Development of an Automated System to Incorporate Holes in Lay-Flat Irrigation Tubing During Initial Deployment in Mississippi Soybean Production Systems, Project 27-2022
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Background and Objectives for Research: The ability to irrigate row crops from the Mississippi River Valley Alluvial Aquifer (MRVAA) is crucial to the sustainability of soybean production in Mississippi and the Mid-South. However, groundwater is a limited resource; therefore, even in humid regions, groundwater must be prudently managed to ensure its continued viability and protect the ability to groundwater access for agricultural production. Declining aquifer levels, coupled with impending well monitoring, serve as a catalyst to improve water use efficiency. The RISER program has identified several technologies and management practices that have the potential to eliminate the 300,000 ac-ft/yr. overdraft on the Mississippi Alluvial Aquifer while ensuring that producers stay within permitted irrigation limits. However, the adoption of Best Management Practices (BMPs) by producers in the Mississippi Delta is minimal.

One technology that has been proven to reduce water usage and provide these positive economic impacts is the use of Computerized Hole Selection (CHS). CHS determines the correct hole size for each individual furrow in a lay-flat irrigation pipe system by accounting for row length, inlet and required individual furrow flow, pipeline pressure and hydraulics, and crown elevation. Two software programs exist for CHS: a research-based tool, Pipe Hole and Universal Crown Evaluation Tool (PHAUCET), (Burch, 2012), and a commercial product, Pipe Planner, developed and maintained by Delta Plastics (2020). From 2013 to 2017, the four irrigation water management practices were evaluated in the region using paired field comparisons (Bryant et al., 2017; Spencer et al., 2019). The paired field comparisons consisted of one field receiving the demonstration of irrigation water management practices while the other field was the producer-managed field, holding other management practices (e.g., cultivar selection) constant. Bryant et al. (2017) implemented these practices on 20 paired furrow-irrigated soybean fields and found no significant difference in yield between irrigation water management and the control ($p = 0.67$), while irrigation water management reduced water use by 21% ($p = 0.0198$) and increased irrigation water use efficiency by 36% ($p = 0.0194$).

Performance of lay-flat irrigation tubing with respect to hole integrity is a crucial component of effective irrigation strategies that conserve water while maintaining crop yields. In addition, correct hole size is also important to this process and changes to them due to mechanical damage from over pressurization can be detrimental to maintaining the desired water output per row. Current hole insertion methodologies utilized for CHS are also crude and produce variations in flow that hinder optimization of water management. In order to address these issues, the following objectives were established:

1. <u>Assessment of hole performance in lay-flat irrigation tubing at the farm-scale.</u>
2. <u>Assess different mechanical methods hole insertion to determine the optimum technique.</u>
3. <u>Develop an automated mechanism to insert holes into irrigation tubing and assess the accuracy and performance of the mechanism relative to material thickness.</u>

4. Assess the integrity of the mechanically inserted holes relative to those inserted manually utilizing the test stand and flow/pressure methodologies developed in year one material properties testing.

Report of Progress:

Objective 1: Assessment of hole performance in lay-flat irrigation tubing at the farm-scale.

Virgin poly-pipe material was cut into 420 ft. lengths and pre-punched with 13/16" holes at 80" centers (63 holes per length), connected to irrigation risers, and subjected to pressures equivalent to the 150% of maximum calculated yield strength determined from Year 1 testing utilizing the ASTM D882 – 18 "Standard Test Method for Tensile Properties of Thin Plastic Sheeting". During this procedure, poly-pipe pressure and water flows were recorded at intervals along the length of poly-pipe prior to the over pressurization event and afterward to assess the effects of over pressurization relative to individual hole water flow and to observe if changes in flow were consistent along the length of poly-pipe. Additionally, six individually-spaced sections of poly-pipe were removed from the full-length runs and evaluated on the test fixture developed in Year 1 to further quantify the over pressurization effects as a function of distance from the riser. In both evaluations, there were observed increases in hole flows across the length of pipe at all hole locations. However, larger increases in individual hole flows were observed nearest the riser, decreasing linearly as the distance from the riser increased, indicating that hole geometries and the subsequent water flows are more greatly affected nearer the pressure source. This data indicates that the effects of over pressurization may be a contributing factor in CHS prescription failures and points to the criticality in maintaining pipe pressures below the material yield strength in order for CHS prescriptions to work as intended to achieve maximum water use efficiency. There is also a strong indication that automated pump control could be very beneficial in improving these efficiencies by adjusting pump outputs to maintain pressures below yield strength and also could potentially lessen or prevent in-season poly-pipe burst failures. This information, along with maximum yield strength tables by material thickness, will continue to be collected throughout the remainder of the project to create a usage guideline for poly-pipe selection and pump management strategies for producers.

Objective 2: Assess different mechanical methods hole insertion to determine the optimum technique.

Hole insertion methodologies were evaluated to determine an optimum solution for inserting holes into uncharged poly-pipe for the development of an automated mechanism. Preliminary evaluations conducted in Year 1 and 2 with multiple insertion techniques have continued to indicate that a circular hole is the best choice for achieving the desired hole size and for adjusting the hole size to integrate with CHS prescriptions currently being utilized. Manufacturers specializing in material cutting were consulted and two preliminary mechanisms were initially chosen for evaluation; one utilizing paired cutting surfaces (positive and negative) and one with a single cutting surface and a solid surface underneath for the die to press against to cut the material. Delays in manufacturing coupled with discussions with the manufacturers resulted in the choice to utilize the single cutting surface die from Chicago Cutting Dies in Chicago, Illinois due to its' simplistic mechanism design and also its' immediate availability. These heat-treated steel dies are designed to have a long service life while also being relatively inexpensive. Additionally, the dies are a typical stocked item for the manufacturer, which is an added benefit when considered with a future transition of the prototype to a commercially-available mechanism once the prototype has been fully developed and tested.

Objective 3: Develop an automated mechanism to insert holes into irrigation tubing and assess the accuracy and performance of the mechanism relative to material thickness.

Development of the design of the automated mechanism for hole insertion was conceived through discussions with PI's, industry suppliers, and Dr. Chris Delhom of USDA. The design utilizes a rotary die mechanism to insert holes into the folded edge of poly-pipe during deployment at intervals corresponding to each furrow within the field. The cutting die is attached to a radial fixture that rotates to match the deployment speed of the poly-pipe, cutting a hole at each desired interval. The die mechanism indexes relative to the edge to change the hole area to match the desired flow for each furrow as prescribed by CHS. High-precision sensors are utilized to determine system operational parameters such as groundspeed and material location and their data are processes with a programmable logic controller that adjusts the mechanism for hole size and location with capability to upgrade the mechanism to directly incorporate CHS prescriptions into its' operation in the future. It is controlled through a touch-screen user interface, allowing for real-time system performance adjustment, fine-tuning relative to each of the system parameters, and can be used for troubleshooting should a malfunction occur.

Preliminary testing of the mechanism has been successful with all poly-pipe material thicknesses and sizes. Future plans will incorporate the mechanism onto a commercial poly-pipe laying implement and evaluate in field conditions, incorporating CHS prescriptions to determine hole sizes and locations. Modifications to the poly-pipe laying implement will also take place to change the pipe delivery mechanism to accommodate the mechanism and aid in maintaining hole orientation during the initial irrigation event.

Objective 4: <u>Assess the integrity of the mechanically inserted holes relative to those inserted manually utilizing the test stand and flow/pressure methodologies developed in year one material properties testing.</u>

Delays in the development of the automated mechanism for hole insertion has currently prevented a full evaluation of the mechanically-inserted holes as the automated mechanism is not fully functional. However, preliminary testing of the mechanically-inserted holes has indicated no issues with flow variances observed when utilizing the Poly Piranha II. As the automated system becomes fully functional, full-scale testing will continue utilizing the flow testing apparatus to fully asses the automated mechanism performance.

Impacts and Benefits to Mississippi Soybean Producers

Results of this project will provide Mississippi Soybean Producers with new resources to aid them in irrigation efforts, will provide much-needed knowledge and technology that contributes to improved water use efficiency, and delivers potential cost savings through proper material selection. Additionally, the automated mechanism for hole insertion will streamline poly-pipe deployment, creating a single-pass implement that is more efficient, reduces the need for additional labor, and potentially improve CHS hole accuracy by incorporating hole insertion methodologies that create clean, consistent holes.

End Products–Completed or Forthcoming

Master's Thesis – Victor Frank Carey, IV - Completed
Master's Thesis – Micah Foster – Forthcoming
Producer's Guide for Poly-Pipe Selection - Forthcoming
Producer's Guide for Pump and Well Operation/Monitoring/Control - Forthcoming
Automated Poly-Pipe Implement – Forthcoming

Graphics/Tables

Figure 1. Turbulent water flow from Poly Piranha II (left, center) vs. mechanically inserted hole (right).

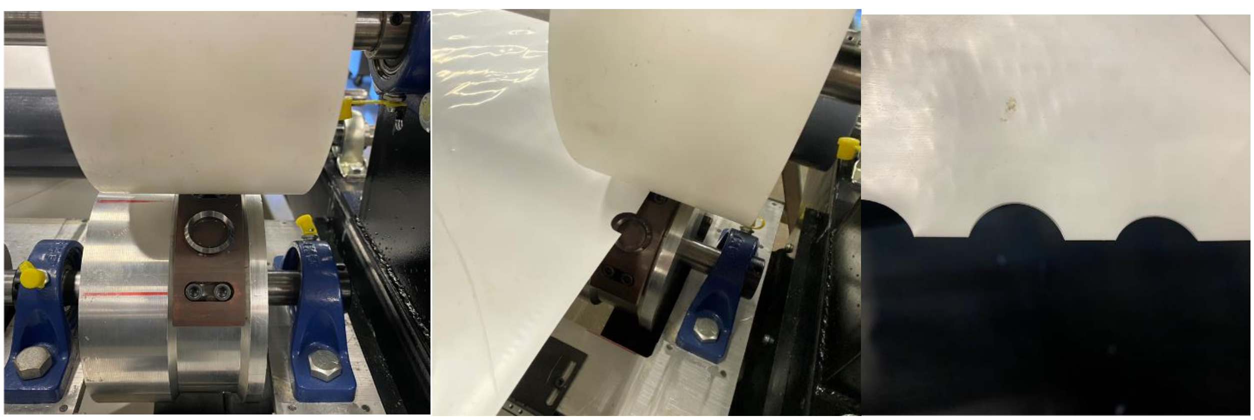

Figure 2. Automated Hole Insertion Mechanism – Die (left), Hole created with mechanism (center), Holes of varied sizes created with mechanism (right).

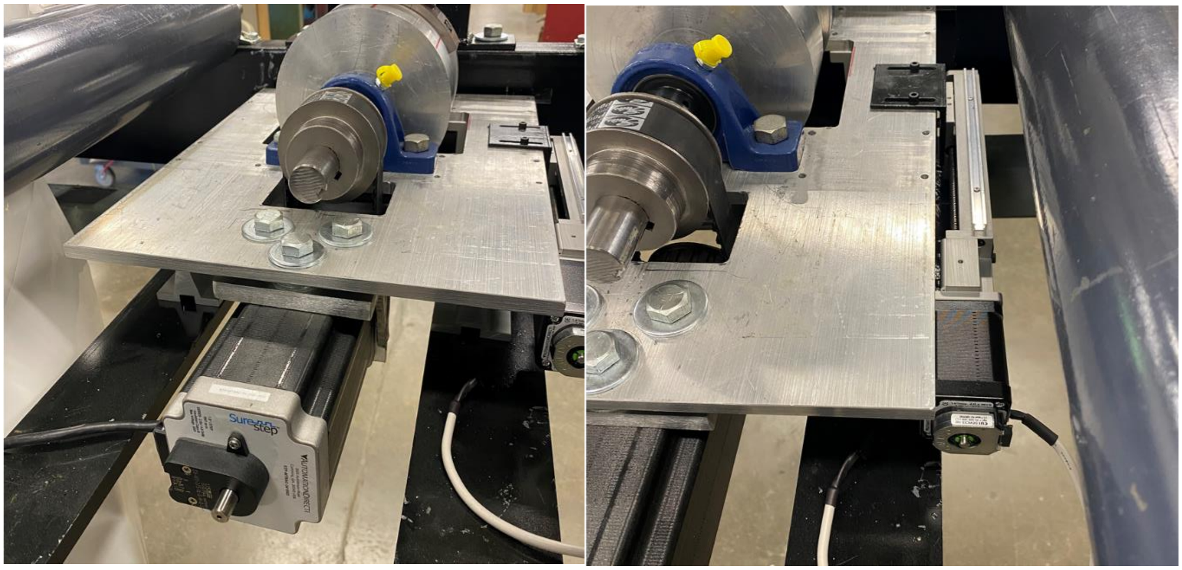

Figure 3. High-precision motors that control hole location and position.