EVALUATION OF SUBSURFACE DRIP IRRIGATION ON PEPPERS

Stuart W. Styles[1]
Charles M. Burt[2]

ABSTRACT
This paper is a summary of two farms that utilized the California Energy Commission's low-interest loan program to facilitate their entry into drip irrigation. One farm is located near Oxnard, California, USA and the other is located near Gilroy, California, USA. Both of these growers farm about 162 hectares (400 acres) in their overall operations and used the loans to purchase subsurface drip irrigation systems for Peppers. Over $4 million in low-interest loans have been made available to California growers from the California Energy Commission (CEC) since 1986. The CEC initiated the loan program for growers to help implement energy conservation practices.

The primary findings of this paper include: 1) The growers needed a two to three year learning curve to solve basic problems. They continually adapt to new challenges by trying different approaches to management and hardware. 2) The nature of problems will change from year to year. 3) Peppers have an excellent yield response to drip irrigation. The energy used (per unit yield) decreased and the volume of water required (per unit yield) decreased. Fertilizer application accounts for a significant amount of the total input energy for peppers (over 30%) due to the energy required to manufacture N-based fertilizers. Fertilizer application rates remained relatively constant. This is the area for greatest future reduction in energy use, by gradually using less fertilizers. 4) Both growers are expanding the amount of drip irrigation systems on their farms.

CALIFORNIA ENERGY COMMISSION - FARM ENERGY ASSISTANCE PROGRAM
Over $4 million in low-interest loans have been made available to California growers from the California Energy Commission (CEC) since 1986. The CEC initiated the loan program for growers to help implement energy conservation practices. This popular program was designed to give growers the impetus to try new, cutting edge ideas. In 1993, about $1.3 million was made available at an interest rate of 2.6 percent.

As part of the loan program, the Irrigation Training and Research Center (ITRC) at California Polytechnic State University (Cal Poly) - San Luis Obispo provided technical assistance to the CEC in the review of applications. Once applications were approved, technical assistance was then

1 Project Manager, Irrigation Training and Research Center (ITRC), California Polytechnic State University (Cal Poly), San Luis Obispo, CA 93407 email: sstyles@calpoly.edu
2 Director, ITRC, Cal Poly, San Luis Obispo, CA 93407 email: cburt@calpoly.edu

provided to the growers participating in the program. In addition, ITRC also documented changes in resources before and after implementation of the new systems. The main idea was to help accelerate the learning curve for other growers who might be interested in trying the new technology.

DEFINITIONS

Total Energy Use = On-farm pumping energy + field operations energy + pipe installation energy + pipe manufacturing energy + fertilizer manufacturing energy

Water Use Efficiency = $\frac{\text{Reported Yields (tons (short) per hectare)}}{\text{Applied Water Use (hectare-meter per hectare)}}$

Energy Use Efficiency = $\frac{\text{Reported Yields (tons (short) per hectare)}}{\text{Total Energy Use (MJ per hectare)}}$

Investment Efficiency = $\frac{\text{Average Net Revenue Increase (\$ per hectare)}}{\text{Annualized Investment Cost (\$ per hectare)}}$

Distribution Uniformity (DU) = Measure of the uniformity with which irrigation water is distributed to the plant uptake areas in a field.

CASE 1 - UNDERWOOD RANCHES

The following is a summary of the 1994 and 1995 growing seasons. The new technology evaluated was buried row crop drip irrigation near Oxnard.

- New System - Subsurface Drip Irrigation on Jalapeño Peppers
  - Tape: 0.1 mm (4 mil), high flow T-Tape (94). 0.2 mm (8 mil), high flow T-Tape (95).
  - Supply Manifold: 10 cm (4") diameter oval hose, supplied by buried PVC or layflat hose.
  - Booster Pump: Cornell end suction pump (95/96).
  - Filters: Three 1.2 m (48") Yardney sand media filters.
- Old System - Sprinkler Irrigation
- CEC Loan: $50,000
- Actual Capital Cost: $66,214
- Size of Project Field: 20 hectares (50 acres)
- Average Yield Increase: 29 ton (short) / hectare (6 tons/acre)
- Investment Cost (Annualized): $381/hectare ($154/acre)
- Average Net Revenue Increase: $4,670/ha per year (1994 and 1995) ($1,890/acre per year)
- Investment Efficiency: 12.3 fold increase

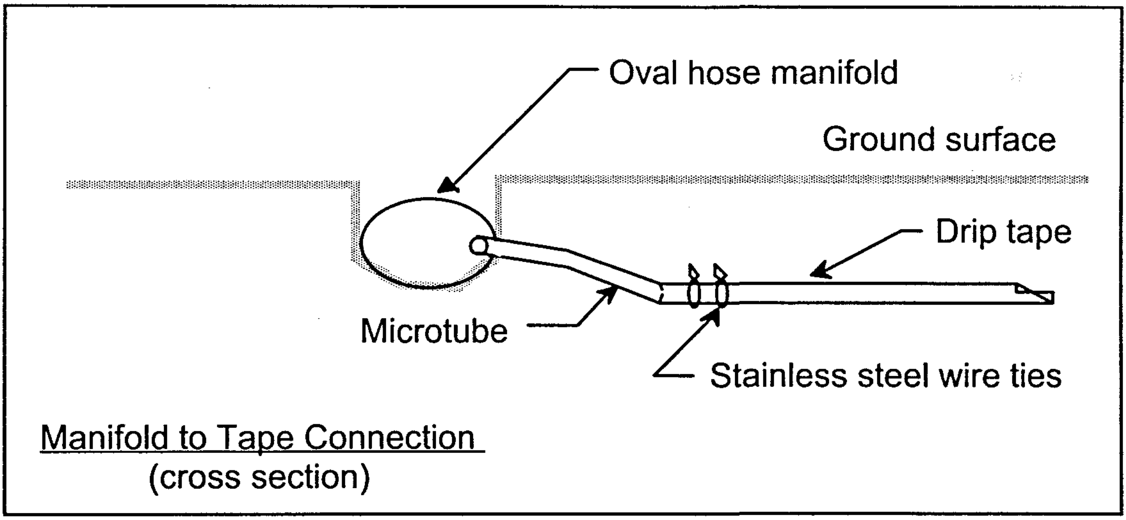

Figure 1. Manifold to Tape Connection at Underwood Ranches.

MAJOR LESSONS LEARNED - UNDERWOOD RANCHES

A grower needs approximately two years of experience and technical assistance in order to feel comfortable with a buried drip system. Even after that time, the grower will continue to make many changes to both hardware and management in an effort to customize the irrigation system to his own operation and needs. With a crop such as peppers, the "system" receiving the loan is fluid - fields and situations change annually. Buried drip has enabled the grower to achieve significant improvements in yield with his peppers. This experience has also been noted by many other pepper farmers.

The Water Use Efficiency and the Energy Use Efficiency, both of which relate the yield to resource consumption, were improved significantly under this project. Buried drip significantly reduced water consumption compared to the previous sprinkler irrigation system. Fertilizer consumption represents a major energy use for peppers (about 30%). Fertilizer reduction appears to be one area where reductions in energy use could be made.

WATER AND ENERGY USE - UNDERWOOD RANCHES

The following table was generated by reviewing the farming inputs and outputs for pre-project and post-project conditions. The analysis was primarily a differential analysis. This means that not all of the energy use was accounted for in the figures. For example, the energy to manufacture a tractor would be the same for both irrigation systems so it was not included.

Table 1. Water and Energy Use Efficiencies for Underwood Ranches

Item	Before CEC Project		1994 After CEC Project		% Change
Water Use- ha-m/ha (Ac-ft/ac)	0.73	(2.4)	0.55	(1.8)	-25
Energy Use- MJ/ha (MBtu/ac)	47.7	(18.3)	52.1	(20.0)	10
Yield- ton (short)/ha (Ton/ac)	44.8	(20.0)	67.3	(30.0)	50
Water Use Efficiency ton (short)/ha-m (Tons/AF)	62.5	(8.5)	121.0	(16.5)	94
Energy Use Efficiency ton (short)/MJ (Tons/MBtu)	0.95	(1.1)	1.39	(1.5)	36

Item	Before CEC Project		1995 After CEC Project		% Change
Water Use- ha-m/ha (Ac-ft/ac)	0.73	(2.4)	0.61	(2.0)	-16
Energy Use- MJ/ha (MBtu/ac)	47.7	(18.3)	51.1	(19.6)	7
Yield- ton (short)/ha (Ton/ac)	44.8	(20.0)	49.3	(22.0)	10
Water Use Efficiency ton (short)/ha-m (Tons/AF)	62.5	(8.5)	81.6	(11.1)	31
Energy Use Efficiency ton (short)/MJ (Tons/MBtu)	0.95	(1.1)	0.95	(1.1)	0

Item	Before CEC Project		'94-'95 Average After CEC Project		% Change
Water Use- ha-m/ha (Ac-ft/ac)	0.73	(2.4)	0.58	(1.9)	-19
Energy Use- MJ/ha (MBtu/ac)	47.7	(18.3)	51.6	(19.8)	9
Yield- ton (short)/ha (Ton/ac)	44.8	(20.0)	58.3	(26.0)	30
Water Use Efficiency ton (short)/ha-m (Tons/AF)	62.5	(8.5)	101.0	(13.8)	62
Energy Use Efficiency ton (short)/MJ (Tons/MBtu)	0.95	(1.1)	1.1	(1.3)	18

DISCUSSION - UNDERWOOD RANCHES

The buried drip system resulted in an averaged 19% reduction of water use over the sprinkler system. The drip system had an average 30% increase in pepper yield. This is primarily a result of a reduction in the *Phytophthora* problem. *Phytophthora* does well in the moist, humid environment which is common to sprinkler irrigation. Buried drip reduces humid conditions.

The grower achieved a 22 tons (short)/hectare (10 tons/acre) increase in yield for the project in 1994 to 67 tons (short)/hectare (30 tons/acre). This was due to the capability to harvest greens - 2.7 tons (short) at $386/ton (3 tons at $350/ton) and an increase in yield on the reds - 6 tons (short) at $331/ton (7 tons at $300/ton). It was not possible to harvest the greens on the sprinkler plots due to lack of adequate yield for harvest.

The 1995 pepper yields dropped off significantly. The 57 hectares (140 acres) of peppers under drip irrigation produced 2 810 total tons (short) (3 100 total tons) of red and green peppers. Yield was only 49 ton (short)/hectare (22 tons/acre) due to increased *Phytophthora* problems.

The heavy *Phytophthora* problem in 1995 was caused by both the unusually wet season and emitter plugging problems. Emitter plugging was severe on the sections of the drip system still using aluminum mainlines. Aluminum mainlines prevented the periodic use of acid, which is a necessary component of the maintenance strategy for the control of emitter plugging. The continued use of acid will eventually destroy aluminum pipe. Where aluminum mainlines were used, emitter plugging problems caused under-irrigated areas in the field, which subsequently reduced the system DU values. To offset the under-irrigation problem more water was applied to the field, resulting in over-irrigation and ponding on other areas of the field. The excessive moisture enhanced the *Phytophthora* problems. Emitter plugging problems became so great in the under-irrigated areas of the field that workers cut holes in the tape with pocket knives. The grower noted a 95% reduction in yield on 10 hectares (25 acres) of over-irrigated fields. The grower has since abandoned the use of aluminum mainlines.

In 1995, a problem arose with the placement of the buried drip tape. The tape was installed after splitting the preceding crop's 2.0 m (80 inch) beds to the 1.0 m (40 inch) beds required for peppers, without leveling and reshaping the field. A uniform tape depth could not be achieved and resulted in a shallow undulating installed tape elevation. The tape was not deep enough and was susceptible to machinery damage. This problem, along with emitter plugging problems on the aluminum mainline equipped sections of the drip irrigation system, caused under-irrigation and over-irrigation of the fields, adversely affecting DU.

CASE 2 - HIGH RISE FARMS

The following is a summary of the 1993, 1994 and 1995 growing seasons. The new technology evaluated was buried row crop drip irrigation near Gilroy.

- New System - Subsurface Drip Irrigation on Bell Peppers

Tape:	0.2 mm (8 mil), high flow Chapin Tape (93/94). 0.2 mm (8 mil), high flow T-Tape (95).
Supply Manifold:	10 cm (4") diameter oval hose.
Filters:	Three 1.2 m (48") ATEK sand media filters.
Water Source:	3 Wells

- Old System - Furrow Irrigation
- CEC Loan: $42,700
- Actual Capital Cost: $42,700
- Size of Project Field: 16 ha (40 ac) (93/94) 18 ha (45 ac) (95)
- Average Yield Increase: 15 ton (short)/ha (6.7 Tons/acre)
- Investment Cost (Annualized): $467/ha ($189/acre)
- Average Net Revenue Increase: $2,733/ha per year (1993-1995) ($1,106/acre per year)
- Investment Efficiency: 6 fold increase

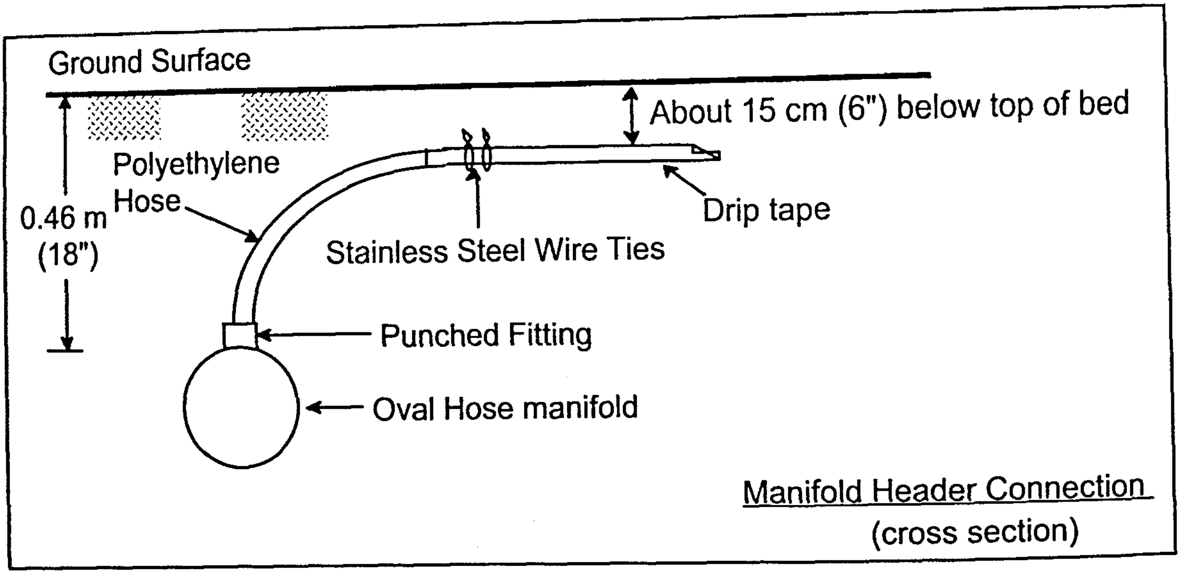

Figure 2. Manifold to Tape Connection at High Rise Farms.

MAJOR LESSONS LEARNED - HIGH RISE FARMS

The yield differential between drip and the furrow irrigation methods was attributed to the ability to irrigate during multiple pickings with drip. Using furrow irrigation, the ranch has experienced tremendous losses between pickings.

The problem encountered in the second year was root intrusion of the drip tape. The farm is planning to abandon/remove the old tape and replace it with a tape having improved root intrusion prevention characteristics. In addition, they are modifying the operation to use a removable surface drip system. This was done to reduce the plugging problems and add more flexibility for using the drip for the crop rotation. The farm is also planning on expanding the drip irrigation acreage. This CEC project helped provide the seed money to get the farm involved with drip irrigation.

WATER AND ENERGY USE - HIGH RISE FARMS

The following table was generated by reviewing the farming inputs and outputs for pre-project and post-project conditions. The analysis was primarily a differential analysis. This means that not all of the energy use was accounted for in the figures.

Table 2. Water and Energy Use Efficiencies for High Rise Farms

Item	Before CEC Project		1993 After CEC Project		% Change
Water Use- ha-m/ha (Ac-ft/ac)	0.82	(2.7)	0.73	(2.4)	-11
Energy Use- MJ/ha (MBtu/ac)	55.3	(21.2)	63.9	(24.5)	16
Yield- ton (short)/ha (Ton/ac)	40.0	(18.0)	52.7	(23.5)	31
Water Use Efficiency ton (short)/ha-m (Tons/AF)	49.0	(6.7)	72.0	(9.8)	46
Energy Use Efficiency ton (short)/MJ (Tons/MBtu)	0.73	(0.85)	0.83	(0.96)	13

Item	Before CEC Project		1994 After CEC Project		% Change
Water Use- ha-m/ha (Ac-ft/ac)	0.82	(2.7)	0.73	(2.4)	-11
Energy Use- MJ/ha (MBtu/ac)	55.3	(21.2)	63.9	(24.5)	16
Yield- ton (short)/ha (Ton/ac)	40.0	(18.0)	40.0	(18.0)	0
Water Use Efficiency ton (short)/ha-m (Tons/AF)	49.0	(6.7)	55.0	(7.5)	12
Energy Use Efficiency ton (short)/MJ (Tons/MBtu)	0.73	(0.85)	0.64	(0.74)	-13

Item	Before CEC Project		1995 After CEC Project		% Change
Water Use- ha-m/ha (Ac-ft/ac)	0.82	(2.7)	0.94	(3.1)	15
Energy Use- MJ/ha (MBtu/ac)	55.3	(21.2)	72.0	(27.6)	30
Yield- ton (short)/ha (Ton/ac)	40.0	(18.0)	72.9	(32.5)	81
Water Use Efficiency ton (short)/ha-m (Tons/AF)	49.0	(6.7)	77.2	(10.5)	56
Energy Use Efficiency ton (short)/MJ (Tons/MBtu)	0.73	(0.85)	0.96	(1.12)	39

Item	Before CEC Project		'93-'95 Average After CEC Project		% Change
Water Use- ha-m/ha (Ac-ft/ac)	0.82	(2.7)	0.79	(2.6)	-2
Energy Use- MJ/ha (MBtu/ac)	55.3	(21.2)	66.5	(25.5)	21
Yield- ton (short)/ha (Ton/ac)	40.0	(18.0)	55.4	(24.7)	37
Water Use Efficiency ton (short)/ha-m (Tons/AF)	49.0	(6.7)	69.9	(9.5)	38
Energy Use Efficiency ton (short)/MJ (Tons/MBtu)	0.73	(0.85)	0.82	(0.95)	13

DISCUSSION- HIGH RISE FARMS

The water use increased in 1996 compared to the previous years. This was primarily due to the increased size of the plants. The grower estimated the increased use at 30% more water applied based on reviewing the energy usage of the wells. Fertilizer use increased by about the same proportion (about 30% increase).

The drip system had an average 37% increase in pepper yield. This is primarily a result of a reduction in the *Phytophthora* problem and the crop response to drip irrigation. The original CEC project field was flooded in 1995. The wet season combined with the poorly drained field combined with a cool spring made the original CEC project field unplantable. However, the farm expanded the irrigation system to the west (higher ground) and was able to grow 18 hectares (45 acres) of bell peppers using the same mainline, filter station, and pumps.

The farm had an excellent crop on the 18 hectares (45 acres) bell pepper field in 1995. Yield was 78.9 ton (short)/ha (32.5 Tons/Ac). The grower had a 90 ton (short)/ha (40 Ton/Acre) field on another drip irrigated field. Yields on fields irrigated with conventional methods were closer to 40 - 45 ton (short)/ha (18 - 20 Tons/Acre). Greens were not harvested in 1995. A higher planting density was used in 1995, with 2 transplants per bed. The higher density provides for a better yield potential due to a more vigorous growing environment. It also provides better coverage of the plants in order to minimize sun spotting problems. The farm is using a hybrid that grows about waist-high.

The water pH is maintained at 5.0 at the end of the irrigation system when injecting N-Phuric acid to the water. Once a month, the pH is lowered to 3.0 for about 1/2 hour. The operation has been modified to have a surface tape retrieval system. The farm obtained a retrieval machine from Gonzales Irrigation Systems and successfully implemented the system in 1995. It is hoped that the tape can be used 3 times before having to be replaced.

High Rise Farms is committed to drip. They will put another 40 hectares (100 acres) in for the 1996 irrigation season. The CEC loan definitely helped get this operation started in this direction. They have had serious problems with the inexpensive 2-way pressure regulators used to regulate pressures into the supply manifolds. The regulators did not function properly and they needed to be checked during every set change. The farm plans to change to a different pressure regulator that will provide constant outlet pressures regardless of the inlet pressures.

CONCLUSIONS

These growers used the CEC low-interest program to get into drip irrigation. The growers needed a two to three year learning curve to solve basic problems. They continually adapt to new challenges by trying different approaches to management and hardware. The nature of problems will change from year to year.

Peppers have an excellent yield response to drip irrigation. The energy used per unit yield decreased. The volume of water required per unit yield decreased. Fertilizer application accounts for a significant amount of the total input energy for peppers (over 30%) due to the energy required to manufacture N-based fertilizers. Fertilizer application rates remained relatively constant. This is the area for greatest future reduction in energy use, by gradually using less fertilizers. Both growers are expanding the amount of drip irrigation systems on their farms.