Evaluation of RDI™ Precision Irrigation

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Abstract: *Irrigation faces many challenges as the world's resources come under more pressure. Some of these challenges include availability of fresh water, energy to deliver and labor to operate and manage. Precision irrigation via various forms of drip and mechanized irrigation, such as center pivots and linears, are addressing the resource pressures well, but opportunities for improvement still exist. Each has some limitations such as water quality, ability to effectively irrigate irregularly shaped fields, energy requirements, and management expertise required, to name a few. This paper will discuss Valmont® Industries' work to evaluate the potential of a new form of irrigation Valmont is calling Root Demand Irrigation™ (RDI). This new type of subsurface irrigation system depends on the plant to release irrigation as needed from non-coated, non-woven, porous tubes. In addition, the proposed delivery system is expected to operate at very low pressures and have minimal filtration requirements. This paper will detail the first two years of field evaluation of the potential of RDI™.*

Keywords: Precision irrigation, plant roots, sub surface irrigation-

Introduction:
Irrigation to meet crop water requirements has been used for thousands of years. To provide for the needs of an ever expanding world population and shirking availability of resources, many advances in the methods of applying irrigation have occurred. In the last fifty years, the changes have been rapid with the introduction of the center pivot and linear mechanized machines and drip irrigation. Much has been discussed about modifying the root environment (Arkin, 1981). These forms of irrigation have continued to develop toward the more precise application of water for plant production. While the mechanized and drip forms of irrigation are overall doing a good job, there may still be other opportunities to improve the irrigation delivery system. Center pivots and linear are a very economical delivery system, but may not meet farmer needs to irrigate small irregularly and oddly shaped fields. Drip irrigation buried can be very efficient, but has limitations due to costs and required water quality. Both types of irrigation require good management practices to work well, but there appears to be opportunities for improvements in the irrigation delivery system.

Objective:
The goal of this project is to evaluate the potential of another form of irrigation, which relies on the plant roots to release water for meeting the water demands of the plant.

Discussion:
In a continuing effort to better provide for precision irrigation, Valmont Industries looks for improvements to center pivots and linears and the potential for other forms of irrigation. In 2011, Valmont became aware of a potential new technology for irrigation based around a non-coated, porous, non-woven tube that releases water based on the

plant. The basic theory is the tube holds the water at a pressure just below what would break the surface tension of the water. Surface tension is broken by root exudates and water flows from the tube into the root system (Nobel, 1983). Root exudates include the secretion of ions, free oxygen and water, enzymes, mucilage, and a diverse array of carbon containing primary and secondary metabolites.

Root exudation can be broadly divided into two active processes. The first is root excretion of waste materials, and the second is secretion of compounds with known functions such as lubricants and defense (Bais, 2006). It is the second type of exudates that will break the surface tension of the water and release it for plant use. Utilizing the plant system to control the release of water could change how irrigation is approached. Today all forms of commercial irrigation depend on the soil acting as a reservoir to store water to meet plant needs (NRCS National Engineering Handbook). With RDI, the theory is to continuously have water available for the plant rather than going through wetting and drying cycles of the soil.

A plan for testing was designed to evaluate a non-woven, non-coated porous tube's potential to irrigate a crop based around the concept of Root Demand Irrigation. The basic plan was to test a basic concept and if success was seen then move onto larger tests with additional parameters.

Results:

Florida Phase I – Fall 2011

- Goal - determination of basic characteristics of the tube
- Success – defined as relatively uniform delivery based on a crude test
- Area - ~ 0.10 acres
- Plan –
    - Water source – well
    - Filter - none
    - Soil - sand
    - Lay tube on the soil surface with minimal elevation change
    - Space lines 30 inches apart x 800 feet long
    - Operating pressure – 2.1 PSI
        - This pressure was just above the point of breaking surface tension to encourage flow
    - Pressure controlled with a head tank
- Crop - none
- Measurements
    - Pressure at the beginning and end of tubes
        - Measured with a manometer tube
    - Flow at 100 foot locations along the tube

        - Measured with trays placed under the tube

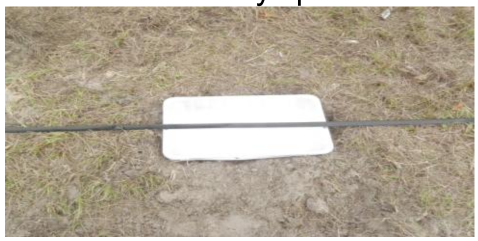

Figure 1. Test setup

- Success – best as could measure met expectations
- Comment – Interesting phenomenon noted was touching the tube would increase the flow. Believe the oils on the fingers were breaking the surface tension and potentially disrupting flow. Made accurate measurements very difficult.

From this trial, we observed sufficient indicators to encourage continuous exploration of the viability of the root demand tube with additional tests.

Florida Phase II – Winter 2011-2012

- Goal - determination how the tube would perform irrigating plants
- Success – defined as maintaining crop growth
- Area - ~ 0.25 acres
- Plan –
    - Water source – well
    - Filter - none
    - Bury tube six inches deep
    - Three lines spaced lines 30 inches apart x 800 feet long
    - Operating pressure – 2.1 PSI
        - This pressure was just under the point of breaking surface tension
    - Pressure controlled with a head tank
    - Plant groups of plants at locations along the tubes
        - One group of ornamentals planted near irrigated plants as a control
- Crop – actively growing ornamental in one gallon pots
- Measurements
    - Pressure at the beginning and end of tubes
    - Flow with Omega flowmeter
    - Soil moisture with Irrometer® WATERMARKs
- Success –
    - Partial success in Phase IIa due to installation not meeting expectations
        - Plants in areas where the lines were collapsed did not grow
    - Fully in Phase IIb when lines reinstalled – 70% of plants grew
- Comment –
    - Installation for Phase IIa was done with equipment that did not meet expectations due to poor depth control
    - Bought a new installation toolbar for Phase IIb which worked controlling depth

- If the plant roots were within the wetted area provided by the tube, then growth occurred; but, if the roots did not reach the wetted area, no growth occurred.


Figure 2. Control system Figure 3. Example of plants

Texas Phase I – Spring 2012

- Goal - determination how the tube would perform in a semi-commercial setting with corn in the corner of center pivots
- Success – defined as crop yields of 80% of center pivot
- Area - ~ 1.5 acres

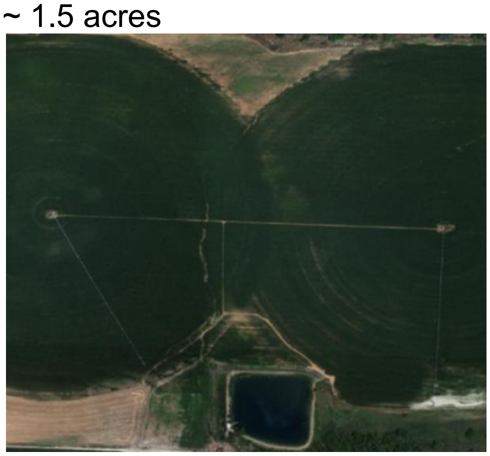


Figure 4. Aerial of field area Figure 5. Plot area

- Plan –
  - Water source – pond
  - None – first challenge to see if the tubes would plug
  - Soil – loamy sand
  - Bury tube ten inches deep
  - Multiple replicated trials including non irrigated
  - Lines spaced at 30 inches apart with lengths of 150 feet to 750 feet
  - Operating pressure – 2.1 PSI
  - Pressure controlled with a head tank
- Crop –

- #2 yellow corn planted at about 32,000 plants per acre
- Tillage same as under the center pivots
- Planted at the same time as the center pivots with the rows straight through
- Slope of three feet maximum across the plot

- Measurements
  - Pressure at the beginning and end of tubes
  - Flow with Netafim[TM] Fertilizer flowmeters
  - Soil moisture with Irrometer WATERMARKs
  - Yield by hand harvest of areas near Irrometer stations
- Success –
  - Yield of 85% of center pivot

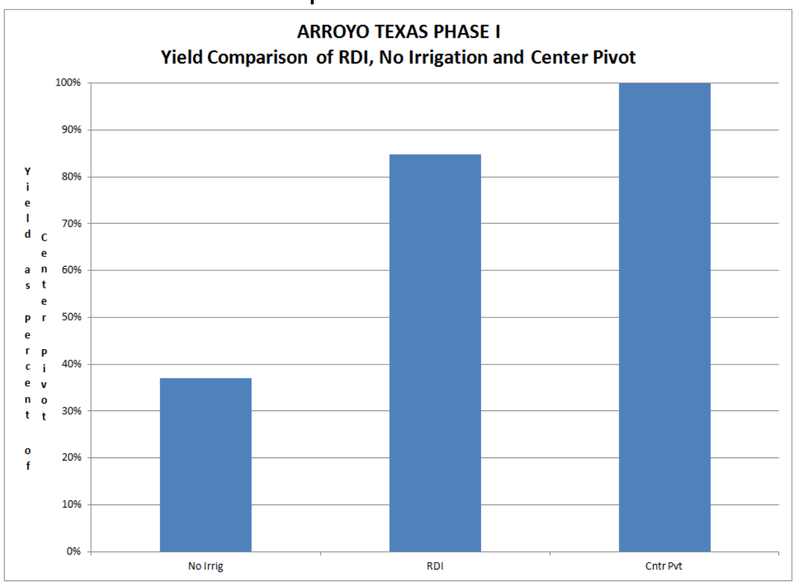

Table 1. Yield information

- Comment –
  - Soil moisture at time of planting was near field capacity to depth of two feet
  - Some weed issues in plots as corner area had not been farmed for several years
  - Far ends of lines run over by farmer limited maximum useable length to 500 feet
  - Did not observe any change in flow along the tube, even though significant moss and algae were growing in the pond

Texas Phase II – Fall 2012

- Goal - determination how the tube would perform in a commercial setting with corn in the corner of center pivots and furrow irrigated
- Success – defined as crop yields of 85% of center pivot and furrow plots
- Area - ~ 4.0 acres
- Plan –

- Moved to a new area in a different corner of the center pivot
- Water source – pond
- Filter - none
- Soil – loamy sand
- Bury tube ten inches deep
- Multiple replicated trials including non irrigated
- Lines spaced at 30 inches apart with lengths of 1,200 feet
- Operating pressure – 2.1 PSI
- Pressure controlled with a pump

- Crop –
  - #2 yellow corn planted at about 32,000 plants per acre
  - Tillage same as under the center pivots
  - Planted at the same time as the center pivots
  - Slope of eight to ten feet across the field
- Measurements
  - Pressure at the beginning and end of tubes
  - Flow with Netafim Fertilizer flowmeters
  - Soil moisture with Irrometer WATERMARKs
  - Yield by hand harvest of areas near Irrometer stations
- Success –
  - Yield of 68% of center pivot – Grade of B-

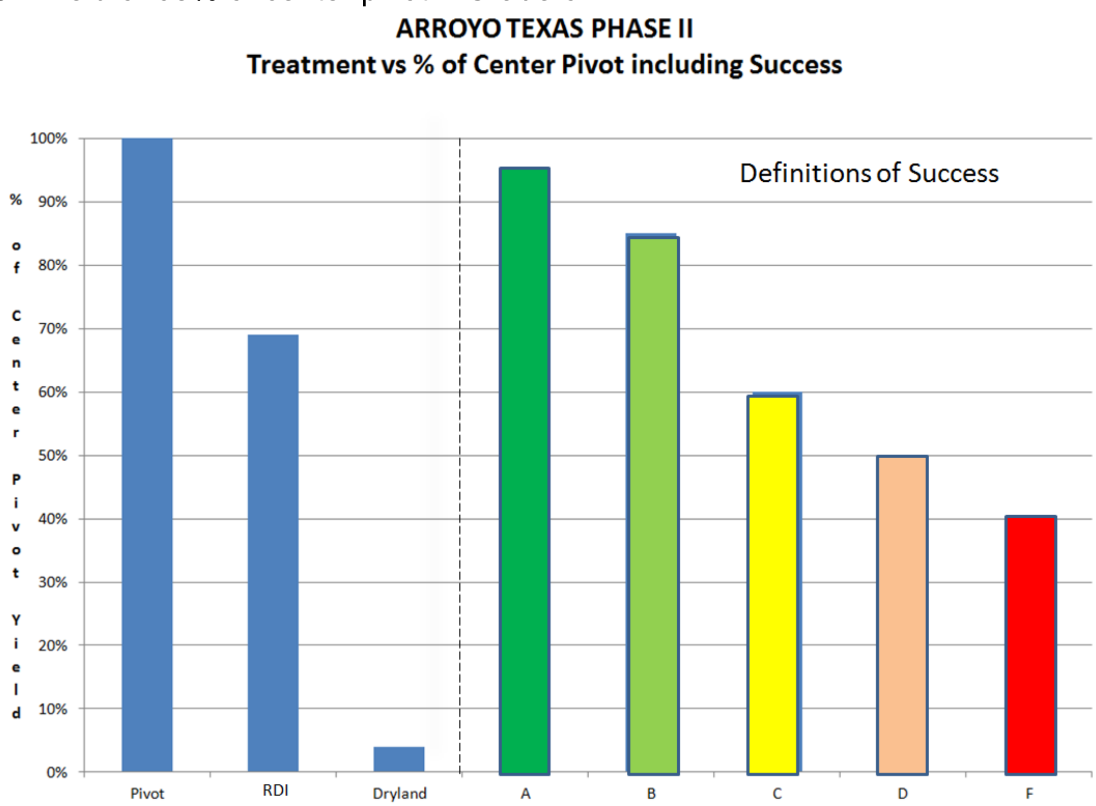

Table 2. Yield vs. success

- Comment –
  - Soil moisture at time of planting was near 50% depleted – it was dry

- Stand was uneven due to germination delayed until rain about two weeks after planting
    - Some weed issues due to challenges of farmer being able to spray around manometers and Irrometer stations
    - Insufficient water to operate the furrow irrigation plots

Texas Phase IV – Spring 2013

- Goal - determination how the tube would perform in a commercial setting with corn in the corner of center pivots and furrow irrigated
- Success – defined as crop yields of greater than 75% of center pivot and furrow irrigation
- Area - ~ 5.5 acres
- Plan –
    - Slightly larger area than Phase II
    - Water source – pond
    - Filter - none
    - Soil – loamy sand
    - Reinstalled with an improved tube product
    - Bury tube ten inches deep
    - Multiple replicated trials including non irrigated
    - Lines spaced at 30 inches apart with lengths of 1,200 feet
    - Operating pressure – 2.1 PSI
    - Pressure controlled with a pump
- Crop –
    - #2 yellow corn planted at about 32,000 plants per acre
    - Tillage same as under the center pivots
    - Planted at the same time as the center pivots
    - Slope of eight to ten feet across the field
- Measurements
    - Pressure at the beginning and end of tubes
    - Flow with Netafim Fertilizer flowmeters
    - Soil moisture with Irrometer WATERMARKs
    - Yield by hand harvest of areas near Irrometer stations
- Success –
    - Yield of 85% of center pivot and furrow irrigation

Arroyo Texas Phase IV

Treatment	% of center pivot yield	Irrigated	Stand	Plant Health
dryland	14%	no	poor	bad
T3 B1	32%	under	poor	poor
T4 B1	60%	under	poor	fair
T5 B1	63%	under	poor	fair
T1 B4	65%	under	fair	fair
T5 B3	66%	under	fair	fair
T5 B2	86%	ok	good	good
T2 B2	99%	ok	excellent	excellent
T2 B3	99%	ok	excellent	excellent
cntr pvt	100%	well	excellent	excellent

Table 3. Treatments and performance

Measures in corn crop as a percent of center pivot irrigated corn

	RDI	No Irrigation
Yield	**78%**	**14%**
Water use	**54%**	**0%**
Labor	**80%**	**0%**
Crop uniformity	**75%**	**20%**

Table 4. RDI performance

- Comment –
  - Again, the soil moisture at time of planting was near 30% depleted – it was dry
  - Stand was uneven due to germination delayed until rain about two weeks after planting
  - Some weed issues due to challenges of farmer being able to spray around manometers and Irrometer stations
  - Biggest challenge was water shortage twice during the crop cycle - once for ten days and again for six days
  - Again there was insufficient water to operate the furrow irrigated plots

Figure 6. Examples of plot crop

Conclusion:
Over the last two years of testing, Valmont has seen sufficient reasons to continue testing and evaluation of non-coated, non-woven, porous tubes as an alternative type of sub-surface irrigation. Strong indications have been seen to show the crop can potentially control at least part of the water from the porous tube to meet crop water demand. Yields from small trials have compared well with the yields from center pivots and other forms of sub-surface irrigation. In addition, the potential has been seen for the Root Demand Irrigation to complement center pivot and linear irrigation by providing a solution to small and/or irregularly shaped fields.

Further work will involve larger field trials and more work to better describe the characteristics, such as uniformity along longer non-coated, non-woven, porous tubes.

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