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Why Field Crop Growers Love Drip Irrigation: Alfalfa, Corn, Cotton, Onions, Potatoes and Processing Tomatoes

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Abstract. *Drip irrigation has long been proven as beneficial and economical on fruit, nut and vegetable crops throughout the world, but recently field crop growers are realizing the benefits as well. Adjustments in both attitude and cultural practices are necessary when converting from flood or sprinkler; however, the benefits of making these changes often outweigh the costs. Cited benefits include increased yields, increased quality and increased uniformity in addition to reduced water, fertilizer, energy, labor, chemical costs and disease reduction. In addition, field accessibility is significantly improved compared to gravity and sprinkler irrigation systems, allowing for simpler logistics with other cultural operations. The increase in revenue, reduction in cost and improvement in convenience have consistently offset the cost of adopting drip irrigation systems, and in many cases have allowed continued production of crops in areas where water supplies are severely depleted or restricted, or where gravity and sprinkler technologies are too wasteful.*

Specific examples are cited for alfalfa, corn, cotton, onion, potato and processing tomato production using surface drip systems, subsurface drip irrigation systems (SDI) and hybrid systems. Keys to success include drip system design, equipment selection, installation and management; specific changes in crop cultural practices; and innovations in cultural equipment design.

Two software tools are introduced: The Drip Micro Payback Wizard to estimate capital recovery and the Drip Tape Irrigation Calculator for calculating run times, drip tape flow rates, spacing and uniformity.

Keywords. Drip Irrigation, Subsurface Drip Irrigation (SDI), Drip Tape, Alfalfa, Corn, Cotton, Onions, Potatoes, Processing Tomatoes, Chemigation, Fertigation, Irrigation Scheduling, Economics.

Introduction

Drip irrigation has long been proven as beneficial and economical on fruit, nut and vegetable crops throughout the world, but recently growers of field crops such as alfalfa, corn, cotton, onions, potatoes and processing tomatoes are realizing the benefits as well. A case study of a grower producing each of these crops is profiled here, and includes the adjustments to both the drip irrigation system and the crop growing practices that were often necessary to achieve success in a real world, economically viable production environment. In each case, the independent operators report that the benefits of making these changes have outweighed the costs and challenges such that continued investment in drip irrigation is likely.

For those unfamiliar with drip irrigation, Figure 1 illustrates a typical layout of several different types of drip irrigation systems. In general, drip irrigation systems can be thought of in two halves. First, the "headworks" portion of the system contains the water sources, pumps, filters, chemical injection equipment and controls. Second, the "field" portion of the system contains the transmission and emission devices used to deliver precise amounts of water, fertilizer, and other compounds directly to the crop. The field portions of five different types of drip irrigation systems are shown: field crop sub-surface drip irrigation (SDI), short term vegetable crop, longer term vegetable crop, vineyard and orchard. The case studies profiled in this paper use surface drip systems, subsurface drip irrigation systems (SDI) and hybrid systems.

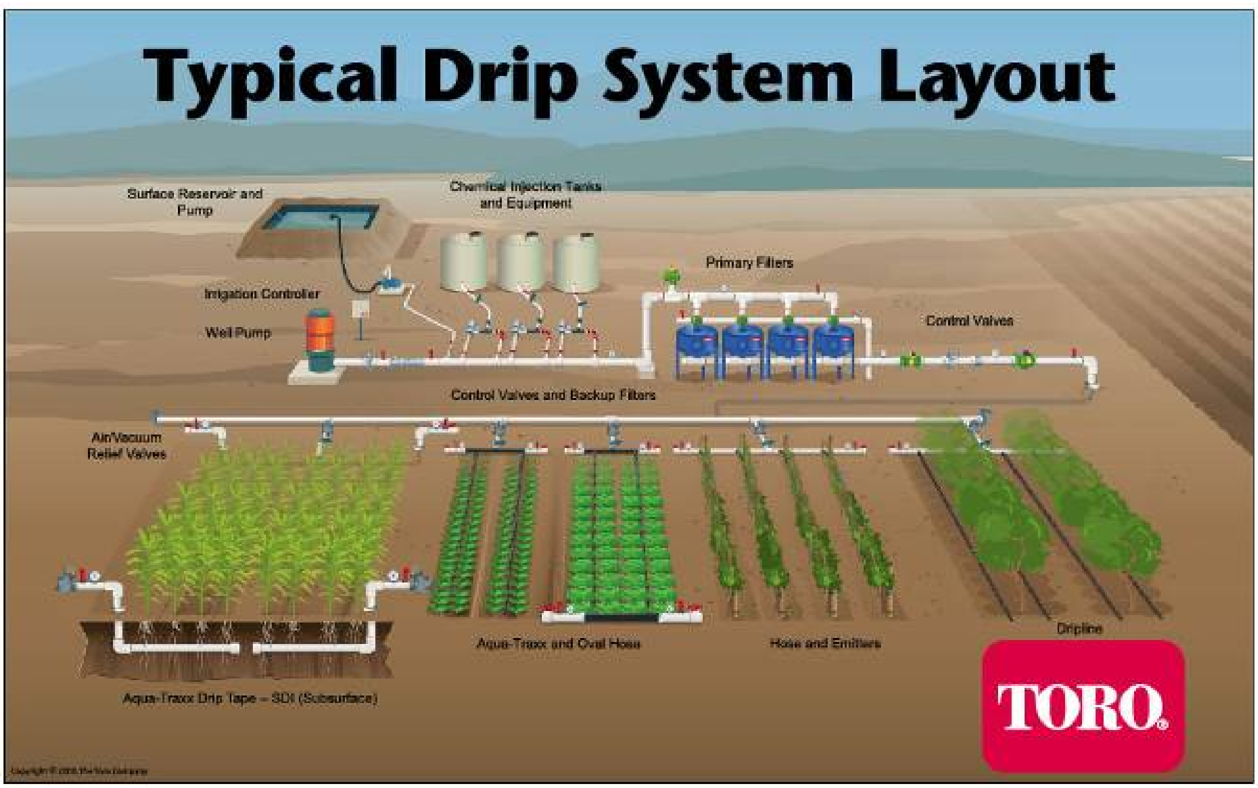

Figure 1: Typical Drip System Layout

As growers new to drip explore the technology and begin using it, software tools have been developed to assist. Specifically, Toro has developed two such tools to help evaluate the investment in drip irrigation prior to adoption, and to help with scheduling irrigations after adoption. First, the Drip Micro Payback Wizard allows growers to estimate the payback period associated with an investment in drip irrigation, and estimates additional acres that could be farmed with conserved water. Second, the Aqua-Traxx Irrigation Calculator helps drip irrigation system users calculate system application rates and appropriate irrigation system run times. It can also be used to help select the appropriate drip tape flow rates and spacing, and to assess the impact of emission uniformity on estimated irrigation run times and operating costs. Both have been well received by growers who are in the "shopping stage" as well as the "management" stage.

Safety Emphasis

There are several aspects of drip irrigation that can contribute to a safer work environment and improved food safety. First, drip systems typically eliminate the need to manually move heavy sprinkler pipe through terrain that is often rough, steep and/or muddy, thus reducing worker risk of injury from this activity. Second, drip systems contain far fewer electronic and mechanical components than mechanized irrigation systems like linear move, center pivot and traveling "big guns", further reducing worker risk of injury and downtime from servicing and working with such components. Finally, drip systems may reduce runoff and/or flooded field conditions that attract wildlife, which can increase the risk of potentially harmful *E. coli* in foodstuffs.

Drip Irrigation on Alfalfa

Bob Thomas Farms, Seeley, CA

Bob Thomas is a newcomer to farming, but no stranger to success. With the proceeds of his recently sold construction company, he has purchased ranches in Utah, Colorado and California's Imperial Valley. In California on the Lyons Road Ranch near Seeley in the Imperial Valley, he plans to continue growing the same crops that have been grown for decades, but not the same way. Rather than gravity irrigating the alfalfa with traditional flood irrigation with borders, Thomas and his son Rob have installed a subsurface drip irrigation system on 116 acres (47 ha) of the 660 acre (267 ha) ranch. And they already have plans to install another 250 acres (112 ha) in August of 2010.

"When I learned how water was applied to crops here, I began researching alternatives. In the process, I discovered how a few cutting edge growers were using drip to not only save water, but significantly increase yields as well. That's what I'm after – getting more crop per drop – and making this farm as efficient as my construction company was."

After months of research, the Thomas' settled on a design and ordered materials. Towards the end of August 2009, they installed Toro's 0.875 inch (22 mm) internal diameter Aqua-Traxx drip tape with a 10 mil (.010 inches, .25 mm) wall thickness and 12 inch (30 cm) emitter spacing. The tape lines were injected 10-12 inches (25-30 cm) deep with 40 inch (1 m) lateral spacing as shown in Figure 2 to accommodate both alfalfa and future vegetable crops as well. "The system is designed to apply about .06 inches (1.52 mm) of water per hour, and peak ET can be replaced on each set of the two-set system in about 8 hours for a total of 16 hours of run time of any 24-hour day. This way we have a little breathing room if we need to run a little longer or work around harvest logistics."

Figure 2: Injecting drip tape prior to planting alfalfa at Thomas Farms.

The Thomas' planted the drip blocks in September, and by May had already cut three times to reap a total of 4.5 tons of alfalfa per acre. Since they are irrigated the rest of the ranch's alfalfa acreage with traditional flood irrigation with borders, they have a basis for comparing one method to the other. "Harvesting the drip field was a lot easier than harvesting the bordered fields," says Thomas. "With flood irrigation with borders, it's a two step operation to accommodate all the different elevations, but with drip, the field is planted flat with no waste, so harvesting was as easy as mowing the lawn."

Just ten days after harvest there was already healthy re-growth as shown in Figures 3A and 3B. "We are hoping to achieve annual yields of 16-17 tons per acre with this system – that's how we will recover the investment. As we work out the installation and construction bugs, future investment costs will be lower, but bottom line, with water at $18 per acre foot today, it's the yield that is motivating us." The flood irrigated fields typically use about one acre foot of water per ton of yield. On average, that equates to about 12-13 acre feet of water per acre to yield about 12-13 tons of alfalfa per acre. "Even if we use the same amount of water in the future, which I doubt we will, we will hopefully be yielding 30 to 40 percent more alfalfa with the same amount of water. Other growers have achieved this – there is no reason why we can't."

Figure 3A and 3B: Alfalfa re-growth 10 days after cutting at Thomas Farms.

The system was built for longevity and efficiency. Buried PVC pipelines feed the tape laterals at the top end of the field, and collect water from the ends of the lines to allow flushing via gate valves approximately every 2 weeks. Specialized valves regulate the pressure to each block and ensure that air is released and vacuum prevented at system start-up and shut down. Filters cleanse the water of organic and inorganic contaminants, including weed seeds, from the canal water, and a chemigation unit injects fertilizer and acid to control pH. Two variable frequency drive lift pumps pressurize the water flowing from the Imperial Irrigation District's Westside Canal directly into the drip system. The pumps run at optimum efficiency during both irrigation and flushing and will significantly reduce energy costs compared to the existing flood irrigation pumps.

Irrigation scheduling is probably one of the most challenging tasks. Drip systems irrigate at the push of a button and don't require field preparation or a lot of labor, so growers have the luxury to decide exactly when to irrigate and for how long. In addition, varying soil textures, harvest schedules, weather conditions and district water availability add to the complexity. But the Thomas' are tackling the logistics and getting the hang of it in hopes of improving efficiency and increasing yields. "Most of the ranch is a sandy loam, but there are areas that are even lighter and need water more often. With flood irrigation, with borders, extra water was always diverted to these areas haphazardly. With drip, we will run those blocks a little more often to more precisely satisfy crop needs," says Rob Thomas.

Labor and dry down times are also affected by the drip system. "Flood irrigation with borders requires an irrigator to stay with the crop overnight. In contrast, the drip system is typically run in 12- hour sets every 2-4 days as needed. As the weather warms up, we'll run more often, but not necessarily over night," continues Thomas. In addition, flooded fields must be dried down prior to harvest and irrigation does not resume until the crop is removed. With drip irrigation, the dry down period before and after harvest can be reduced, further preventing unnecessary crop stress around the harvest period.

Labor is now freed up to perform more important tasks. For the short term, one of those tasks is controlling gophers which can chew through buried drip irrigation lines and create leaks. "We were warned from the very beginning that this was one of the main obstacles to successfully using drip irrigation in alfalfa fields since the fields would no longer be regularly flooded to control the gophers," Thomas recalls. "This parcel was heavily populated with gophers when we purchased it five years ago, but we were diligent in our control efforts this past year and have experienced very few problems with gophers."

Eventually the Thomas' would like to automate their system. This would allow remote system monitoring and operation, but would never replace the need for on the ground field personnel. "At the end of the day, someone has to grow the crop. Automation would just eliminate redundant tasks, and would increase our ability to monitor system activities."

Bob Thomas is obviously enjoying his new occupation. When asked how he likes farming in comparison to the construction world, Thomas points to his son and replies, "I'm in it for the long haul, for him. It's a big challenge, but relaxing. There's a ton of opportunity here if you're willing to work hard, think outside the box and do things differently than they've been done for the last few decades. I changed the game in my construction business, and that's what I intend to do here. We look forward to fine tuning this technology and making a business out of it."

Considering the Imperial Irrigation District services over 450,000 acres (182,115 ha) of crop land, and 25% of it is gravity irrigated alfalfa, it seems there will be ample opportunity.

Drip on Corn Case Study

Cox Valley View Farms, Long Island, Kansas

Even before the perfect storm of diminished water supplies, rising corn prices and government cost-share funding hit the plains, Steven Cox knew his irrigated farms would have to change. That's why he installed his first subsurface drip irrigation (SDI) system over nine years ago on his 4,000 acre (1,619 ha) operation, and has installed an additional 120 acres (49 ha) of the Toro SDI system since.

The heart of the system is Toro's Aqua-Traxx PC drip tape in a .875 inch (22 mm) inside diameter and 0.015 mil (0.015 inch, .38 mm) wall thickness. Emitters are spaced 24 inches (61 cm) apart and deliver an application rate of .033 inches (.84 mm) per hour. The tape is supported by pipelines, filters, valves, vents and monitoring devices to ensure proper operation, including a flushing manifold to ensure system longevity.

The conversion has allowed him to stretch limited water supplies while increasing yields and grain quality at the same time. "Before drip, we were trying to flood irrigate 60 acres (24 ha) with a 250 gpm (16 lps) well. We were lucky to get top yields on 25 percent of the field. I now get top yields on 100 percent of the field because of the increased uniformity and efficiency I get with drip irrigation." This is important considering the Ogallala Aquifer is now a dwindling resource. All stakeholders must act quickly to save this resource for future generations of farmers.

Figure 4 shows a yield map from Cox's gravity irrigated field in 2004, and the same field irrigated with SDI in 2006. Although grown in different years, Cox believes the growing years were similar and that a comparison between the two is justified.

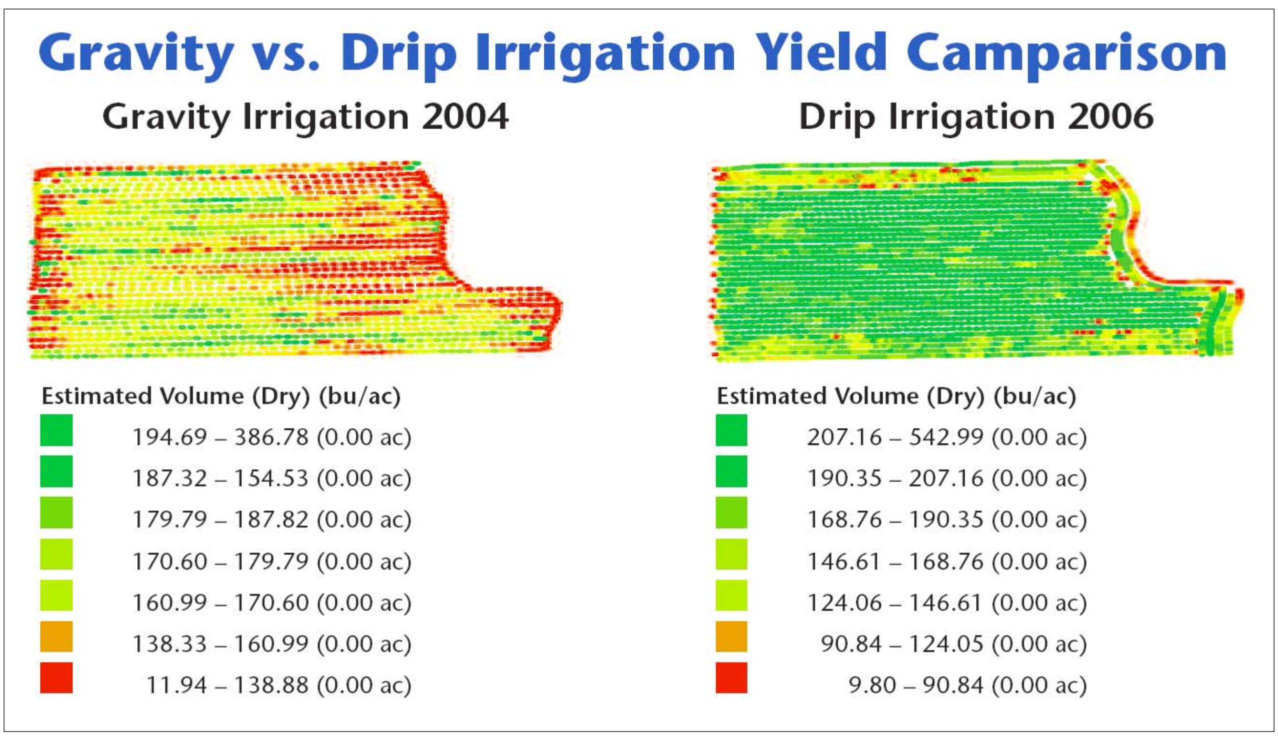

Figure 4: Gravity vs. Subsurface Drip Irrigation (SDI) Yield Comparison at Cox Farms.

With SDI, Cox feels both farming and the Ogallala Aquifer are sustainable. Cox stretched his allocation of 18 inches (48 cm) of water per year to produce 300 bushels of corn per acre compared to 150 as shown in Figure 4, and to achieve a grain test weight of 62 pounds per bushel in comparison with 58. This meant that Cox would have to buy less corn on the open market to supply the 1.5 million bushels he needs to supply his pork facilities each year, a real benefit considering the ethanol boom's recent affect on corn prices.

But Cox has experienced other benefits from SDI. In comparison with flood, SDI requires little labor, and in comparison to pivots, energy requirements are low. Fertilizers can be placed precisely where needed, and no-till farming becomes a reality. Corn is planted directly into the residue, which is managed by rotating with soybeans. Best of all, no water is wasted to evaporation, runoff, wind drift or deep percolation, thus uniformity is generally greater than 90%. "This allows me to get the most from every gallon of water I pump from the aquifer."

Figure 5 reveals a profile of the corn root system and drip tape lines. "We place our drip tape on 60 inch (1.5 m) centers, and bury the drip lines between 12-18 inches (30 – 46 cm) deep. A recent root dig with a backhoe revealed roots down to five feet (1.5 m) deep and beyond, including an impressive root density in the top 12 inches (30 cm) below both the tape line and corn row."

Figure 5: Photo of corn root dig at Cox Farms.

Making Drip Irrigation Pay

Cox originally believed that his drip irrigation conversion would take over 5 years to pay for itself, but was pleasantly surprised that it took less than two years. This is partly because corn prices rose, yields were better than expected, and government EQIP funds contributed $330 per acre towards the system's cost. In addition, costs dropped an estimated $160 per acre due to reduced fuel, labor, chemical, fertilizer and cultivation expenses. Even without subsidies, these benefits would have paid for the system in a little over three years as shown in Table 1 where three different financial payback scenarios are shown. Scenario #3 represents actual conditions experienced and reported by Cox Farms. Scenario #1 and #2 represent theoretical payback periods assuming EQIP funds were not available and/or if corn prices were lower than the actual scenario.

Table 1: Drip Irrigation Payback in Years Based on Theoretical and Actual Results.

Drip Irrigation Payback in Years Based on Actual Results*

	Drip Scenario 1:	Drip Scenario 2:	Drip Scenario 3: (Cox Farms)	
Drip Irrigation System Investment	$1,200	$1,200	$1,100	per acre
EQIP Cost Share	$0.0	$0.0	$330.0	30% of cost
Grower Investment	**$1,200.0**	**$1,200.0**	**$770.0**	per acre
Potential Yield Increase with Drip (assuming 175 bu/ac with Gravity)	50	50	100	bushels/acre
Corn Price	$3.50	$2.50	$3.50	per bushel
Potential Additional Revenue	**$175.00**	**$125.00**	**$350.00**	per acre
Potential Savings				
Fuel Savings	$25.00	$25.00	$25.00	per/acre
Labor Savings	$26.62	$26.62	$26.62	per/acre
Chemical/Fungicide Savings	$27.50	$27.50	$27.50	per/acre
Fertilizer Savings	$43.88	$43.88	$43.88	per/acre
Culitvation Savings	$37.50	$37.50	$37.50	per/acre
Potential Cost Savings	**$160.50**	**$160.50**	**$160.50**	per/acre
Payback Calculation †	**3.6**	**4.2**	**1.5**	**Years**

*Results based on specific conditions - variations may apply.
† Grower Investment divided by sum of Potential Additional Revenue and Potential Cost Savings.
Drip Scenario 1: No Subsidy; 50 bu/ac yield increase; $3.50/bu
Drip Scenario 2: No Subsidy; 50 bu/ac yield increase; $2.50/bu
Drip Scenario 3: EQIP Subsidy; 100 bu/ac yield increase; $3.50/bu

Many of the benefits experienced for corn also apply to winter wheat and soybean rotation crops. Steven's son Chris is optimistic that with SDI, a yield of 100 bushels per acre or more will be achieved on soybeans. Since soybeans cost less to plant than corn, and market prices are approaching $8-10 per bushel, soybeans may pay for the investment in SDI even quicker than corn. Perhaps best of all, SDI and no-till helps build the soil, and attracts wildlife nests by keeping the soil surface dry.

SDI on Cotton Case Study

Loyd Jordan Farms, Meadow, Texas

Loyd Jordan is a 3rd generation farmer who cultivates 3,500 acres (1,1416 ha) southwest of Lubbock in Terry and Lynn counties, Texas. He irrigates 1,250 acres (506 ha) with pivots and, most recently, 300 (121) acres with subsurface drip irrigation (SDI). A neighbor had tried SDI and said good things about water savings, getting increased yields on fewer acres, and how easy it was to apply fertilizers and control insects. So in 2004, Jordan installed 40 acres (16 ha). He liked it so much that he installed an additional 120 acres (49 ha) in 2007, and then another 140 acres (57 ha) in 2009. Now he prefers SDI to the pivots he has used for so many years.

"I can get three bales of cotton per acre with 16 inches (41 cm) of drip water, but only 2.25 bales per acre with 16 inches (41 cm) of pivot water," says Jordan. "Wind is a big factor out here where we have limited water supplies." Although water is not yet being allocated, there are limitations on drilling new wells in the Ogallala aquifer, so every drop counts. But there are other reasons he likes the drip, too. "Pivots are always in the way when we need to cultivate, and water is always heavy in one spot so it gets muddy. And you need a mechanic to deal with all the electrical and mechanical problems. The energy costs associated with pivots are a concern, and the insurance costs add up, too."

Lessons Learned Reap Results

After six seasons, Jordan has learned a great deal about SDI installation, operation and maintenance. In his most recent installation as shown in Figure 6, Jordan shanked in his 0.875 inch (22 mm) internal diameter Toro Aqua-Traxx drip tape 12-15 inches (30 – 38 cm) deep on 80 inch (2 m) centers in sandy loam soils with a little clay. The emitters were 16 inches (41 cm) apart, and the flow rate 0.17 gpm/100 ft (1.32 lph/metro), resulting in an application rate of 0.025 inches (.64 mm) per hour. In the past, Jordan had used 24 inch (61 cm) spaced emitters. "I liked the closer, 16 inch (41 cm) spaced emitters better than the wider 24 inch (61 cm) spacing I used in the past. With 16 inch (41 cm) spacing I'm able to wet up quicker."

Cotton was planted the 1st week of May on 40 inch (1m) centers, but hail forced Jordan to replant the first week of June and to finish the year with typical yields. "We run the drip system continuously on a three-set system for about 3 weeks to germinate and fill the 3 foot (.91 m) rootzone with a little over 4 inches (10.2 cm) of water. Then, with the help of a consultant, we schedule irrigations pre-bloom according to crop needs. If we get one inch (2.54 cm) of rain, we can back off for 3 to 5 days." After bloom, Jordan irrigates continuously at a rate of about .2 inches (5.1 mm) per day, alternating the schedule such that each block gets equal amounts of irrigation during both daylight and night time hours. "Our consultant told us this is a good thing, so we're going along with it."

One system irrigates 43 acres (17.4 ha) with 500 gpm (31.5 lps) divided into three zones with four valves running at once. A total of twelve zone valves are automated with Toro control equipment which worked great and cut down on labor costs. "After bloom, there is little margin for error. Everything has to work right," Jordan reminds us.

Figure 6: Drip tape laterals were shanked into the ground and connected to PVC submains at Jordan Farms.

Jordan acknowledges that SDI requires a little more intensive management and has its own problems. But he hired a consultant to help with irrigation scheduling, fertigation and scouting, and injects Vydate through the system at a rate of about 8 soluble ounces per acre to control the gophers. And occasionally, hose kinking can be a problem after the ditch settles in.

"But it's not a big deal – we just go out and fix it," says Jordan. In spite of the gophers and occasional repairs, Jordan believes SDI requires less labor than pivots. Ultimately, he prefers SDI because it applies water more evenly and efficiently, which is of utmost importance in this region of limited water. "I can get the same number of bales of cotton from 80 acres (32 ha) of SDI as I can get from 120 acres (49 ha) of pivots. Why farm more acres for the same result? Yield, and crop per drop, is the bottom line."

Asked about the future, Jordan says he hopes to work in rotation crops. Depending on the schedule, he believes he could get a crop of winter wheat, sorghum or milo in after the cotton. If Verticillium wilt is present, rotation will be a must. Fortunately, there have been no cotton root rot problems in the area. But what he hopes for most is that some of his 3 children or 8 grandchildren will come back to farm with him. "Farming is a struggle, but we're hanging in there." Hopefully, with the help of SDI, Loyd Jordan Farms will prosper well into the future.

Drip on Onions Case Study

Standage Farms, Inc., Vale, Oregon

Larry Standage has reaped all the typical benefits of converting to drip irrigation on his onions including less use of water, fertilizer and labor, increased yields, and reduced runoff. But the most important benefit is that Standage builds customer loyalty as a result of a higher quality, more uniform crop as shown in Figure 7. "The contents of each 50 pound (23 kg) bag of onions is superior because the crop is more uniform in size, shape and color, thus the customer is more pleased. I use drip to keep my customers coming back." Standage, who farms along with his father Dorrance and son Joseph, began experimenting with drip in 1999 as part of continuous efforts to find better ways to farm. "Government regulators were getting serious about reducing runoff from farms, and we felt this was important." Half his acreage is in onions which are rotated with corn, wheat and sugar beets. He purchased three pivots to begin upgrading from flood, but disease problems made him keep looking. He had been watching some of the early, local drip pioneers in Vale, Nyssa and Jamison, and was wondering who would help him with the learning curve if that's the direction he chose. Then he met Brian Andersen, owner of Clearwater Supply, at a local show. "I was impressed with Clearwater's ability to not only design, sell and install a system, but to also guide me through start-up and operation. The chief designer lived here for a month to help me through the first system, and for the 9 years since, the service has been exceptional."

Figure 7: Onion crop uniformity is very important for Standage Farms.

Design and Installation Made Easy

Today half of Standage's onions are grown with drip. Since crops are rotated on each field, the portable drip system is custom designed each year. This could be confusing, but Clearwater makes it easy by supplying him with a new "Design and Installation Manual" for each field with all the pertinent data. In addition, Clearwater's Jim Klauzer has set him up with moisture sensors which, together with ET data, help him determine how many hours to irrigate, and when. They still look at crop color and visual appearance to decide when to irrigate, but have learned that moisture sensor readings of about 30 centibars coincides with a crop appearance that typically triggers an irrigation event. "All this helps save water – otherwise, we'd probably over-irrigate."

But equally important is that it improves the crop, too. Although yields vary from year to year, drip always outperforms flood or sprinklers in marginal fields, and has never performed worse in good fields. "Drip nurtures a healthier, stronger plant, which really shows up during extreme heat events," explains Standage. "Drip also creates an advantage for cultural activities during the growing season since the furrows are always dry as opposed to flood, which always leaves wet spots. The root system is more robust which prevents stress, and uniformity of water application translates into uniformity of crop. Considering the weather we had this season, this drip field is incredibly uniform. This is a huge advantage for our customers, and even in our own packing sheds, because variable size, shape and color creates problems in both packing and marketing."

Drip Uses Less Fertilizer

Drip also allows spoon feeding of fertilizers. Pre-plant fertilizers are applied in the fall according to yearly soil tests, but in-season needs are supplied through the drip. "We use 30% less fertilizer with drip, and with recent fertilizer costs tripling from $.18 per pound to over $.50 per pound, the savings are significant," says Standage. "To keep the lines clean, chlorine is injected late in the season to achieve 3 ppm total chlorine at the ends of the lines, and then the lines are thoroughly flushed before retrieval."

Durable, Quality Tape

Clearwater supplies Standage with Aqua-Traxx premium 6 mil (0.006 inches, 0.15 mm) wall thickness drip tape from Toro Micro-Irrigation with a flow of .22 gpm/100 feet (1.7 lph/metro). Outlets are spaced 12 inches (30 cm) apart, and lateral lines are spaced 42 inches (1.1 m) apart to achieve an application rate of about .06 inches (1.52 mm) per hour. In Standage's experience, the best wetting pattern is achieved with a 12 hour set, with intervals between irrigations determined by weather and sensors. Since the tape is installed after the onion seeds are planted, and supplies the moisture for germination, it is critical that the tape functions properly. "The 6 mil Aqua-Traxx is tough and durable and doesn't break or have problems like other tapes. As any drip farmer knows, once you have a problem with tape in the field, there is nothing you can do to correct it, so it's important to get it right from the start."

Drip on Potatoes Case Studies

From the arid irrigated west to the largely rain-fed fields in the East, agricultural innovators are discovering significant benefits in adopting a potato production system designed around the use of drip irrigation. Yield increases, quality improvements, ease of field accessibility and a reduction in water, fuel, labor and fungicide use are all reported by case study growers as reasons to use drip irrigation to grow potatoes. It's a mainstream technology in dozens of other crop production systems throughout the world because it allows producers to evenly spoon-feed precious water and nutrients directly to every plant's root zone despite variable soil conditions, undulating terrain, odd field dimensions or long lengths of run. But potato producers have been slower to adopt drip since there are significant changes in bed configuration, agronomic decisions, planting and harvesting equipment that go along with this technology. Despite the challenges, cutting edge producers, suppliers and researchers are coming up with viable answers in hopes of bolstering the potato industry against the inevitable vagaries of the market, economy, costs and resource availability. Some even believe their future livelihood will depend on mastering this new technology.

Clearwater Supply, Ontario, Oregon

Irrigation professionals with an eye toward productivity, quality and efficiency have been working for over a decade to adapt drip irrigation to potatoes in the Pacific Northwest, where over 475,000 acres (193,000 ha) of potatoes are grown in Washington, Oregon and Idaho alone (USDA, 2008). To date, over 500 acres (202 ha) have been under commercial production for processing, fresh pack and specialty potatoes. Jim Klauzer, sales agronomist for Clearwater Supply in Ontario, Ore., reports that area growers have experienced clear benefits:

1. Improved water use efficiency: drip has consistently produced more tonnage per acre inch of water applied, for example, 1.5 tons payable per inch.
2. With drip, row closure occurs faster, thus growth is accelerated and there is a potential for an early dig as shown in Figure 8. When potatoes can be harvested a month early, processors can level-load their plants and start processing in August instead of September. So they can finish up in May instead of June, reaping them a larger processing window.
3. There is less disease pressure from alternaria, rhizoctonia, early death, sclerotinia, etc. since the crop is not wetted from above. Less moisture results in less disease and less fungicide use, saving the producer money.
4. More uniformly sized tubers and a higher percentage of U.S. No. 1's: Klauzer explains that processors offer an incentive for that, and it's possible to achieve that with drip.

But no innovation comes without effort. "There are definitely problems to overcome to reap these benefits. First, tape placement in relation to the seed is very important. Second, equipment must be modified to accommodate the drip tape and a new bed configuration. Third, fertilizer needs under drip are different than with sprinklers and must be managed accordingly. And fourth, after tape is lifted to the surface during harvest, it must be removed immediately to avoid subsequent compaction by harvest trucks."

With these challenges in mind, Clearwater Supply has worked out a new patented bed configuration and modified equipment to properly place the drip tape in relation to the seed. The bed consists of a paired row configuration where one line of drip tape is placed between each paired row. Ultra-low flow tapes have been an integral part of the success.

Bob Mittlestadt, General Manager of Clearwater Supply in Othello, Wash., says, "Our experience with innovative onion growers is that they have used drip to improve their production practices. Clearwater Supply is looking forward to similar opportunities in potato production. This is because water availability is a challenge and the marketplace continues to demand high quality potatoes. Drip is a way to meet that challenge."

Figure 8: This photo shows a furrow system on the left, and a drip system on the right in the Pacific Northwest. Note the degree of row closure and size of the drip in comparison to the furrow. Photo courtesy of Jim Klauzer, Clearwater Supply.

Nolan Maser Farms, Pitman, Pennsylvania

Clear across the country, Nolan Masser grows 120 acres (49 ha) of potatoes in the Pitman, Pennsylvania area. After years of dry land farming and irrigating with a pivot and a hard hose traveler, he knew he needed to make a change because of rising fuel costs and the growing scarcity of water. He evaluated pivots, solid set and drip, and settled on trying a one-acre drip test block last year. He was impressed enough with the improved yields and size profile in comparison with a non-irrigated check that he has installed an additional 20 acres (8 ha) this year on Superiors, Yukon Gold and Reba varieties. He just finished harvesting the Superiors.

"Irrigating with a hard-hose traveler is like using a club; irrigating with a center pivot is like using a hatchet; but with drip, it's like irrigating with a scalpel," said Masser after realizing a 25 percent yield increase on the drip irrigated Superiors. "The potatoes reach maturity at a faster pace and early dying of the vines is greatly reduced. The drip carries the vines right through to the end. The system can be turned on or off with the flip of a switch."

Figure 9: Grower Nolan Masser grows potatoes with drip using a de-stoned bed configuration.

Masser plants on a de-stoned bed system with two rows of potatoes on each bed, 30 inches (76 cm) apart, and beds spaced on 72-inch (1.8 m) centers. One line of Toro AquaTraxx pressure compensated drip tape with emitters spaced 16 inches (41 cm) apart is placed in-between the two rows of potatoes in a shallow furrow. With a tape flow rate of .25 gpm/100 ft (1.9 lph/metro), the gross application rate is approximately 0.04 inches (1.0 mm) per hour. "With drip, we don't have to second- guess our irrigation schedule according to rain predictions. If it doesn't rain, we can irrigate. If it rains, we don't need to." Masser continues, “We felt that by running six to seven hours each day this season we could keep up with evapo- transpiration losses. However, we know that schedule may need to be adjusted for a hotter year, and are mindful that one row of tape per two rows of crop is not wetting the entire root zone and must be watched closely."

Masser is quick to point out that Toro's local District Manager Bill Wolfram was a huge asset in the adoption process. "He made sure the system was designed properly, which is extremely important, and introduced me to supportive, knowledgeable dealers such as Nolt's Supply. He also introduced me to Toro's pressure compensated drip tape, which really made sense on my hilly terrain and small, odd shaped parcels and corners."

Masser also credits Dr. Bill Lamont of Penn State University, who has been experimenting with drip on potatoes for over nine years and provided much guidance. In addition to the 20-acre (8.1

ha) system he purchased, Masser accepted loaner equipment from Penn State to conduct additional trials.

In addition to growing a better crop, Masser notes that runoff was reduced to nothing on the drip fields, and that fuel consumption was about a third of a hard hose traveler. "I estimate that with a traveler, it costs about 10 gallons (38 liters) of fuel to apply an inch of water. With drip, it costs about four gallons (15 liters) of fuel to apply an inch (2.54 cm) of water." In addition, laborers no longer have to respond to the fixed schedule of a traveler - they can dictate the irrigation schedule with drip, metering small, even doses exactly where and when the plants need it.

Masser is happy with the changes he has made, but acknowledges it wasn't easy and there is more work to be done. "We know we have to improve our installation and removal equipment, and we're still wary of the cost of replacing the drip tape each year. But with the fuel savings and yield increases we have seen so far, it appears to pencil and is worth the effort."

Drip on Processing Tomatoes Case Study

Worth Farms, Huron, California

Chuck Herrin manages Worth Farms in California's Westlands Water District. Founded by his grandfather, a custom harvester turned farmer, Worth Farms today grows 4,500 acres (1,821 ha) of drip irrigated crops including 3,500 acres (1,416 ha) of processing tomatoes. Herrin first learned about drip on their 300 acres (121 ha) of almonds, but it took some time to translate that knowledge to their tomatoes. This is because canning companies remembered some bad experiences with over-watered and over-fertilized drip-irrigated tomatoes from other farms that resulted in undesirable low brix content.

But when the Worth management team leased a piece of sandy ground that was difficult to irrigate otherwise, they decided to give drip a try on their own operation. A local dealer helped them get started, along with neighboring farmers who had previous experience. The first system was such a success that they set out to convert more acreage as quickly as possible.

"Our best-ever yield on conventional sprinkler/gravity acreage was 64 tons per acre in 2004. Five years later, that is our *average* per acre operation wide, representing a 50 – 100% increase in yield with drip. On top of that, water, labor, fertilizer and herbicide savings are substantial. We used to apply 36 inches (91 cm) of water per acre to meet a crop ET of about 18 inches (46 cm). Now we only apply 24 inches (61 cm) of water, a 33% savings. At the same time, we have cut labor use by half, and fertilizer use by a third. This is significant."

The Keys to Success

Herrin explains that the key to successfully growing tomatoes with drip irrigation is water, fertilizer and variety management. "Today we use transplants and set them with the drip as opposed to conventional seeding and sprinkling up." The transplants are 6-8 inches (15 – 20 cm) long and planted on 60 inch (1.5 m) beds, 14 inches (36 cm) apart and 2-3 inches (5 – 8 cm) deep into moisture supplied by the drip tape. Toro's Aqua-Traxx drip tape, with a 0.875 inch internal diameter, 15 mil (0.015 inch, .38 mm) wall thickness, 12 inch (30 cm) emitter spacing and a flow rate of .22 gpm/100 ft. (1.7 lph/metro), is buried about 12 inches (30 cm) deep, supplying .04 inches (1 mm) of water per hour. A consultant was hired to help with soil moisture monitoring and management decisions, but in water-short years when surface water deliveries are cut, the crop must survive from limited supplies of groundwater alone. “The wells run full time during the summer months and barely keep up with crop water use. We have about 2,200 gpm (139 lps) available to irrigate 320 acres in a 3 set system – if all goes well, we can apply .36 inches (9 mm) on any given day in the summer.”

To prevent emitter clogging, the ground water is treated with both acid and chlorine. N-phuric is injected into the drip irrigation system to reduce the pH from 8.5 to about 6.5 at the ends of the lines. In addition, chlorine is injected at a rate of 1 ppm continuously. “We are hoping that the 15 mil tape will last the length of the lease, about 7 years. In order to achieve this goal, we have to prevent clogging by applying the right chemicals and flushing the lines properly,” says Herrin.

Herrin would like to move towards automation and more sophisticated valve control in the future. Currently, hand labor is used to open the ends of the lines and flush as shown in Figure 10, but automating with a buried flush line would be more efficient. “We started with a flexible PVC layflat feeder submain, and then moved to semi-permanent, buried PVC pipe. The next logical step is to connect the ends of the lines to a semi-permanent, PVC flushing submain and bury it as well. Then the whole system is below ground and can be automated.”

Figure 10: Submains and the ends of tape lines are flushed manually at Worth Farms.

As Herrin reflects on the benefits, he summarizes: “Farming the tomatoes is now as easy as farming the almonds. We can access the field anytime without worrying about pipes or ditches in the way, or muddy drive rows. Now that we grow tomatoes with drip, I can’t imagine farming them any other way. It’s definitely the way to go – the way of the future.”

Drip Irrigation Software Tools for Growers

Toro Drip-Micro Irrigation Payback Wizard

According to the 2008 Farm and Ranch Irrigation Survey (www.agcensus.usa.gov), less than 10% of irrigated acreage in the United States uses drip irrigation. Unpublished research conducted by the Irrigation Association’s drip/micro common interest group recently found that the key barrier to the adoption of drip irrigation technology is the expense. In order to help growers evaluate whether the investment has a reasonable payback period, Toro has introduced a “Drip-Micro Irrigation Payback Wizard” (www.toromicroirrigation.com or www.dripirrigation.org). Developed in partnership with the Irrigation Association, this online software tool estimates how long it takes to offset the investment of a new drip or micro irrigation system, and estimates how many additional acres could be farmed with the water saved by using drip irrigation technology.

The tool is extremely fast and easy to use. Once accessed, growers only enter five pieces of information to receive an initial report: region (state), the type of crop, how many acres they wish to evaluate, what type of irrigation system they are currently using (gravity, sprinkler or mechanized) and the cost of water per acre-foot. Within seconds, a report is generated citing the payback period and additional acres that could be farmed with conserved water. Next, growers may customize the report by viewing, and changing if desired, the default data and assumptions that the Wizard used to produce the report. In this way, growers may use the wizard to create a customized report that better reflects their specific production scenario. The report can then be downloaded and printed. This software is available for online use or for download.

Figures 11 A,B,C and D show example output for corn:

> **Step 1.** Initial criteria: Nebraska, Corn, 160 acres, Gravity Irrigation and Water Costs of $50/ac-ft. (Fig. 11A).
> **Step 2**. Initial report: Investing $1,000/ac in a drip irrigation system would have a 3.99 year payback period and 50.15 additional acres could be farmed with the water conserved. Side by side columns display the critical cost and yield assumptions driving the payback period. (Fig 11B).
> **Step 3**. Modify data for local conditions: The United States Department of Agriculture Environmental Quality Incentive Program (USDA EQIP) funding of $300/ac is available. (Fig 11C). New payback period would be reduced to 2.79 years. (Fig 11D). Note that any other parameter could also be changed including drip irrigation system investment cost, assumed yield and quality increases, and/or operating costs.

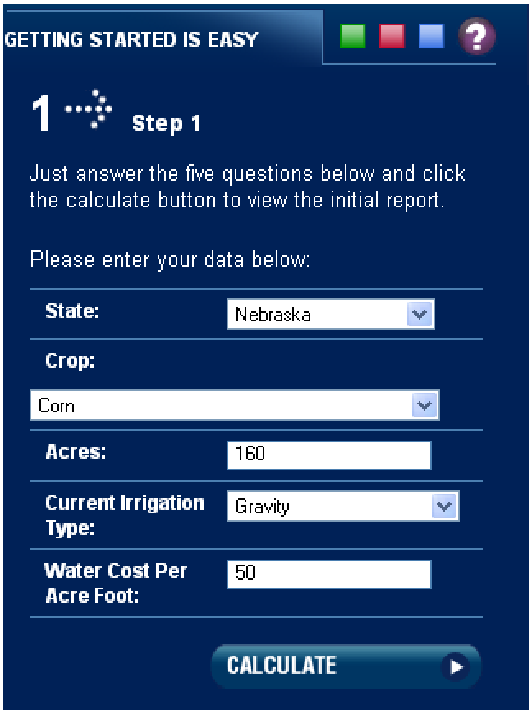

Figure 11 A: Output from Drip Micro Payback Wizard.

Figure 11 B: Output from Drip Micro Payback Wizard.

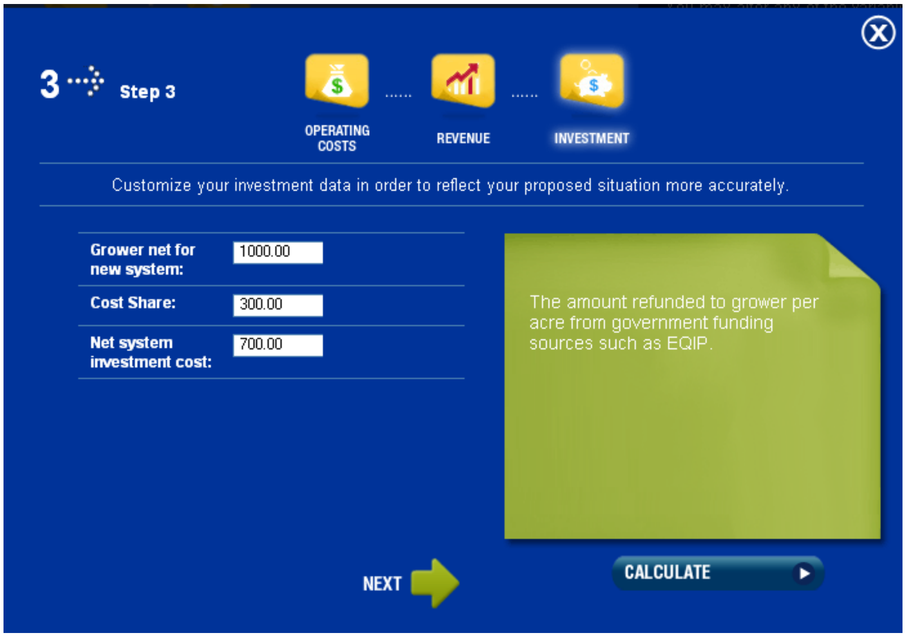

Figure 11 C: Output from Drip Micro Payback Wizard.

Figures 11 D: Output from Drip Micro Payback Wizard.

In the case that the payback period is extremely long, drip irrigation is likely not a viable investment. However, in the case that the investment period is reasonable, the investment likely warrants further research and/or serious consideration. In this case, growers are encouraged to seek advice from fellow colleagues and government, academic and industry resources.

The Drip Tape Irrigation Calculator

The application rate of a drip irrigation system with a specific drip tape model varies according to three basic factors: inlet pressure, tape lateral spacing and emission uniformity. Calculating the drip system application rate can be confusing, so Toro developed the Drip Tape Irrigation Calculator (www.dripirrigation.org) as shown in Figure 12 to easily calculate 1) drip system application rates and 2) how long the system needs to run to apply 0.1 inches per hour or 1.0 inch per hour. Once the application is accessed online via a computer or any smart phone, growers can quickly get answers by simply choosing a Toro Aqua-Traxx drip tape model and then entering the tape inlet pressure, tape lateral spacing and drip system emission uniformity. Different Aqua-Traxx models and new data may be entered as often as desired.

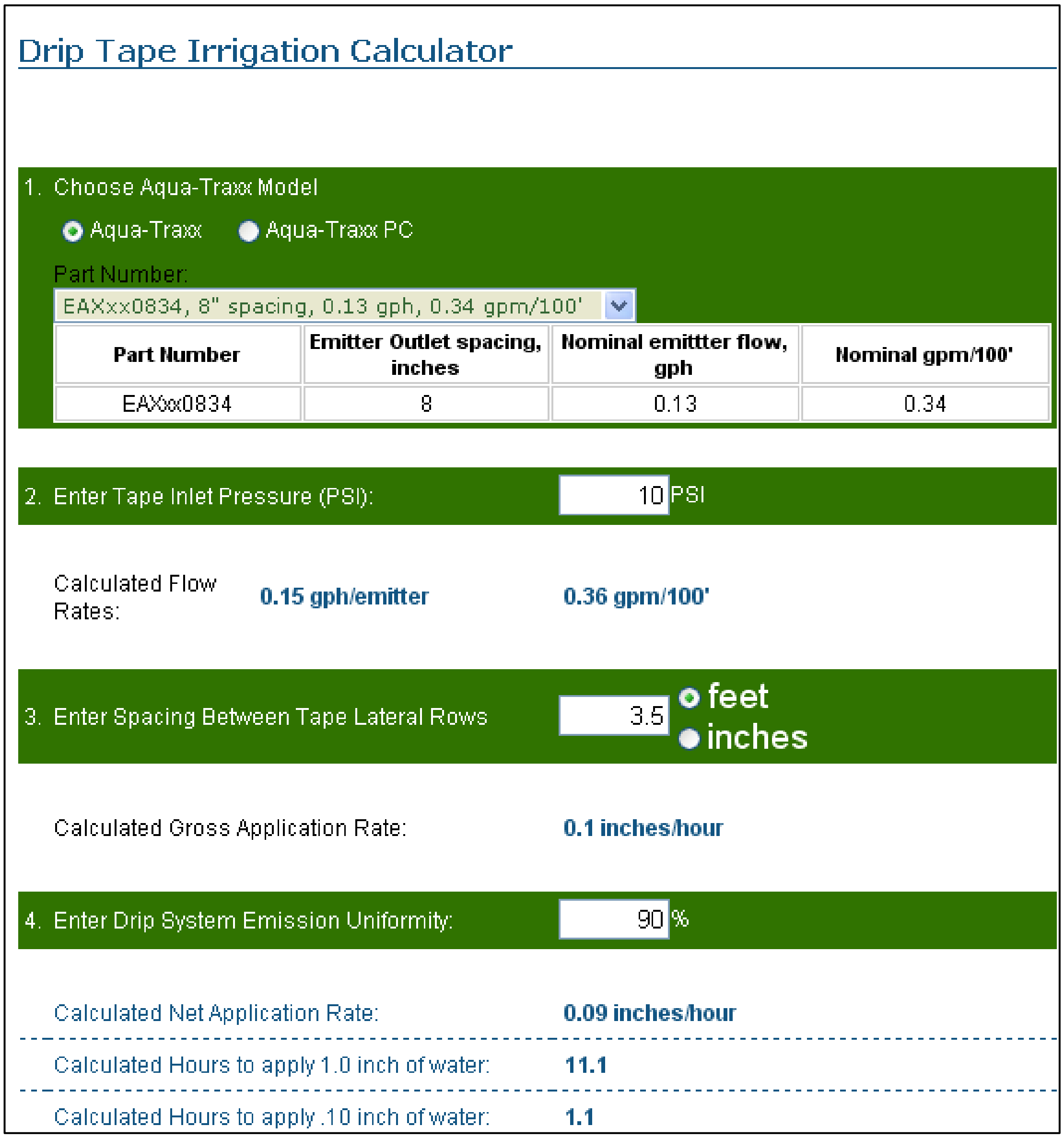

Figure 12: Output report from the Drip Tape Irrigation Calculator.

For example, Figure 12 shows that an Aqua-Traxx model has been chosen that has emitters spaced 8 inches (20 cm) apart with a flow rate of 0.36 gpm/100 ft. (2.54 lph/metro) at an inlet pressure of 10 psi (.7 bars). The tape lateral spacing is 3.5 feet (1.1 m) and the emission uniformity is estimated to be 90 percent. In this case, the Drip Tape Irrigation Calculator reports that the net application rate is 0.09 inches (2.3 mm) per hour. Thus it will take 1.1 hours to apply 0.1 inch (2.54 mm) of water, or 11.1 hours to apply one inch (25.4 mm) of water. This software is available for online use or for download.

Conclusion

The case studies profiled in this paper use surface drip systems, subsurface drip irrigation systems (SDI) and hybrid systems on alfalfa, corn, cotton, onions, potatoes and processing tomatoes. Drip irrigation was successfully integrated into each of the six field crop case studies presented. Although each crop and system had unique challenges, the benefits outweighed the cost and effort to successfully adopt drip irrigation into each of them. In general, each farming operation continues to actively use and invest in drip irrigation because of the benefits cited by the case study growers including increased yields, increased quality, increased uniformity and reduced water, fertilizer, energy, labor, harvest and chemical costs.

As growers new to drip explore the technology and begin using it, software tools have been developed to assist. Specifically, Toro has developed two such tools to help evaluate the investment in drip irrigation prior to adoption, and to help with scheduling irrigations after adoption. First, the Drip Micro Payback Wizard allows growers to estimate the payback period associated with an investment in drip irrigation, and estimates additional acres that could be farmed with conserved water. Second, the Drip Tape Irrigation Calculator helps drip irrigation system users calculate system application rates and appropriate irrigation system run times. It can also be used to help select the appropriate drip tape flow rates and spacing, and to assess the impact of emission uniformity on estimated irrigation run times and operating costs. Both have been well received by growers who are in the “shopping stage” as well as the “management” stage.

The results of each crop and grower profiled are unique to the particular application and production years reported. However, it is hoped that the information contained in these case studies contributes to a better understanding of how, and why, drip irrigation is being adopted on more and more acres of field crops each year. Ideally this information will serve as an example to guide those who are interested in adopting and managing drip irrigation systems on these or similar crops, and will promote further research where warranted.

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