roughly the same total amount of irrigation water. At the other site (Annex), irrigation decision making was independent for drip- and furrow irrigation plots. In general, irrigation was managed to match crop evapotranspiration demand and maintain the moisture at field capacity level. Soil moisture was monitored at 15-cm and 45-cm depths using Watermark soil moisture sensors connected to portable data loggers (WatchDog, Model 200, Spectrum Tech. Inc.). The amount of water applied to each plot through irrigation was recorded with ½-inch diameter totalizing water meters (Model DLJSJ50, Daniel L. Jerman Co., Inc. Hackensack, NJ) connected to the irrigation system. Water meters were installed at the junction between the main water delivery tube and the drip tape. Several water meters were installed in each field and data were averaged based on the total land area that was planted and irrigated. Prior to installation, each water meter was calibrated at typical drip tape flow rates (Max. 0.45 gal/minute/100 ft) by connecting it in series with a flow monitor (Model Eggs Delta FLM21-10NCW, Sparling Instruments, Inc. El Monte CA). Cumulative water inputs from rainfall and irrigation were calculated at the end of the irrigation treatments.

Onions were harvested on April 21, 2005, at Sullivan City and on April 25, 2005, at Weslaco. Yield was calculated on a unit area basis and onions were further classified by size as small (less than 5 cm in diameter), medium (between 5 and 7.5 cm), large (between 7.5 and 10 cm), and colossal (greater than 10 cm). Additionally, the quality parameters – pungency (measured as the pyruvic acid concentration, µmoles/mL) and soluble solids content (°Brix) were measured following standard procedures (Randle and Bussard, 1993). Water use and yield data were used to calculate crop water use efficiencies (crop yield/water applied).

This photo provides a close-up view of economical totalizing water meters that were installed to record water inputs on onion fields. At each site, a sensor (inset) was installed to record irrigation data

Results and Discussion

Sullivan City Site: Cumulative onion evapotranspiration (ETc) calculated from weather station data was 16.0 inches. Reference ET values at and shortly after planting were fairly low (0.01 – 0.25 inches), hence crop water use was also low. Total rainfall throughout the study duration (2004-2005 growing season) was 6 inches and an additional 16.1 inches of irrigation water was applied to the crop. Thus, the amount of water supplied throughout the growing season from rain and irrigation exceeded crop water demands (ETc) by nearly 35 percent (5.6 inches). This may be due, in part, to the fact that on a few occasions there was a heavy rainfall event following irrigation. However, the total amount of water supplied by irrigation alone was similar to the calculated crop ETc. As expected, more water was applied to furrow-irrigated fields (66 percent of crop ETc or 11 inches) compared to drip-irrigated fields. However, average onion yields from drip-irrigated fields were more than double (125 percent) those from furrow-irrigated fields. Long intervals between irrigations in the furrow-irrigated fields probably predisposed plants to water deficit stress and poor stand establishment, ultimately contributing to the diminished yields. Switching from furrow to drip irrigation saved 10.6 inches of irrigation water and increased yields and water use efficiency.

Table 1: Weather parameters and water use of sweet onion grown at two locations in the Lower Rio Grande Valley using two irrigation types (sub-surface drip, SDI or furrow).

Site	Irrigation method	Season ET_c, in	Irrigation (inches)	Combined irrigation & rain (inches)
Sullivan City	Drip	16.0	16.1	21.6
	Furrow	16.0	26.7	32.2
Weslaco	Drip	20.2	14.9	18.6
	Furrow	20.2	13.0	16.7

Weslaco Site: Crop water demand as calculated from cumulative ETc throughout the growing season was 20.2 inches. Total rainfall received during the growing season was 3.7 inches and irrigation water inputs totaled 14.9 inches. The amount of water supplied (18.6 inches of rain + irrigation) throughout the growing season was 8 percent less than the crop water demand (Etc) of 20.2 inches. The total amount of water supplied by subsurface drip irrigation alone was 26 percent less than crop ETc. Even though ETc was greater in Weslaco than in Sullivan City, significantly less irrigation water was applied (compared to ETc) in Weslaco, but average yield from the SDI fields were similar (65 $t \cdot ha^{-1}$) at both sites. The higher water savings at the Weslaco site may reflect the improved irrigation scheduling approach which was based on a combination of soil moisture monitoring, weather-based irrigation scheduling and volumetric measurement of irrigation water. This resulted in reduced water use without compromising yield and quality. The amount of water used in furrow-irrigated onions was similar (13 inches) to the amount of water used in drip-irrigated fields. However, the furrow-irrigated fields probably experienced water deficit stress which resulted in significantly reduced yields compared to the drip-irrigated fields. Yields from drip-irrigated fields were 70 percent greater than those from furrow-irrigated fields.

Table 2: Yield and quality (pyruvic acid development, PA; total soluble solids content TSS) of sweet onion as influenced by irrigation type (sub-surface drip, SDI or furrow) at two locations in the Lower Rio Grande Valley.

Site	Irrigation method	Yield, $t \cdot ha^{-1}$ Small	Medium	Large	Colossal	Total	PA $\mu mole \cdot ml^{-1}$	TSS %
Sullivan City	Drip	0.67	13.2	43.1	7.5	64.5	4.1	8.1
	Furrow	-	-	-	-	28.7	4.9	8.8
Weslaco	Drip	0.40	10.8	42.3	10.9	64.5	3.1	7.1
	Furrow	0.38	19.3	17.9	0.24	37.9	3.7	6.5

At a second field site in Weslaco (Annex), water use of drip- and furrow-irrigated onions and cabbage were compared. As expected, more water was applied to furrow-irrigated fields compared to drip-irrigated plots (68 percent for cabbage and 46 percent for onion plots) during each irrigation event. Compared with cumulative ETc for the study period, drip-irrigated plots saved about 4.5 inches of water whereas furrow-irrigated plots were over-irrigated by about 0.75 inches. The lower water savings (of drip vs. furrow irrigation) at the Weslaco sites compared to the Sullivan City site are an indication of improved irrigation scheduling techniques (weather + soil based) used at the Weslaco sites. Notwithstanding the lower water application rates under drip- compared to furrow-irrigated plots, yields were significantly higher in drip-irrigated fields. The yield difference between drip- and furrow-irrigated plots was much greater in onions (103 percent) than in cabbages (11 percent). The shallow rooting habit of onions, together with greater water loss from exposed soil in onion plots, may account for the much of the difference.

Table 3: Yield and water use efficiency of 'sweet onions' (Texas Grano 1015Y) and cabbage (Blue Vantage) as a function of irrigation method.

Crop	Irrigation method	Irrigation (inches)	Combined irrigation & rain (inches)	Yield, $t \cdot ha^{-1}$	WUE $t \cdot in^{-1}$
Onion	Drip	9.5	18	34.5	1.92
	Furrow	13.9	22.5	17.0	0.76
Cabbage	Drip	8.8	17.4	56.8	3.27
	Furrow	14.8	23.3	51.0	2.19

Conclusions

Significant water savings were obtained by switching from furrow to drip irrigation without compromising productivity. Portable, reusable and affordable totalizing water meters enabled precise monitoring and measurement of irrigation water inputs. When used in conjunction with soil moisture monitoring and improved irrigation scheduling techniques, these methods resulted in observed water savings and increased water use efficiency. Volumetric water measurement will give growers a more precise idea of crop water requirements and may reduce wasteful water applications. This technique could potentially increase growers' profit margins by reducing production costs. The current total acreage of major vegetables (onions, muskmelons, cabbages, watermelons, and peppers) grown in the Lower Rio Grande Valley is approximately 30,000 acres. With the exception of muskmelons, most of these vegetables are still grown with furrow irrigation. Converting from furrow to drip irrigation could conserve a significant amount of water and reduce production costs. For shallow-rooted crops such as onions, supplying water directly to the root zone where it is most needed can lead to improved crop water use efficiency.

Future Research

The second year of this research was established in October 2005 in two additional field sites in Edinburg (Hidalgo County) and Rio Grande City (Starr County). This research is expected to provide the basis for development of best management practices for on-farm water conservation in vegetable production systems in the Lower Rio Grande Valley.

Acknowledgements

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Implementing Biological Control of Saltcedar in the Upper Colorado River Watershed

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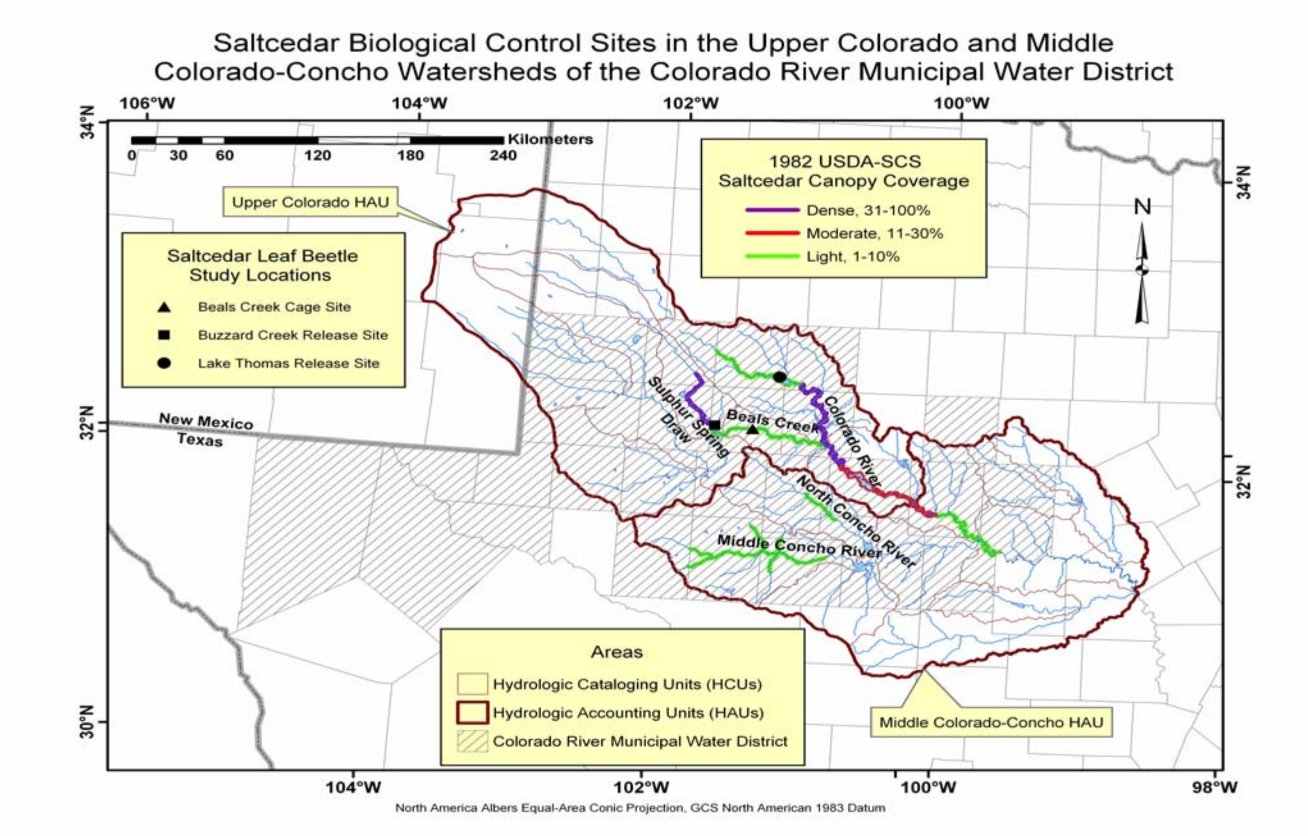
Introduction

Saltcedar is an exotic plant, introduced into the United States in the 1800s as an ornamental and later planted along waterways and stream banks for erosion control. Saltcedar soon naturalized and by the 1920 was rapidly spreading throughout western Texas and adjacent states. Today, saltcedar infests an estimated 500,000 acres of stream banks and water courses in Texas. Saltcedar is an aggressive invader, grows in extensive, monotypic stands, and displaces native vegetation. The greatest economic impact of saltcedar is the high water use of extensive saltcedar stands. Studies have shown that along the upper portion of the Pecos River in Texas, an acre of dense saltcedar consumes an estimated 5-7 acre feet of water, or 2.5 million gallons, each year. Roots of saltcedar can grow deeper than native cottonwoods and willows and as a result saltcedar can extend across more of the river basin, tapping deeper layers of water.

The high water consumption resulting from extensive stands of saltcedar is especially serious in west Texas where long-term drought conditions have prevailed since 1992. In 2002, the combined capacity of the Colorado River Municipal Water Authority's three reservoirs, Lake Thomas, Lake Spence and Lake Ivie, fell below 25 percent. These reservoirs provide water to 450,000 citizens in west central Texas, including the cities of Midland, Odessa, Big Spring and Abilene. There is an estimated 16,000 acres of saltcedar in the basins of these reservoirs and an additional 6,000 acres grow along the Colorado River and its tributaries. The Colorado River Municipal Water Authority estimates that saltcedar annually consumes enough water to meet the yearly needs of the city of Odessa.

Area-wide control of saltcedar can be achieved with herbicides applied by helicopter or airplane at a cost of about $200 per acre. In recent years, 6,300 acres of saltcedar have been treated with herbicide along the Pecos River in Texas. A program planned for 2005 to apply herbicide to the 22,000 acres of saltcedar in the Upper Colorado will cost an estimated $3.2 million. Herbicides are toxic to native trees and plants which limits their use to areas where saltcedar is the dominant vegetation.

Biological control uses natural enemies to limit the competitiveness of exotic plants like saltcedar. Biological control programs using imported natural enemies have been used to control rangeland and aquatic weeds for many years in the U.S. and are currently being used to control maleluca in Florida, purple loosestrife in the northern states, leafy spurge in the plains states, and



yellow star thistle in California. This approach is closely regulated by state and federal agencies and has a long history of safety and effectiveness.

Saltcedar is an excellent target for biological control as it is widely regarded as a pest species and has no close relatives in North America, reducing the risk that imported natural enemies could damage non-target plants. Saltcedar is a native of Europe and Asia, and was introduced without the many natural enemies that attack it in its native home. Introduction of selected natural enemies will help re-establish the natural enemy complex that is expected to suppress saltcedar survival and reproduction, making it less competitive with native plants. Biological control will not eradicate saltcedar, and it is much slower than the use of herbicides. However, once populations of natural control agents are established, they are self-sustaining and no additional releases are necessary.

Biological control has the potential to provide a low-cost and sustainable compliment and in many areas is an alternative to the sole reliance on herbicides for area-wide management of saltcedar in west Texas. Aerial application of herbicides is best suited to extensive, monotypic stands of saltcedar as costs are minimized and in areas where there are few or no native trees which are susceptible to the herbicide. Herbicide programs are not cost-effective when saltcedar stands are small and intermixed with desirable native vegetation. Biological control is well suited to both situations.

The saltcedar leaf beetle, *Diorhabda elongata*, is the first insect approved for introduction into the U.S. for biological control of saltcedar. Research by Dr. Jack DeLoach, USDA-ARS at Temple, TX, has demonstrated that the saltcedar leaf beetle feeds only on saltcedar (genus *Tamarix*) and does not attack any plant of economic importance or any endangered species of plant. The USDA Animal and Plant Health Inspection Service, the U.S Fish and Wildlife Service, and the Texas Department of Agriculture, have approved release of this beetle in Texas. The saltcedar leaf beetle is highly specific, feeding only on saltcedar, and thus effective where saltcedar is mixed with native trees. Once saltcedar infestations are reduced by herbicides or natural enemies, it is expected that saltcedar beetles will persist at low levels and feed on seedling plants, thus limiting re-invasion of treated areas by saltcedar. In fact, the value of these beetles may be especially significant in the control of seedling plants which invade newly exposed mud flats and regrowth from root pieces which re-infest areas cleared of saltcedar by herbicides, fire or mechanical means.

Objectives

The saltcedar leaf beetle was released at three sites near Big Spring, Texas in 2003-2004 and a small population established in the field in 2004. The goal of this project is to increase beetle numbers and re-distribute them along saltcedar infested areas of the Upper Colorado River and its tributaries. This mass rearing and redistribution program is needed to speed the increase and spread of beetles and maximize their potential benefit in reducing saltcedar infestations.

The objectives of the project are to:

1. Establish additional nursery sites for rearing large numbers of saltcedar beetles in field cages in west Texas.
2. Collect beetles from the field and nursery cages and release them at selected sites on the upper Colorado River and its tributaries in cooperation with the Colorado River Municipal Water Authority and local landowners.
3. Determine the establishment rate and quantify the increase in beetle numbers, their dispersal from the release site and the defoliation of saltcedar trees by beetles.
4. Conduct research to improve establishment by optimizing the number of beetles released, timing of release, and evaluate cutting back trees to stimulate new growth attractive to egg-laying beetles.

Maintain and Monitor Nursery Site on Beals Creek

The population of saltcedar leaf beetles established on Beals Creek in 2004 overwintered and steadily increased in numbers and distribution in 2005. By late July, the beetles had moved ca. 200 meters from the original release site and completely defoliated about 100 saltcedar trees. By mid-July, beetle numbers had increased such that we felt confident we could collect beetles for release at additional sites without risking the loss of the Beals Creek population. In August, this population had completely defoliated about 200 saltcedar trees. The Beals Creek site was intensively monitored by Dr. Jack DeLoach, ARS Research Entomologist and his staff from Temple, TX.

Release at New Sites and Evaluation of Release Methods

Three transects were established along Sulphur Springs Draw, Beals Creek and on the Davidson Ranch southwest of Big Spring, TX in May and June 2005. Each transect consisted of 6-9 release trees spaced 0.2 miles apart following the drainage along which saltcedar grew. 5,200 beetles were released at these sites in July and September and several release methods were evaluated as described below.

Trial 1. July-August, 2005. Methods and Materials

The objective of this trial was to determine the optimum number of beetles per cage as measured by the subsequent number of eggs and larvae recovered per cage and to evaluate large branch cages for releasing adults. A second objective was to determine if cutting trees back in the spring to encourage succulent regrowth prior to releasing beetle influenced the number of egg masses deposited by released adults or survival of resulting larvae. Three of the six trees on Beals Creek were cut back to about 3 feet above the ground in April. The resulting regrowth appeared more succulent than foliage on the uncut trees which was more woody.

On July 23-23, about 1,000 beetles were collected from the field nursery site on Beals Creek and 200 from the nearby field cages. Beetles were collected by hand and also by beating branches into a bucket fitted with a funnel. All beetles were expected to be in good condition and recently emerged. Adult beetles were separated from larvae and other insects, counted and placed in sleeve cages made from nylon mesh and measuring 12 inches wide by 36 inches long. Cages were open at one end and designed to be slipped over a branch and the open end fastened around the base of the branch. A total of 10, 20 or 30 beetles was placed into each bag. A small saltcedar twig was placed in the bottom of each bag and the bags held overnight at 70 °F. The following morning, the sleeve cages were pulled onto saltcedar branches on trees in the field and the ends were tied to cage the beetles on the branch.

Three release rates were used: 40 beetles/tree (4 cages of 10 beetles each), 80 beetles/tree (4 cages of 20 beetles each) and 180 beetles/tree (6 cages of 30 beetles each). Release rates were replicated four times (4 trees) and a total of 1,200 adults were released into cages. Two replications (six trees) were positioned along the Beals Creek transect and the other two replications (six trees) were along Sulphur Springs Draw transect. Foliage on the release trees was in good to excellent condition with very little or no evidence of scale insects. The area had received rains several weeks earlier and many of the saltcedars were blooming. Also, predator densities were very low on the released trees.

On August 4, 12 days later, each cage on every tree on both transect was opened and the number of egg masses and living adults were recorded. The adults were retained in the cage and caged on a nearby branch, designated “branch two.” Ten days later, August 14, the cages along the Beals Creek transect were again opened and the number of egg masses, larvae and living adults was counted. The cage was removed and the remaining adults freed on the tree. Also, the number of larvae on Branch 1 was recorded. On August 22, the number of larvae on branches 1 and 2 were recorded as well as the percent defoliation of each branch. Each release tree was also searched for larvae and adults. Due to heavy rainfall and flooding on August 14-15, the Sulphur Springs transect was inaccessible. The cages on this transect were opened August 21 and the number of egg masses, larvae and adults and percent defoliation of the branch was recorded. The cages were removed at this time and adults were liberated on the tree.

Trial 1. July-August, 2005. Results

<u>Egg Mass Density</u>:
When egg mass data were subjected to ANOVA a significant cut or non-cut tree by adult release rate per cage interaction occurred. Therefore, data were reanalyzed by whether trees had been cut or not. This analysis revealed that in the cut trees total egg mass densities were significantly higher in the 20 beetles per cage release rate relative to the 10 beetle, but not the 30 beetle release rates (Table 1). However, the mean number of egg masses in the 30 adults/cage treatment (16.2 masses) was numerically less than in the 20 adults/cage (23.9 egg masses), suggesting that overcrowding of adults may have reduced fecundity. Egg mass densities were significantly higher when counts were made at 14 days post beetle release relative to the 22 day post beetle release rate, indicating most of the eggs were deposited during the first two weeks. In the non-cut trees, egg mass density was not significantly influenced by beetle release rate or sample date (Table 1). Two weeks after adults were released in the cages, the mean number of egg masses per cage for the cut trees (22.6) was greater than for not cut trees (13.3) for all release rates.

Table 1. Effect of release rate (adults/cage) and days post beetle release on number of egg masses per cage based on cut or non-cut trees: Beals Creek 2005.

Tree	Add Release Rate	Egg Masses /Cage	Day Post Adult Release	Egg Masses/Cage
Cut	10	9.5a	14	22.6a
	20	23.9b	23	10.3b
	30	16.2ab		
LSD (P=0.05)	7.8		6.2	
P>F	0.0066		0.0006	
Not Cut	10	8.4	14	13.3
	20	9.6	23	9.0
	30	14.0		
LSD (P=0.05)	NS		NS	
P>F	0.0967		0.0905	

The number of egg masses deposited per beetle, rather than total egg masses/cage, is also of interest in terms of optimizing beetle fecundity. Analysis of variance by sample date indicated that adult release rate and tree cut significantly influenced the number of eggs laid per adult beetle at 14 days, but not at 23 days after adults were released into the cages (Table 2). The number of egg masses deposited per beetle for the 10 and 20 adults/cage release rates were significantly greater than for the 30 adults/cage at 14 days after release. This result again suggests that overcrowding occurred in the high release rate cages and depressed beetle fecundity. The adults transferred to branch two continued to oviposit and ten days later egg masses and young larvae were present in the cages on the six trees at Beals Creek. However, neither adult release rate nor cut vs. uncut trees influenced density of egg masses 23 days after release (Table 2). At this time, only 14-31 percent of the originally released adults were alive in the cages. Some beetles had escaped through holes in the cage or while opening the cages and others were found dead in the cage. In the 30 adult/cage release rate, only 4 and 9 live beetles were observed per cage. This decline in beetle numbers may have reduced the overcrowding effect and subsequent reduction of egg mass production per adult beetle as observed on the first date. Also, beetle fecundity (masses/beetle) was significantly greater on cut trees (1.2 masses/beetle) than on not cut trees (0.70 masses/beetle) and confirmed the conclusion based upon total egg masses/ cage (Table 1). Fewer eggs were recovered from the second branch 23 days after adult release and these effects of adult release rate and tree cut were not observed.

These results suggest that 1) 20 beetles/cage is an optimum release rate as measured by egg masses/beetle and total egg masses deposited, and that 2) beetles respond to cut trees by depositing more eggs per beetle. Female beetles deposit masses of about 20 eggs/mass and a total of about 190 eggs (8-9 masses) during a three week life span. However, the number of egg masses deposited per beetle in these cages (about 1) is only one-fourth the expected fecundity of 8 egg masses/female (four masses per beetle). Assuming a 1:1 sex ratio, releasing 20 adults/cage should have resulted in a mean of 80 egg masses/cage (10 females X 8 egg masses/female). The results reported herein suggest that many of the eggs were missed in searching branches, or beetles had deposited egg masses prior to being field collected and released in the cages or that beetle fecundity of field-reared beetles is much lower than expected.

Table 2. Effect of beetle release rate and tree cut or not cut on eggs laid per beetle. Beals Creek 2005.

Day Post Adult Release	Adult Release Rate	Eggs laid/Beetle	Tree Status	Egg Masses per/Beetle
12 Days	10	1.25a	Cut	1.20a
	20	1.20a	Not cut	0.70b
	30	0.59b		
LSD (P=0.05)	0.51		6.2	
P>F	0.0214		0.0190	
22 Days	10	0.54	Cut	0.48
	20	0.47	Not Cut	0.46
	30	0.42		
LSD (P=0.05)	NS		NS	
P>F	0.8920		0.8154	

Larval Density.
Results of ANOVA of the influence of number of beetles released per cage (10, 20, 30), saltcedar trees cut or not cut, study site location, and number of days post adults released in cages on saltcedar beetle larvae densities indicated that all main effects were significant and also interactions between location by beetles per cage and days post release by cut or uncut trees. Thus, data were reanalyzed by location and days post beetle release. This analysis takes the cut or uncut trees and the days post beetle release effect out of the Sulfur Springs data since none of the trees were cut at this site
For the Sulphur Springs Draw trees, the number of beetles released per cage had no significant effect on the number of larvae recovered per cage at 23 days after release (Table 3). However, a release rate of 20 beetles per cage resulted in numerically higher larva densities relative to the 30 and 10 beetles per cage.

Table 3. Effect of beetles/cage on number of larvae 23 days after beetles placed in cage: Sulfur Springs 2005.

Beetles/Cage	Mean Larvae/Cage
10	57.1
20	92.5
30	64.9
LSD (P=0.05)	NS
P>F	0.3079

When Beals creek data were subjected to ANOVA all interactions were significant (ie. days post release by beetles per cage, days post release by cut or non-cut trees, and beetles per cage by cut or non-cut trees). Thus data were subjected to ANOVA by days post beetle release. Analysis of the data collected at 23 days post beetle release resulted in no interaction effect but significant main effects of cut or non-cut trees and number of beetles per cage. Results of the analysis indicated that releasing 20 or 30 beetles per cage resulted in a significantly higher densities of larvae per cage relative to the 10 beetles per cage release rate (Table 4). As before, the mean number of larvae was numerically greater in the 20 adults/cage relative to the 30 adults/cage. Releasing beetles on the regrowth from cut trees also resulted in a significantly greater number of larvae per cage relative to the non-cut trees at 23 days post beetle release (Table 5).

Table 4. Effect of beetles/cage on number of larvae 23 days after beetles placed in cage: Beals Creek 2005.

Beetles/Cage	Mean Larvae/Cage
10	11.5b
20	43.6a
30	32.2a
LSD (P=0.05)	
P>F	0.0120

Table 5. Effect of cutting or not cutting release trees on number of larvae 23 days after beetles placed in cage: Beals Creek 2005.	
Beetles/Cage	Mean Larvae/Cage
Cut	43.0a
Not Cut	16.1b
LSD (P=0.05)	15.0
P>F	0.0015

The number of larvae per cage counted at 30 days post beetle release indicated a significant interaction effect of number of adults released per cage by cut or non-cut trees. Larva data were reanalyzed by adult release rate. Results of the analysis indicate that regardless of whether trees were cut or not there was no significant difference in larva densities at the 10 and 20 beetles per cage release rate. At 30 beetles per cage; however, larva densities were significantly higher in the cut trees relative to the non-cut trees (Table 6). The cages at Sulphur Springs Draw were not examined until August 21 due to flooding along this draw the previous week. Adults had been caged for 18 days and in some cages all of the foliage had been consumed by adults and larvae and some insects had died. All of the trees at Sulphur Springs Draw were not cut trees and the larval mortality in these cages may have contributed to the lower density reported in Table 6 for the not cut trees.

Table 6. Effect of tree cut and adults per cage on number of larvae per cage 30 days after beetles placed in cage: Beals Creek and Sulphur Springs. 2005.			
	Beetles Released/Cage		
Tree	10	20	30
Cut	5.5	7.5	35.5a
Not Cut	4.0	3.2	13.7b
LSD (P=0.05)	NS	NS	17.82
P>F	0.6520	0.4781	0.0208

When data were analyzed by beetle release rate, densities of larvae were numerically or significantly higher in the 30 beetles per cage release rate relative to the 10 and 20 beetles per cage release rate regardless of whether trees had been cut or not (Table 7). Thus, even though each adult deposited fewer eggs per adult at the highest adult density, the greater number of resulting eggs per cage yielded a greater number of larvae per cage. This is in contrast to 23 days after beetle release when the mean number of larvae/cage was not significantly different for the 20 and 30 adults/cage treatments (Table 4). For each adult released, an average of 1-2 larvae or less were recovered 23 days after release (Table 4) or 30 days after release (Table 7). As each female deposits about 190 eggs, and assuming a 1:1 sex ratio, and 50 percent larval mortality, each beetle should have resulted in about 47 larvae (0.5 females X 190 X 0.5). As observed with egg density estimates, the released beetles either had deposited many eggs prior to being released in the cages, field fecundity is less than estimated, or mortality of eggs and larvae is very high.

Table 7. Effect of number of beetles released/cage on number of larvae/cage 30 days after beetles placed in cage: Beals Creek and Sulphur Springs. 2005.		
Beetles/Cage	Mean Larvae/Cage (Not Cut Trees)	Mean Larvae/Cage (Cut Trees)
10	5.5	4.0a
20	7.5	3.25a
30	13.7	35.5b
LSD (P=0.05)	NS	15.9
P>F	0.2384	0.0004

Three of the six trees on Beals Creek were cut back to about 3 feet above the ground in April. The resulting regrowth appeared more succulent than foliage on the three uncut trees which was more woody. There were significantly more eggs/beetle deposited on cut foliage and significantly more larvae present in cages on cut foliage than on uncut. This suggests the flush of new growth that follows cutting back a tree may stimulate greater egg deposition.

On August 22, 30 days after release, only one adult was observed on the six release trees at Beals Creek. On two of the six trees, a few larvae were observed on branches other than the branches on which the adults were released. However, defoliation was only evident on release branches. Branches one and two, which were caged for about 10 days, showed highly variable degrees of defoliation (range 1-100 percent). There was no relationship between percent defoliation and release rate.

A total of 3.5 inches of rain fell on August 14 and early on August 15. Examination of the cages on August 15 showed no evidence that larvae or adults drown or died from other causes while in the cages during this time.

Trial 2. September. Methods and Materials

The objective of this study was to compare the establishment rate of adults released in branch cages relative to the release of adults on trees without the use of cages. The later method is used by the multi-state release program initiated in 2005 in the northwestern US.

The two treatments were 1) 25 beetles/cage and 20 cages/tree for a total of 500 beetles /tree and 2) 500 adults released per tree without a cage. Each treatment was replicated three times (three trees) for a total release of 3,000 beetles. These beetles were collected from the field nursery site on Beals Creek on September 5, 2005, during 2 hours of collecting. Trees from which beetles were collected were 99.9 percent defoliated. Beetles were collected during the evening, counted, separated from other insects, placed in branch cages or cardboard tubes and provided saltcedar foliage. Beetles were held overnight at 70 °F. On September 6, beetles in branch cages were placed on trees along a transect on the Davidson Ranch near Big Spring, Texas. Each of the six trees was 0.2 miles apart. The open field release was made about one hour before sunset to encourage beetles to remain on the release tree and not disperse which often happens when released during the heat of the day. On September 12, 7 days post-release, each bag was opened and the number of adults, egg masses and larvae were counted. Cages with adults were transferred to a new branch on the same tree as tied shut as before. Each open field release tree was visually searched for five minutes and then adjacent trees were visually searched for five minutes for adults and larvae. On September 21, 15 days post-release, each cage was opened again and the number of eggs, larvae and adults was counted. Open release trees were visually searched as before.

<u>Trial 2. September. Results.</u>
On September 12, 7 days post-release, an average of 36 percent, 48 percent and 56 percent of the beetles were dead in the cages on the three cage-release trees. Very few eggs or larvae were present. The average number of eggs per cage was 0.1, 0.1 and 0.3 while the average number of larvae per cage was 0.1, 0.1 and 0.3 for the three release trees. Cages and living adults were moved to the second branch on each tree. No adults or larvae were observed on the three open field release trees. On September 21, 15 days post-release, very few eggs or larvae were present in the cages. The average number of eggs was 0.2, 0.6 and 1.0 per cage and the average number of larvae was 0.05, 0.05 and 0.2 per cage. The average number of adults per cage was 0.9, 0.6 and 1.3. As each cage originally held 25 adults, about 96 percent of the adults collected on September 5 had died by September 21. A visual search of the open field release trees failed to detect any adults or larvae.

Beetles collected September 5 were assumed to be recently emerged adults because they were present in high numbers. However, the high mortality of adults experienced in this trial suggests the beetles collected September 5 were actually old beetles of the previous generation that had deposited all of their eggs and were soon to expire. The larvae present in the field in early September must have represented those which, as adults, would overwinter. The lesson from this trial is that beetles should not be collected for re-distribution in late summer or fall as the age and fecundity (egg-load status) of the beetles is unknown. Also, many beetles enter diapause at this time and although they will overwinter, they will not deposit eggs in the fall.

Additional Nursery Cage Site

Two additional caged-nursery sites were located southwest of Big Spring and near Ft. Stockton, Texaa. In 2005. The purpose was to establish a new populations of beetles in the event the Beals Creek population should suffer a disaster and to serve as sources of beetles for later release in the open field. Beetles were released in a 10 X 10 X 6 foot screened cages. The site at Big Spring was on property owned by the Colorado Municipal Water Authority. Three cages were established at this site in the fall of 2004 and 25-50 beetles released into each cage. However, no beetles or larvae were observed in these cages the following spring on April 6, 2005. Two additional cages were set up at this site on April 13 and 7-8 beetles were released into each of these cages. A search of these cages on May 25 revealed 12-34 larvae observed in a 4 minute search. On July 23, no larvae or beetles were present in Cage 1. Grasshoppers in the cage had stripped the bark on many branches. Grasshoppers were removed and the tree cut back to encourage new growth. In cage 2, only 2 beetles were present and 30 new beetles were released inside. In cage 3, only one beetle was observed and 50 adults and 10 larvae were added to the cage. Trees in both cages were 60-80 percent defoliated by leafhoppers. On August 4, no larvae or beetles were present in Cage 2 and only one beetle was observed in Cage 3. On September 6, 300 adults and 100 larvae were released into Cage 2 and 100 adults and 50 larvae were released into Cage 3. Foliage in both cages was abundant and in good condition. These insects should overwinter in the cages and provide an additional source of insects for release in 2006.

A second field cage was established near Ft. Stockton, TX under the supervision of Dr. Mark Muegge. Beetles were released into this cage in the late summer to establish a local population for release along the Pecos River in 2006.

Conclusions

A total of 5,200 beetles were released at 18 new sites along two saltcedar-infested watercourses southwest of Big Spring during July through September, 2005. Large numbers of eggs were deposited on the release trees from releases made in July, but not from releases made in early September. The success of these releases in establishing new populations will not be known until the 2006 summer when established populations should increase to detectable numbers.

Studies on release methods suggest the following protocol for establishing new populations of saltcedar leaf beetles:

1. Beetles should be released at new sites as soon as beetles can be collected in sufficient numbers in the spring (April through June). Also, beetles should be collected soon after emergence to increase chance that they carry a large proportion of their eggs.

2. Trees planned for caging should be cut back to 2 to 3 feet above the ground in the winter or early spring (April) to encourage regrowth that appears to stimulate greater egg deposition and larval survival.

3. Beetles can be transported in and caged on release trees inside 1 x 3 foot fabric cages. Each cage is slipped over a saltcedar branch. Cage seams should be double-sewn for strength and loose threads removed so they do not snag adjacent branches.

4. A release rate of 20 adult beetles per cages results in an optimum number of eggs/adult but a release rate of 30 adults per cage results in a greater total number of larvae per cage. These results suggest a release rate of 25 adults/cage may be optimum.

5. Ten days after release, each cage should be opened to allow larvae to disperse to new foliage. The adults should be retained and caged on a second branch to continue egg deposition. After one week, the cage should be removed from this second branch and the adults released. This procedure provides protection from predators during caging and concentrates eggs on the release tree.

Plans for 2006

Beetles will be collected from the field nursery site and field cages at Beals Creek and released during April through June, 2006 following the protocol detailed above. The relationship between the total number of released beetles per tree and establishment rate has not been determined. We propose to release 25 beetles per cage and evaluate the release of 100 beetles (4 cages), 200 beetles (8 cages) and 400 beetles (16 cages) per site. Additional releases will be made in large 10 X 10 X 6 foot field cages enclosing a saltcedar tree at 1-2 sites in Borden, Scurry, Mitchell and Howard Counties and on the Pecos River in Pecos County. The goal is to establish field populations of beetles at these sites for local distribution. These releases will be conducted in cooperation with the Texas Cooperative Extension and the USDA Natural Resource Conservation Service.

Predicted Water Conservation Benefits Expected From This Project

Recent studies by Texas A&M University have shown that along the upper portion of the Pecos River in Texas, an acre of dense saltcedar consumes an estimated 5-7 acre feet of water (2.5 million gallons per acre) each year. There are an estimated 16,000 acres of saltcedar in the basins of the reservoirs on the Colorado River (Lakes Thomas, Spence and Ivie) and an additional 6,000 acres along the Colorado River and its tributaries. The Colorado River Municipal Water Authority estimates that saltcedar annually consumes enough water in the district to meet the yearly needs of the city of Odessa or about 7 billion gallons (Annual Report 2002. Colorado River Municipal Water Authority, Big Spring, Texas). These and other studies predict that a reduction in saltcedar acreage will have water conservation benefits.

The impact of beetle feeding on saltcedar survival and reproduction is only now being documented and results indicate biological control of saltcedar will be slow process requiring years. Research by Jeremy Hudgeons, MS student at Texas A&M and a partner on this project, indicates that repeated defoliation by saltcedar beetles may deplete stored carbohydrates in the tree. This suggests that as stored energy needed to regrow leaves and shoots declines over time, saltcedar trees will suffer dieback and small trees may die. Experience in Nevada indicates five or more years of repeated defoliation by beetles may be necessary before large trees begin to die. However, during this time water use by defoliated trees is less than trees not fed upon by beetles. Seedlings and small tress with less stored energy in the root crown should die more quickly.

The net amount of water saved by controlling saltcedar is difficult to predict for a variety of reasons. First, the impact of beetles on tree survival and water use has not been yet been determined and will likely vary by location across the state. Also, the impact of biological control will depend on how rapidly beetles increase in numbers and the success of programs to distribute beetles across Texas. As saltcedar density declines, native trees and shrubs will re-establish and consume water once used by saltcedar. However, roots of saltcedar can grow deeper than native cottonwoods and willows and as a result saltcedar can extend across more of the river basin, tapping deeper layers of water. This suggests there will be a net water savings as saltcedar is replaced by native vegetation. In conclusion, insufficient time has elapsed to document the impact of biological control on saltcedar survival and reproduction in Texas and therefore no estimate of water conservation benefits is possible at this time.

Acknowledgement

In addition to the investigators listed above, the following contributed to the success of this project:

- Jeremy Hudgeons, MS student, Entomology Department, Texas A&M University
- Terrell Bib, Summer Field Technician, Big Spring, Texas
- Okla Thorton, Natural Resource Manager, Colorado River Municipal Water Authority

Irrigation Scheduling in Pecan Orchards using a Soil Water Balance Model

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Problem

Pecans (*Carya illinoinensis* (Wangenh.) K. Koch) are distributed over a wide area of geographic and climatic variation, extending from northern Illinois and southeastern Iowa to the coast of the Gulf of Mexico. Pecan trees require large amounts of water for their growth. The water use of pecan trees is greater than that of most row crops and it is estimated to be 40 to 51 inches per season for mature pecan trees growing in West Texas and New Mexico (Miyamoto, 1983). Flood irrigation is the oldest and most common irrigation system used in western pecan orchards and annual irrigation is about 80 inches (Miyamoto, 1983). Irrigation amounts and timing must be determined based on the ET requirements of the pecan trees to optimize growth and production (Stein et al., 1989; Miyamoto, 1985).

Most small- to mid-size pecan growers still base their irrigation schedule on intuition, or by counting the calendar days since the last rainfall or irrigation. Previous studies have shown that most well-managed pecan orchards receive much more water than what is really needed to optimize tree performance and productivity (Sammis and Herrera, 1999; Sorensen and Jones, 1999). As much as 10 feet of water per year have been applied in pecan orchards near Las Cruces, NM (Sorensen and Jones, 1999). Overirrigation not only leads to loss of water to deep drainage, but it also increases nitrate leaching into groundwater (Basso and Ritchie, 2005; Jones et al., 1999). Consequently, new strategies for irrigation of pecan orchards are now a necessity to reduce the volume of water used. Plant-soil-weather simulation models quantify soil water and soil nutrient processes and integrate knowledge from various disciplines to offer reasonable decision-making aids for evaluating probable outcomes and recommendations independent of location, season, crop, cultivar, and management. The number of costly, multi-treatment, multi-location, time-consuming field trails can be substantially reduced by combining field research with crop simulation models to quantify the magnitude and variability in response to various management strategies.

Objectives

The objective of the proposal was to introduce an alternative method for scheduling irrigation in pecan orchard through the use of the System Approach to Land Use Sustainability (SALUS) soil water balance model. The validation of the model in pecan orchards will allow for its use in other locations with different soil and climatic conditions.

Research method

The SALUS soil water balance model used in this study was initially developed by Ritchie et al. (1985), and further described in Ritchie (1998), Basso (2000), Basso et al. (2001) and Batchelor, Basso, & Paz (2002). The soil water balance model requires inputs for establishing how much water the soil holds by capillarity, how much drains out by gravity and how much is available for root uptake. The calculation procedures require knowledge of soil water contents (volumetric fraction) for the lower limit of plant water availability, for the limit where capillary forces are greater than gravity forces, and for field saturations. These variables can be estimated by soil texture using pedotransfer functions (Ritchie et al., 1999). The model has been tested for a wide range of soil and weather condition mostly on annual crops.

Data collection was conducted in the summer months of 2005 at the Texas A&M University Pecan Experimental Orchard (lat. 30°31'N, long. 96°24'W, elevation 220 feet), located near College Station, Texas. The size of the orchard is approximately 8.6 acres, and the soil type is a Westwood silt loam soil, 0 percent to 1 percent slope (fine-silty, mixed, thermic Fluventic Ustochrepts). The orchard was established in 1984 with trees at 35x35 feet spacing. The orchard is irrigated with microsprinklers. The experiment represents the first attempt to monitor soil water content in the orchard and to develop a system to schedule irrigation based on actual plant and soil needs.

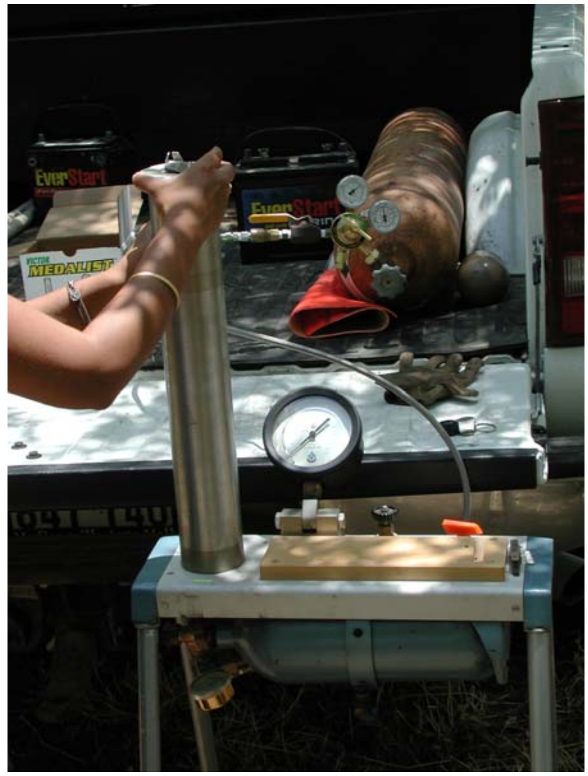
An automatic weather station (Campbell Scientific, Logan, Utah) was installed at the orchard and used to record solar radiation, wind speed and direction, air temperature and relative humidity, precipitation. Weather data were collected every minute, and recorded as 15-minute averages.

Nine ‘Pawnee’ pecan trees were selected for uniformity of height, canopy width, and trunk diameter. On July 21, 2005, the crop load of the test trees was adjusted by thinning overbearing test trees using a mechanical shaker. The reduction of the 2005 crop load allowed for better late-season carbohydrate accumulation and will potentially increase blooming and yield in the 2006 growing season.

A soil coring truck with a hydraulic press and auger attachments was used to extract soil cores for bulk density, particle density, particle size analysis, and tube installation. The vertical holes drilled with the auger were roughly 1.75 inches in diameter. Four PVC tubes (i.d. = 1.5 inches; length = 10 feet) where then placed on the north, south, east and west sides at 6 feet distance from the trunk of one tree.

Soil water content was measured using a neutron probe (Model 3321, Troxler Electronic Laboratories, Inc., Research Triangle Park, N.C.). Predawn and midday leaf water potential (ψ) was measured using a Scholander-type pressure chamber (Soil Moisture Equipment Corp., Santa Barbara, Calif.). Predawn ψ was measured between 4 a.m. to 5 a.m.(Central Time), while midday ψ was collected between 12 p.m. and 2 p.m. according to the procedure described by McCutchan and Shackel (1992). Predawn ψ was measured on Sept. 5, 2005. The orchard was then irrigated for 48 hours and ψ was measured again on the morning of Sept. 9, 2005.

PVC pipes were installed using the soil coring truck to facilitate the use of neutron probes to monitor water conditions.



Pressure chambers were utilized to measure predawn and midday water potential of pecan leaves.

After 48 hours of whole block irrigation, the soil profile was wetted to a minimum 18" depth on the north, south, and west sides of the trees. Irrigation riser placement on the west side of the trunk does not allow for complete coverage of the east side of the tree's soil, due to trunk shadowing. The average leaf water potential of the north and south side of the test trees measured before the irrigation was -0.25 MPa and -0.27 MPa, respectively. After the irrigation, the average predawn leaf water potential of the north and south side of the tree canopy was -0.22 MPa and -0.23 MPa, respectively.

Results

Preliminary data collected in 2005 have allowed us to become familiar with the technology that will be utilized in 2006. Setting up an experiment which involves the use of a delicate and somewhat hazardous instrument such the neutron probe requires extensive training and paperwork on behalf of the operators. General radiation safety training, field training and transportation training for the neutron moisture probe have now been completed by Mr. Byron Whisnant (a M.S. student involved in the project) to allow full use and mobility of the moisture probe. Mr. Whisnant has also become very familiar with the installation of the access tubes in the ground, a lengthy process that is still underway. When completed, a total of 18 tubes will be in place, with two tubes per tree and two additional tubes will be placed outside the tree influence. Mr. Whisnant has also been working on building a set of "calibrating barrels" to use when neutron probe measurements will be performed. This "saturated and air dry barrel" system allow us to calculate the slope of the calibration curve more precisely and thus to minimize the error in calculating soil water content.

Future Studies

The information gathered so far is not sufficient to make particular conclusions until it is integrated with the data that will be collected in 2006. Now that the preliminary data have been gathered, the instruments have been calibrated and utilized several times, and the installation of access tubes is almost complete. Our plan for 2006 is to apply three different irrigation regimes and monitor soil water content and plant physiology parameters for the entire season. The three treatments will include trees that will receive water only from natural precipitation (rain-fed treatment), trees that will be irrigated at regular intervals (a traditional treatment that is still common among growers), and trees that will receive water based on soil water content readings (conservation treatment).

This proposal herein seeks to accomplish, through the model validation procedure of soil water content measurements, a correct estimate of the soil water available for pecan trees, thus minimizing water losses and environmental impact. Research results will consist of soil water content measurements at different depth in the soil profile. Simulated soil water content data will be shown and compared with measured data. Soil water content data will then be correlated with tree size, leaf area index, leaf transpiration rate and leaf water use efficiency to further validate the model prediction for irrigation scheduling.

Deliverables and Outcomes

Pecan cultivation is a type of horticultural operation that can be maintained *only* with enormous volumes of water, which is extremely precious in regions where natural rainfall and supplemental irrigation are limiting. Reducing water inputs is vital for the future of the pecan industry.

With the results of the present study, we intend to obtain more information on how to optimize crop water use and quantify the variability of soil water content in commercial pecan orchards. The overall goal is to better estimate processes that account for water availability and water use in pecan orchards, thus leading to best management practices for water conservation.

The enhancement and optimization of water productivity (in measures of production or economic savings per units of water transpired) require accurate knowledge on the dynamics of crop growth and productivity responses to water stress. Such knowledge can be provided and improved with the use of such simulation models as SALUS. This is particularly important for areas where rainfall is limited and irrigation water supply is declining and/or is unreliable. Previous studies have shown that the use of SALUS to precisely apply irrigations based on crop and soil water needs reduced the volume of irrigation by roughly 30 percent. Perhaps similar water savings could be achieved by using SALUS in pecan orchards, but this will need to be verified by field research.

The application of the SALUS model will provide a better tool for an integrated plant water productivity assessment and enhancement across such domains as production and farming systems. SALUS can help decision makers in determining where and how effective savings in water use and consumption can be made, as well as where and how the highest productivity gains can be achieved by redirecting saved water resources.

Final results will be presented at industry and Extension meetings (e.g., Texas Pecan Growers Association, Western Pecan Growers Association, field days, etc.), and published in industry publications (e.g., *Pecan South*) and in scientific journals (e.g., *HortTechnology, Agriculture, Ecosystems and Environment, etc.*).

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Biological Control of Saltcedar at Lake Meredith, Texas

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Introduction

The National Park Service has estimated there are approximately 6,000 acres of saltcedar (*Tamarix* spp.) around the Lake Meredith National Recreation Area in the Texas High Plains. As part of a cooperative saltcedar biological control program involving the Texas Agricultural Experiment Station in Amarillo, the U.S. Bureau of Reclamation, the Canadian River Municipal Water Authority and the National Parks Service, saltcedar infestations along the Canadian River were targeted near the Lake Meredith area. Saltcedar-feeding beetles (*Diorhabda elongata*) from Posidi, Greece, were introduced into a test site near Lake Meredith during the summer of 2004 in an effort to establish a biological control program against the noxious weed. The beetles were released into two cages, monitored throughout the summer and found to establish viable populations with good reproductive success in their first season, despite atypical climatic conditions. In conjunction with the beetle release, 40 sentinel saltcedar trees at various distances from the release site were tagged for extensive vegetation surveys to monitor dispersal and subsequent effects of the beetles.

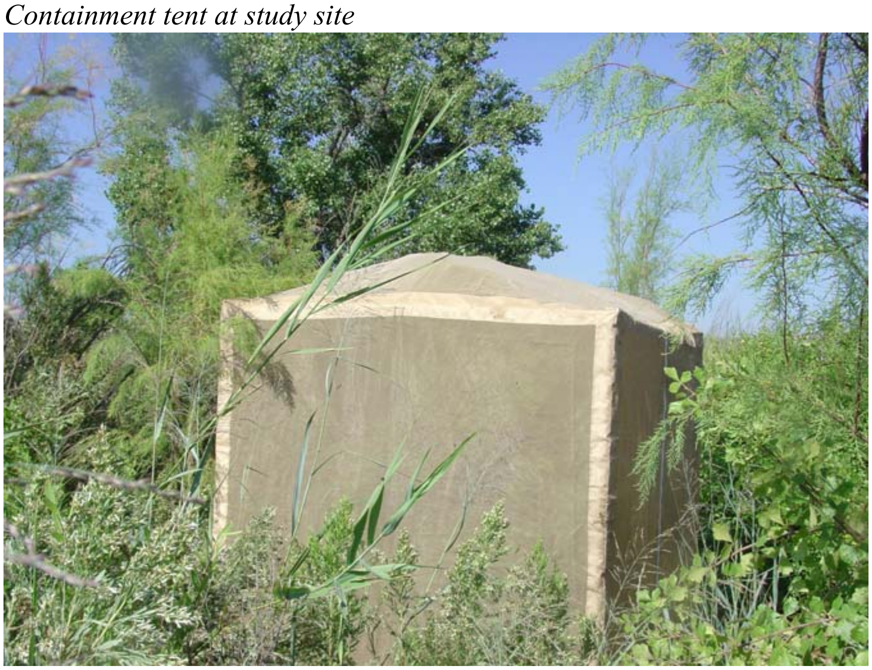
One of the 40 sentinel saltcedar trees selected for the vegetation survey

Program Activities in 2005

Photo of an adult D. elongata

Beginning in March 2005, monitoring was initiated at the study site to detect emergence of the beetles. While the beetles had been released into tents and were thus fully contained during the beginning of the 2004 season, the tent sites were opened for an extended period in the fall of 2004 and again in 2005 to allow for natural establishment of the population to the surrounding area. Overwintering success was confirmed on April 26, 2005 when 7 male beetles were located actively feeding on saltcedar. Weekly surveys of the tent sites and surrounding areas continued to yield adult beetles indicating that the beetles were effectively emerging from a period of diapause. By June 7, multiple sites around the initial release points were showing light herbivory damage and defoliation indicative of activity by the saltcedar-feeding beetle. Reproduction was corroborated with the sighting of numerous larvae in various stages of development throughout the site and extending in a 6 meter radius from the release site. These sites continued to be surveyed throughout the summer resulting in the verification of three generations of beetles. The development rate of *D. elongata* observed in 2005 corresponded to observations made the previous season. On June 30, 112 adult beetles obtained from a rearing facility in California were released into the original tent site to add genetic diversity to the established population. By August 9, reproduction in the release tent had produced large numbers of larvae with resultant heavy damage to the saltcedar trees contained within the tent.

Containment tent at study site



Four new containment tent sites were established to accommodate a redistribution of these beetles and larvae to increase their overwintering and distribution success. One hundred adult and larval-stage beetles were transferred to each of the new tent sites. Within two weeks after the transfer, the saltcedar inside each of these tents began to show signs of senescence and the beetles were no longer seen feeding on the leaves. This follows a similar pattern that was noted during the 2004 season, indicating that this generation was preparing for overwintering in the soil.

Vegetation surveys of the 40 sentinel saltcedar that had been selected in 2004 were conducted in June and again in September 2005. Data for each of these trees was recorded relative to growth and seed production. In addition, information regarding the soil type, percent ground cover, vegetative abundance and types of woody plants in proximity to these saltcedar was documented. This data will be used in a comparative study to assess both the impact and extent of the saltcedar in the area, along with efficacy of the biocontrol agents in future years. These saltcedar are located in concentric circles around the release site at distances of 50, 100 and 200 meters. During the June 2005 survey, larvae were located at two of the trees corresponding to 50 meters from the initial release site, and an adult beetle was found feeding on a tree at the 200 meter distance. Another tree at the 200 meter distance showed extensive defoliation consistent with *D. elongata* feeding. A single adult beetle was observed August 24 at the trailhead to the release area, approximately 1 km away from the original release site. These findings confirm that the beetles have successfully dispersed significant distances from the initial release site.

Measurement procedures of sentinel saltcedar taken during the vegetation survey

Saltcedar controlled burn area and habitat site for the ground beetle study

Sparse grasses and brush habitat for the ground beetle study.

A ground beetle species study was initiated to determine their diversity and density within the saltcedar-infested area around Lake Meredith. This study serves as a qualitative means to indicate changes in the ecosystem, particularly as saltcedar is reduced by the beetle biocontrol agents. The sampling sites were established in 3 distinct habitats with 9 collection points in each area. The first sampling area was located east of the release site in saltcedar that had been subjected to a controlled burn in April 2005, the second site was located in a stand of saltcedar near the release site, and the third sampling site was located north of the release site in an open area with sparse grasses and brush. The samples were collected on a biweekly basis and will serve as a baseline indicator of ground insect species richness prior to saltcedar decline. Population levels and species composition of ground beetles are expected to be altered in subsequent years as saltcedar, reduced by the biological control agents, is replaced by a more natural plant and grass community.

Media Attention

KVII TV Channel 7 conducted an interview in 2004 regarding the saltcedar biocontrol project. They followed with an update interview on June 30, 2005 to track the progress of the study. This interview aired in Amarillo and the surrounding area that evening. An article published in the July 2005 issue of *Livestock Weekly* highlighted the saltcedar biological control efforts that are being conducted around the Lake Meredith National Recreation Area by the Texas Agriculture Experiment Station.

Current Status and Future Impact

We have successfully established the beetles at Lake Meredith, a key milestone. The beetles have entered their overwintering stage for the rest of 2005/2006, and we will begin surveys in early spring to note when the beetles break dormancy and begin to feed on saltcedar. The task before us now is to continue to monitor the increase and spread of the beetles and the extent of damage to saltcedar. In 2005, the beetle population was too small to begin any redistribution efforts, however there is the potential to do so in 2006 depending on overwintering emergence and climate.

In 2006, there is a possibility of participating in a regional project that will examine the fitness of various strains of *D. elongata* at several geographic locations. This thrust is being headed by Dr. Tom Dudley of the University of California. Although the Posidi strain which we released at Lake Meredith seems to be the correct choice, there is interest in how other strains from different Palearctic areas may adapt and interbreed with established strains.

The National Park Service plans another controlled burn near our release site in February or March of 2006, and a sufficient buffer zone will be established to prevent the destruction of the site. In some way, these controlled burns are a benefit to the project since fire does little damage to the saltcedar stand, and causes the germination of thousands of new plants, providing fresh, healthy seedlings on which the beetles feed (as noted in the summer of 2005).

As to the beneficial impact these beetles will have, there are a number of facets. Saltcedar does consume large quantities of water, and this fact, coupled with its habit of forming dense stands, makes it a significant problem for semi-arid regions. Although there have been published estimates of saltcedar using up to 200 gallons of water per plant per day, there is a major concern that these figures are empirical at best, and that actual water usage may be much less. However, that does not lessen the impact saltcedar has a as noxious weed. Since it forms dense stands that are unlike native cottonwoods and willows which it replaces, saltcedar does consume more water than native plants per unit area. Therefore, controlling saltcedar will yield water savings. Salt cedar also transports salts to the soil surface. Where cottonwood and willow growth is inhibited at salt concentrations greater than 1,500 ppm, saltcedar can tolerate soil salinity up to 36,000 ppm (Jackson et al. 1990). Finally, saltcedar exacerbates the problem of wildfires. Although we believe that prescribed burns do not control saltcedar, and this is established in the literature as well (Kerpez and Smith 1987, Bush 1995), saltcedar stands produce large amounts of leaf litter and decadent growth that are prone to burning.

At the present time it is impossible to place an economic figure on the impact the beetles may have in the future. If the beetles increase at the Lake Meredith site as they have in other areas of the United States, we can expect significant defoliation to begin in one to three years. We will continue to work closely with the Bureau of Reclamation, National Parks Service, and the Canadian River Municipal Water Authority to develop and promote this project.

Funding and Support

We gratefully acknowledge the support of the Texas Water Development Board for their second year of funding for supplies, travel and wages for summer student workers.

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Determining Plant Water Use and Crop Coefficients of Selected Nursery and Landscape Plants

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Objectives

Landscape irrigation increases dramatically during summer months throughout Texas and the South West of the U.S. Thus, conserving and reducing the amount of water used for landscape irrigation is critically important. The ultimate goal of this project was to increase landscape irrigation efficiency by minimizing over-watering. The specific objective was to determine and compare the actual water use and crop coefficients of selected ornamental shrubs grown in containers (nursery practices) and drainage lysimeters, similar to landscape conditions and to find out if the water use between the two culture systems is convertible.

Methods

The following species were purchased in 1-gallon containers from a local nursery: abelia (*Abelia grandiflora* 'Edward Goucher'), butterfly bush (*Buddleia davidii* 'Burgundy'), holly (*Ilex vomitoria* 'Pride of Houston'), evergreen euonymus (*Euonymus japonica*), and oleander (*Nerium oleander* 'Hardy Pink'). Ten plants in each species were transplanted to 3-gallon containers and were placed in the field in early July and closely spaced to simulate nursery practice. Seven plants from each species were transplanted to the 15-gallon drainage lysimeters in middle June to simulate landscape conditions. After several weeks of acclimatization, water use measurement was initiated in early July.

Water use of container-grown plants was determined by irrigating to container capacity, allowing each to drain completely and then weighing them. The plants were then reweighed after 24 hours. The difference between the beginning and ending weights is the water used over the 24 hours, in cubic centimeters or milliliter (ml).

ET_{crop} (cm) = Volume of water use (cm^3)/container surface area (cm^2)

Crop coefficient was calculated as the following: $K_c = ET_{crop}/PET$

PET was calculated using the weather data recorded in the same field plot.

Water use (ET) of the plants in the lysimeters was estimated by monitoring the soil moisture depletion using the ECH_2O soil moisture probes, a multiplexer, and a datalogger. The 3-gal containers and the 15-gal lysimeters, which were buried in the ground, had the same diameter (25 cm) at the very top of the container. Therefore, same container surface area (490 cm^2) was used for estimating crop coefficients (Kc). Although rainfall was recorded, it was difficult to quantify the amount of rain getting into the lysimeters because of the various shapes of canopies that intercepted rain. Therefore, soil moisture content data were excluded on days when irrigation or rainfall occurred.

 

Plants in 3-gallon containers (the inner-side plants were being studied)(left).

Plants in 15-gallon drainage lysimeters (right).

Results

The growth index determined in October for butterfly bush and oleander plants were much higher (Table 1) in the lysimeters, where growing conditions were similar to those in a landscape, than that for container-grown plants. Leaf area of butterfly bush and oleander increased approximately 300 percent in two months. Since plants in the lysimeters were planted in June, the plants in lysimeters in August were larger than those of the same species in the containers. Abelia and euonymus grew better in the containers, possibly due to the differences in growing media or the micro-environment in the two culture systems. Holly grew similarly in the two systems

Due to the differences in plant size and leaf area, water use of plants was expressed in daily water use per plant and per unit leaf area (Table 2). The average leaf area determined in August and October was used. In both culture systems, water use per plant was highest in butterfly bush and oleander, which had the highest growth index, while abelia and euonymus had the lowest water use. However, holly had the highest water use per unit leaf area, euonymus and oleander had the lowest, while abelia and butterfly bush had slightly lower water use per unit leaf area than that of holly. For the same species, water use per unit leaf area was similar in both culture systems. This indicates that plant water use in a landscape situation can be accurately estimated through the same plant species that are grown in containers, which can be achieved readily by weighing the containers.

The crop coefficient (Kc) of abelia and euonymus was slightly higher in the containers because of larger leaf area. Kc of butterfly bush in the lysimeters was 3.3 times that of container-grown plants because leaf area in the lysimeter was 3.1 times that of container-grown plants. Similarly, Kc of oleander in the lysimeters was much higher than that of container-grown plants. Therefore, Kc of an individual plant is highly dependent on not only plant species, but also on the leaf area of the plant or growth rate.

In summary, water use and crop coefficient differed by species, growth, and months or days for both culture systems. Water use per unit leaf area of the same species was similar in two culture systems. Crop coefficient of the same species was also similar for the two culture systems when growth index was similar. Therefore, water use of landscape plants can be accurately estimated from container-grown plants, provided that growth index and leaf area can be quantified. The information obtained from study can be used to improve landscape irrigation by grouping plants with similar water use and by scheduling irrigation according to plant needs. When applying this information to landscape situation, planting densities as well as growth rate need to be considered.

Table 1. Growth index [((canopy width 1 + canopy width 2)/2 + height)/2] and leaf area of abelia (*Abelia grandiflora* 'Edward Goucher'), butterfly Bush (*Buddleia davidii* 'Burgundy'), holly (*Ilex vomitoria* 'Pride of Houston'), evergreen euonymus (*Euonymus japonica*), and oleander (*Nerium oleander* 'Hardy Pink') grown in containers and drainage lysimeters.

Species	Abelia	Euonymus	Butterfly bush	Holly	Oleander
Growth index (cm)					
Lysimeter	42.5	38.1	98.6	59.1	88.5
Container	37.1	38.8	54.9	51.7	62.6
t-test	NS z	NS	***	NS	***
Leaf area (cm^2)					
August					
Lysimeter	297	1327	773	568	2050
Container	249	1271	233	454	1712
t-test	NS	NS	***	*	NS
October					
Lysimeter	454	1586	3059	706	7655
Container	570	2519	977	460	2205
t-test	NS	**	***	*	***
Leaf area increase (%) from August to October					
Lysimeter	53	20	296	24	274
Container	129	98	319	1	29

z NS, *, **, *** nonsignificant, significant at P = 0.05, 0.01, 0.001, respectively.

Table 2. Average water use and crop coefficients of abelia (*Abelia grandiflora* 'Edward Goucher'), butterfly Bush (*Buddleia davidii* 'Burgundy'), holly (*Ilex vomitoria* 'Pride of Houston'), evergreen euonymus (*Euonymus japonica*), and oleander (*Nerium oleander* 'Hardy Pink') grown in containers and drainage lysimeters over four months.

Species	Abelia	Euonymus	Butterfly bush	Holly	Oleander
Water use per plant (L/d)					
Lysimeter	0.23	0.30	1.13	0.46	1.16
Container	0.31	0.39	0.39	0.40	0.54
t- test	NS	NS	***	NS	***
Water use per unit leaf area(mL/cm^2/d)					
Lysimeter	0.60	0.21	0.59	0.72	0.24
Container	0.76	0.20	0.64	0.87	0.28
t-test	NS	NS	NS	NS	NS
Crop coefficient					
Lysimeter	0.84	1.20	4.37	1.78	4.30
Container	0.93	1.29	1.29	1.30	1.74
t-test	NS	NS	***	NS	***

z NS, *, **, *** nonsignificant, significant at P = 0.05, 0.01, 0.001, respectively.

Impact of Drought on Salinity Tolerance of Landscape Woody Plants Irrigated With Reclaimed Water

Dr. Genhua Niu
Texas Agricultural Experiment Station – El Paso

Objectives

With the rapid increase in urban population, the diminishing potable water supply is less likely to meet future needs. Since urban landscape water use increases dramatically during summer months in Texas and the Southwest, use of municipal effluents (reclaimed water) for landscape irrigation will conserve potable water. Reclaimed water has been traditionally used for irrigating agronomic crops and golf courses. Foliage injury has been reported on salt-sensitive trees and shrubs that were planted on golf courses with reclaimed water irrigation. The objective of this project was to characterize the salt tolerance of selected landscape plants in order to expand the reclaimed water use to landscapes and minimize salt damage.

Method

The following trees and shrubs were used for this project: Black cherry (*Prunus serotina*), Green ash (*Fraxinus pennsylvanica*), Lacebark elm (*Ulmus parvifolia*), Russian olive (*Elaeagnus angustifolia*), Sand cherry (*Prunus besseyi*), Sand plum (*Prunus angustifolia*), and Desert willow (*Chilopsis linearis*). Bare root seedlings were purchased in January and planted in 3-gallon containers filled with commercial substrate (sunshine mix no. 4). Plants were placed in the field. Saline irrigation at 0.8 (tap water), 2, or 4 dS/m electrical conductivity (EC) was initiated in early July and terminated in middle October when leaves started to change color. There were two irrigation regimens: plants were re-irrigated when substrate moisture depleted to approximately 65 percent and 55 percent its container capacity, respectively. Salinity tolerance was evaluated by comparing the caliper growth in three months and visual quality of the plants (photos were taken at various times).

Results

Based on caliper growth and visual quality, lacebark elm was most salt tolerant among the tested species: it did not have any foliage injury due to salt and its caliper increased by 30 to 44 percent in three months. Russian olive had leaf injury and defoliation in some plants when irrigated at 4 dS/m and caliper of most plants increased by 20 to 30 percent. Similar results to Russian olive were observed on Desert willow. Sand plum, sand cherry, and black cherry had severe defoliation in elevated salinity treatments and did not grow significantly. Green ash plants also had leaf injury but was better than the above three species. Drought did interact with salinity on green ash and black cherry growth. Since the salinity and drought treatments were not long enough to reach conclusion, experiment will be continued from next spring.

Figure 1. Photos on the left side: one month after the initiation of saline solution irrigation; on the right side: 3 months after the saline solution irrigation. Plant species from top to the bottom: Green ash, lacebark elm, desert willow, Russian olive, Black cherry, and Sand cherry.

Anticipated Impact on Water Conservation

It is estimated that 40 to 60 percent total household water consumption is for landscape irrigation in the Southwest during summer months. If landscapes can be irrigated with reclaimed water, this amount of potable water can be conserved.

Evaluation of Factors Affecting Extent of Tillering in Dryland Grain Sorghum Clumps

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This photo shows how grain sorghum can be grown in clumps on the Texas High Plains. Growing plants in clumps may decrease tillering, more efficiently use water, and increase yields.

Introduction

Agriculture in Texas High Plains is characterized by limited water supply, high winds and temperatures promoting more evapotranspiration. Average annual rainfall for the region ranges between 400-600 mm. Grain sorghum, with its special characteristics to grow well and produce good yields even in dryland areas, is a major grain crop in the Texas High Plains. Use of stored soil water is critical for development of the crop particularly during the later growth stages. However, much of the stored soil moisture is used during the vegetative growth stages. Under dryland conditions, populations of grain sorghum plants are generally reduced but one to three tillers are commonly formed. Severe stress conditions during later stages of crop growth result in fewer tiller-producing heads that contain less grain. Studies conducted by Stewart and colleagues in Bushland Texas (2002-2004) and Tribune, Kansas (2004) revealed that planting dryland grain sorghum in clumps produced fewer tillers than uniformly spaced rows.

During an exploratory study in 2002, 53,300 grain sorghum plants were maintained per hectare. Four plants were grown per meter in equally-spaced rows and four plants were grown together in clumps. An average of 2.9 tillers per plant was produced in equally-spaced rows compared to only 1.3 tillers per plant in clumps. Plants in the equally-spaced rows showed more visible stress throughout the growing season than plants grown in clumps. Grain sorghum grown in clumps produced less above-ground biomass when compared to equally-spaced plants. Grain yields from plants grown in clumps were 2 times higher than the plants in equally-spaced rows and produced a higher harvest index.

In 2003, a more detailed study was conducted with two grain sorghum varieties grown at a density of about 80,000 plants per ha. About 6 plants per meter were maintained in 75 cm rows, with six plants in a clump every meter. Leaf area, plant biomass, the number of tillers, and leaf temperature were measured at regular intervals. Results showed a dramatic decrease in the number of tillers from grain sorghum plants in clumps (0.6 per plant) compared to the number of tillers per plant (3.0) grown in equally-spaced rows. Leaf area index and plant biomass were lower in grain sorghum plants grown in clumps than in equally-spaced rows. Tillers in grain sorghum plants grown in clumps were more likely to produce heads than plants grown in evenly-spaced rows. The harvest index was higher in plants grown in clumps than those grown in equally-spaced rows. Measurements of the average leaf temperature showed that, during the hottest part of the day, grain sorghum plants grown in equally-spaced plants were 2° C higher than plants grown in clumps. At 60 days after seeding, the difference in temperature was 4° C. which indicates the plants in the equally-spaced rows were under higher water stress.

In 2004, two varieties of grain sorghum were planted in five geometries in no-till and stubble-mulch fields. Three levels of water use were evaluated. Planting geometry had a significant influence on the number of tillers that were produced. Grain sorghum plants grown in rows with spacings of 38 cm and 25 cm produced more tillers compared to plants grown in clumps. Clump treatments consisted of growing four plants in a clump every meter and three plants in a clump every 75 cm. When four plants were grown in a clump, they produced fewer tillers than clumps that consisted of only three plants.

The field had three slope positions that resulted in differing amounts of soil water storage and runoff. Amounts of stored soil water varied across the field for each slope position (upper, middle and bench). The number of tillers produced by grain sorghum plants varied with the different slope levels. Plants grown on upper and middle slopes produced fewer tillers than plants grown on benches. The bench locations collected some runoff water from the upper and middle reaches.

Grain sorghum grown in clumps yielded significantly more grain, indicating plants grown in clumps used water more effectively than plants in equally-spaced rows. It is apparent that plants grown in clumps use less water during the early growth stages so there is more water available during the latter part of the season that can be used for grain filling. Plants grown in clumps showed higher harvest index values than plants grown in equally-spaced rows.

The studies conducted in Tribune, Kansas in 2004 utilized the same planting geometries and grain sorghum varieties used in the studies at Bushland, Texas. Grain yields in Tribune were extremely high for dryland grain sorghum because there was an unusually high amount of precipitation. Because of lack of a water stress, the clumps did not produce more yield than plants grown in equally-spaced rows.

Growing grain sorghum plants in clumps was effective in producing fewer tillers and higher yields under water-stress conditions. It was concluded that growing grain sorghum plants in clumps might be beneficial in dryland farming areas of the Texas High Plains. However, the optimal spacing and geometry needed to grow grain sorghum plants clumps in order to decrease tillers was unclear. The mechanisms that lead to a decrease in the number of tillers formed when grain sorghum was grown in clumps were also not well-understood.

2005 Research at Bushland, Texas

As a result, a detailed study was initiated in 2005 at Bushland Texas to gather additional information.

The objectives were to:

1. Evaluate factors affecting the extent of tillering when dryland agriculture methods are used to grow grain sorghum in clumps, and
2. Evaluate the optimal spacing needed to plant grain sorghum in clumps to decrease tillering.

Researchers and graduate students at WTAMU monitored conditions in this grain sorghum plot on the High Plains.

Past studies showed that the red to far-red (R: FR) light ratio may serve as a signal in the production of tillers. Reduced tillers are observed as the R: FR ratio decreases. Gautier et al. (1999) stated that the R: FR ratio is clearly involved in the regulation of tiller production in perennial grasses, and a reduction in the R:FR ratio decreases tillering. Some studies indicate that mutual shading reduced light interception per plant and a lower R: FR ratio at the bases of plants was linked to a reduced number of tillers. Derigibus et al. (1985) showed that "the R: FR ratio could serve as a signal to indicate canopy cover or leaf density. This signal then interacts with others related to the availability of various resources (water, assimilates, nutrients, etc.) to determine the rate of tiller formation or death." Jones (1985) reported that "environmental conditions favoring main stem also favor tillering. Thus, reduced competition for light, nutrients, and water favors tiller production."

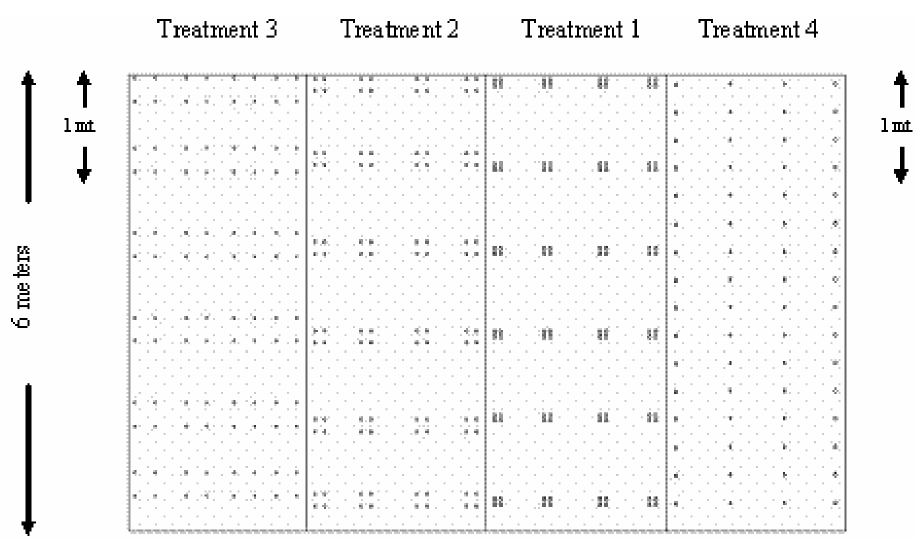
With this information, we designed two experiments for the 2005 study at Bushland, Texas.

Experiment 1

We used four treatments with different spacing between plants: 1) a close clump with all plants close to each other, 2) a clump with seeds 1 inch apart from each other in a square, 3) a clump with seeds spread 4 inches apart in a square pattern, and 4) row plants spaced every 25 cm. For every meter, there were four plants in equally-spaced rows as well as plants in clumps in every 75 cm rows.

Experiment 2

Single plants or groups of two, four or six plants were grown together in clumps every 75 cm in rows that were 75 cm apart. Thus, there were one, two, four or six plants in every 0.5625 meter^2. Tiller counts, the stage of plant growth, leaf count, and plant height were determined 4 times during the vegetative growth period. Light measurements (red to far-red ratio) were taken using a Skye 660/730 sensor. On 2 days, measurements were taken every hour from 9 a.m. to 6 p.m.

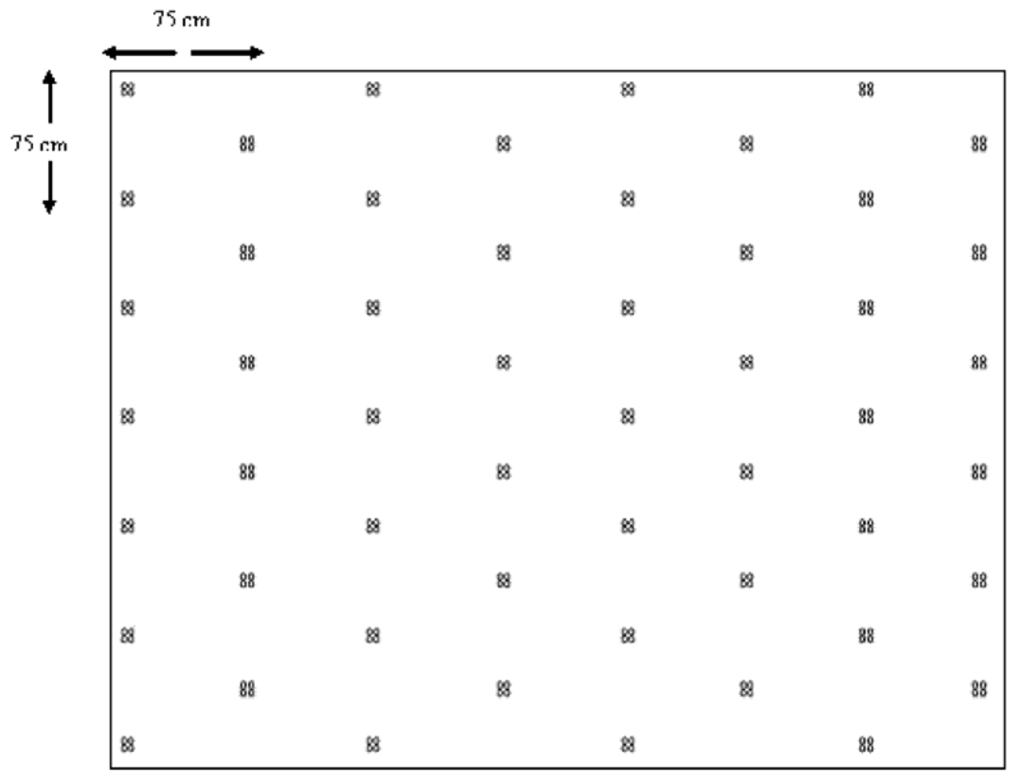


1. Treatment 1 – Four Plants in Clump (close clump)
2. Treatment 2 – Four Plants in Clump (1 inch apart)
3. Treatment 3 – Four Plants in Clump (4 inches apart)
4. Treatment 4 – Four Plants in Row (25 cm apart)

Thus, in all the treatments for every meter, there were four plants in equally-spaced rows as well as plants in clumps in every 75 cm rows.

Funds obtained for this grant was used to purchase a Skye 660/730 sensor. Light was measured in shade and sunlight sides of the plant base to estimate the ratio of R: FR light. Temperature measurements were taken at the plant base and at canopy height using a thermal infrared gun. This information was correlated to the development of tillers. Two grain sorghum varieties were evaluated in both experiments: Pioneer 8699 (variety 1) and NC + 5C35 (variety 2).

In this report, only data about tiller formation on September 2 and light measurements for 1:00 pm on August 19 are interpreted.



Vernon, TX farmer Terry McAlister used this arrangement to plant grain sorghum in clumps in 2005. Four plants were in each clump. The clumps were spaced 75 cm away from each other in 75 cm rows.

Effect of Plant Density on Tillering

Experiment 1:

The number of tillers produced per plant decreased as the plants were located closer to one another. For example, when four plants were adjacent to one another or spaced only 1 inch apart, only about 1.5 tillers were formed for each plant. In contrast, when plants were uniformly spaced several inches apart within rows, 2.3 tillers were formed for each plant. The number of tillers produced per plant in equally-spaced rows was significantly greater than for plants grown in close clumps and 1- and 4-inch clumps.

Treatment	Variety 1	Variety 2
Close clump	1.6 a*	0.9 a
1 inch clump	1.3 a	0.9 a
4 inches clump	1.8 a	1.2 a
Row plants	2.3 b	2.2 b

* Means with the same letter in columns are not significantly different ($\alpha = 0.05$).

Experiment 2:

The number of tillers decreased as the number of plants in the clumps increased. For example, one plant by itself produced 2.7 tillers, while two plants in a clump each produced 1.5 tillers. In contrast, four and six plants in a clump produced less than 1 tiller for each plant (0.6 and 0.8 respectively). Clumps with four or six plants always had significantly fewer tillers per plant clumps with only one or two plants.

Treatment	Variety 1	Variety 2
1 plant per clump	2.7 a*	4.0 a
2 plants per clump	1.5 a	1.7 a
4 plants per clump	0.6 b	0.6 b
6 plants per clump	0.8 b	0.3 b

* Means with the same letter in columns are not significantly different ($\alpha = 0.05$).

Light: Effect of Plant Density on Red to Far-red Light Ratio

Sensor in shade *(Experiment 1)*

The ratio of red to far-red light is measured in micromol/sq.m./sec per microamp ($\mu molm^{-2}s^{-1}/\mu A$) (Skye Instruments, 2005). The sensor output shows that the R: FR ratio in close clumps and 1-inch clumps is about 0.20 μmol. In contrast, the clumps with plants 4 inches apart and plants in equally-spaced plants had R: FR ratios of 0.26 μmol, which were statistically higher. This indicates that the R: FR ratio decreases as plants grow in closer proximity to one another, and fewer tillers are produced when plants are close to one another. These findings are in agreement with Deregibus et al. (1985).

Treatment	Variety 1	Variety 2	Mean
Close clump	0.21	0.23	0.22 a*
1 inch clump	0.18	0.20	0.19 a
4 inch clump	0.27	0.25	0.26 b
Row plants	0.28	0.24	0.26 b

* Means with the same letter in columns are not significantly different ($\alpha = 0.05$).

Sensor in shade *(Experiment 2)*

The R: FR ratios for a single plant (0.33μmol) and for two-plant clumps (0.27 μmol) were significantly higher than those for four-plant clumps (0.21 μmol) and six-plant clumps (0.19 μmol). The R: FR ratio becomes smaller with the increase in plant density.

Treatment	Variety 1	Variety 2	Mean
One plant clump	0.33	0.33	0.33 a*
2 plants per clump	0.25	0.29	0.27 a
4 plants per clump	0.25	0.17	0.21 b
6 plants per clump	0.17	0.20	0.19 b

* Means with the same letter in columns are not significantly different ($\alpha = 0.05$).

Sensors in sunlight (*Experiment 1*)

Treatment	Variety 1	Variety 2
Close clump	1.12	1.03
1 inch clump	1.01	1.04
4 inches clump	1.04	1.04
Row plants	1.03	1.01

Sensors in sunlight (*Experiment 2*)

Treatment	Variety 1	Variety 2
Close clump	1.08	1.04
1 inch clump	1.03	1.04
4 inches clump	1.03	1.05
Row plants	1.02	1.03

There were no statistically significant differences between the sensor measurements for any of the treatments or varieties, and all ratios were close to 1.0. This finding was not surprising because the sensors were placed in positions that received full sunlight, regardless to how close the plants were growing to one another.

Conclusion

It is a common practice to seed dryland grain sorghum in the Texas High Plains during the wetter part of the year. The stored soil moisture supported by seeding during the wetter part of the year produces two to three tillers per plant and large amount of above ground biomass. Because water often becomes a limiting factor during the latter part of the growing season, a larger number of tillers fail to produce head.

However, it appears that growing grain sorghum in clumps may offer a promising strategy to increase the beneficial use of water in a way that decreases tillering and encourages grain filling. Results from 3 years of study at Bushland, Texas and one year at Tribune, Kansas show that growing dryland grain sorghum in clumps produce fewer tillers and increase grain yields and the harvest index. The results from studies at Bushland, Texas in 2005 show that the number of tillers decreased as the plants are placed closer to one another in clumps. The number of tillers produced per plant decreased significantly when there were four plants (0.6) in a clump rather than just one plant by itself (2.7). The R: FR ratio (measured in the shade at the base of a grain sorghum plant) was 0.33 μmol for one plant and 0.19 μmol for six plants in a clump. The R:FR ratio decreased when plants were grown in greater densities. The number of tillers produced per plant decreased when larger numbers of plants were grown in clumps.

As a result of this project, there is increased interest among several agricultural producers throughout the High Plains and the Rolling Plains of Texas in growing grain sorghum plants in clumps. Several of the farmers who have tried this method are satisfied with the yields and water savings that can be accomplished using this strategy.

If the practice of growing grain sorghum in clumps becomes more widespread, it could encourage several growers to consider dryland agriculture, thus reducing irrigation and protecting valuable groundwater resources in the region.

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On-Farm Research to Evaluate Irrigation Scheduling Tools to Increase Yield and Control Diseases

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Water for agricultural, urban and industrial use in the Austin – San Antonio – Uvalde corridor is pumped from the Edwards aquifer. This unique aquifer is in a class by itself in terms of containment, recharge, and political sensitivity. The regulation of this aquifer, however, is portent to the regulation of all aquifers in Texas. In 1993 Senate bill 1477 imposed a maximum draw of 450,000 acre-feet (AF) of water per year from the Edwards aquifer, with an additional reduction to 400,000 AF by the year 2008. However, current water permits amount to 563,000 AF imposing an immediate reduction of approximately 100,000 AF. Since 50 percent of the water drawn from the aquifer is for agricultural use, agricultural water conservation strategies are of utmost importance in the Edwards region and must play a role in reducing the shortfall. Research has repeatedly shown that proper irrigation management is essential to sustaining profitability. PET networks and crop simulation models have proven to be reliable, inexpensive, and effective tools for estimating crop water needs in research settings.

Networks of weather stations have been recently established in the Texas High Plains (TXHPET) as the site-specific basis for computing crop water use. It has been estimated in the northern Texas Panhandle, yearly fuel cost and pumping savings could exceed $18 million annually if all irrigators used the PET network data. This value is based on a reduction of irrigation water applied of only 2 inches.

Based on 90,000 acres of irrigated land in the Edwards aquifer region (TWDB report 347, 2001), we estimate that when all irrigators in the region implement limited irrigation scheduling, 14.6 to 19.5 billion gallons of water (50,000 to 60,000 AF) per year could be saved and made available for water purposes other than agricultural use within the region.

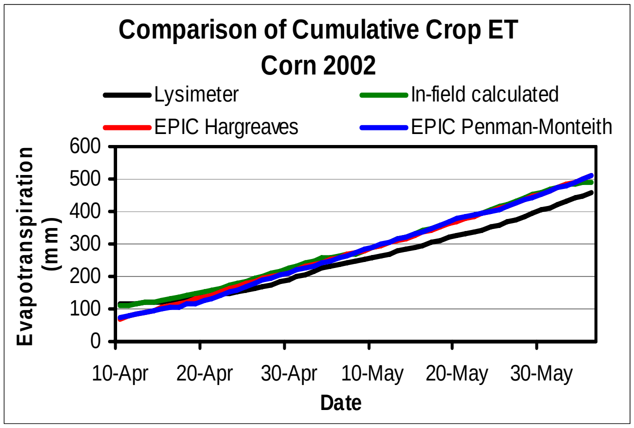
The ultimate goal of this project is to evaluate research findings from experiment stations statewide in a farm environment. Computer models such as CropMan will be utilized and crop ET (ETc) will be computed to assess growth and development and to evaluate production practices that achieve water conservation without adversely affecting yield and profitability.

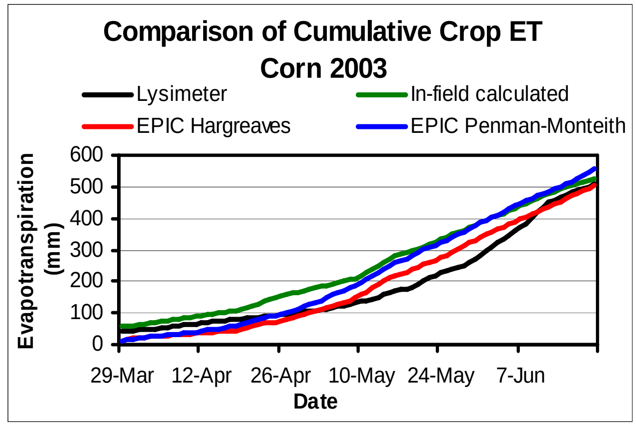
Activities Carried Out In This Project

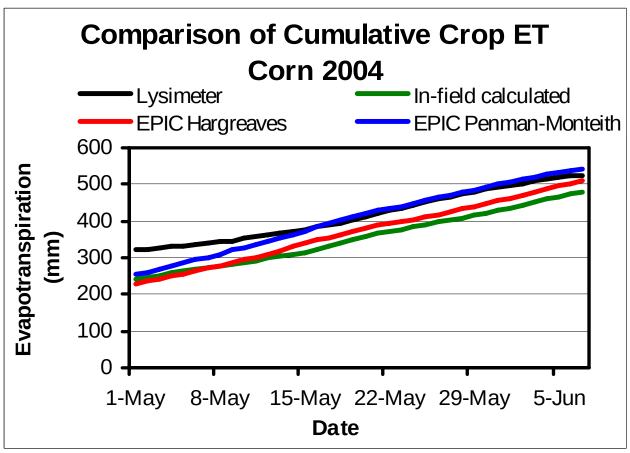
In the spring and summer of 2005, the Precision Irrigators Network (PIN) collected data from the crops grown in Uvalde, Medina, Bexar, Frio, Atascosa, Dimmit, and Maverick counties.

"Water mark" sensors were purchased for 15 participating farmers to record water use data. County Extension agents in the study area traveled to these farms each week and gathered water information on water use, soil moisture, and the growth stages (phenology) of plants during the growing season. The location of pivot irrigation systems was recorded with a global positioning system.

These data were used as inputs to the Texas A&M University "CropMan" model to analyze the relationships between water supplies, water use, and crop yields. The CropMan model was calibrated using various possible ETc formulas. Comparisons were made between corn ET data measured with in-ground weighing lysimeters and calculated with several ETc formulas to validate the model. Results of the calibration equations are in the following graphs and are summarized in numerical form in the table.







Crop Water Usage Under Unstressed Crop Conditions				
Year	**Measured lysimeter**	**In-field calculated (modified PM)**	**EPIC Simulated (Hargreaves)**	**EPIC Simulated (original PM)**
	mm	*mm*	*mm*	*mm*
2002	**457.71**	**491.24**	**509.27**	**511.56**
2003	**507.49**	**523.24**	**502.41**	**560.07**
2004	**526.03**	**477.52**	**509.52**	**541.53**
3-year mean	**497.08**	**497.33**	**506.98**	**537.72**
Difference from measured lysimeter data	**------**	**0.25**	**9.91**	**40.64†**

† indicates the crop ET is significantly different from the measured lysimeter crop ET at the 0.1 alpha level

Managing Water Resources of the Seymour Aquifer Using Subsurface Drip Irrigation

John W. Sij, Jeffrey E. Slosser, and David G. Bordovsky
Texas Agricultural Experiment Station-Vernon

Executive Summary

A long-term management program for water conservation and utilization is essential if irrigated production agriculture is to survive in the Texas Rolling Plains. Subsurface drip irrigation (SDI) is the most efficient (nearly 100 percent) water delivery system to roots of plants and can be considered one component of precision agriculture. Frequently, crop yields equal or exceed those of some traditional irrigation methods while requiring less water, thus saving valuable water resources. The Seymour Aquifer is a fragmented, shallow aquifer that underlies portions of the Texas Upper Rolling Plains and whose recharge is mainly through rainfall. During dry seasons, excessive pumping can deplete underground water resources to the point that wells are no longer functional. Also, during these dry periods, a lowering of the water table often results in reduced water quality; i.e. increased salinity. An additional problem is that nitrates levels in the ground water frequently exceed government standards for water quality.

Due to SDI's water delivery efficiency and labor savings, SDI will play an increasing role in Rolling Plain's agriculture in the near future. The goal of the proposed study is to maximize crop production through prudent management of limited ground water resources that results in economic gain for producers and rural communities. The objective of the current effort is to develop a SDI system at the Chillicothe Research Station to educate producers, through science-based research, on the benefits and utility of SDI as an alternative and superior irrigation technology to less efficient traditional systems (particularly furrow) currently in use.

Initial efforts were to 1) identify and prepare the SDI sight at the Chillicothe Research Station, 2) develop additional groundwater resources (well) to augment existing water resources and thereby dedicate a well to SDI research, and 3) construct a building near the drip site to house electronic controllers, sand media filters, pumps, valves, acid injection equipment, and a storage tank. Following completion of these items, plans to bid the installation of 72 individually-controlled SDI research plots at the Chillicothe Station will be developed in November through December 2005. Installation should commence this winter with the system completed prior to the 2006 planting season. Initial research will focus on deficit irrigation as a means to enhance water-use efficiency and conserve ground water resources. Research results from SDI plots at the former Munday Station showed that a 50 percent reduction in irrigation water (based on Potential Evapotranspiration) resulted in only a 20 percent reduction in yield. Deficit irrigation combined with conservation tillage could potentially extend the groundwater resources of the Seymour Aquifer and perhaps mitigate nitrate movement within the soil profile. Additional research is needed to verify early results on deficit irrigation in a second cotton production region of the Rolling Plains.

Current Progress

A 15-acre site was identified and kept fallow throughout the summer of 2005. A new well was completed and tied into existing underground mains (see figure below). This allowed an older, but higher capacity well, to be dedicated to SDI research, and will permit drip research to be expanded to an additional 15 to 20 acres in the future. The higher capacity well is located near the control building and should reduce installation costs since electrical power is adjacent to the new building. In addition, underground water mains will only be a short distance from the well to the controller building which further reduces installation costs. The foundation of the controller building has also been completed (see figure). By establishing the location of the building, bidders will be able to better determine installation costs. During the preliminary phase of SDI development, a technician was assigned to help in completing some of the ground work. A significant portion of the grant funds were used for technical help.

Drip irrigation was showcased at the Chillicothe Fall Field Day with nearly 200 participants. Representatives from a SDI company were on hand to answer producers' questions. One news article: "Drip Irrigation Opens New Frontier for Research on the Rolling Plains" (AgNews-News and Public Affairs, TAMU System Agricultural Program, Oct. 18, 2005) was written concerning the proposed SDI research effort at Chillicothe. Another news article is being prepared emphasizing the potential of this new irrigation technology.

Acknowledgement

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Texas Water
Resources Institute
make every drop count