Application of AirJecion® Irrigation to Cropping Systems in California

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Abstract

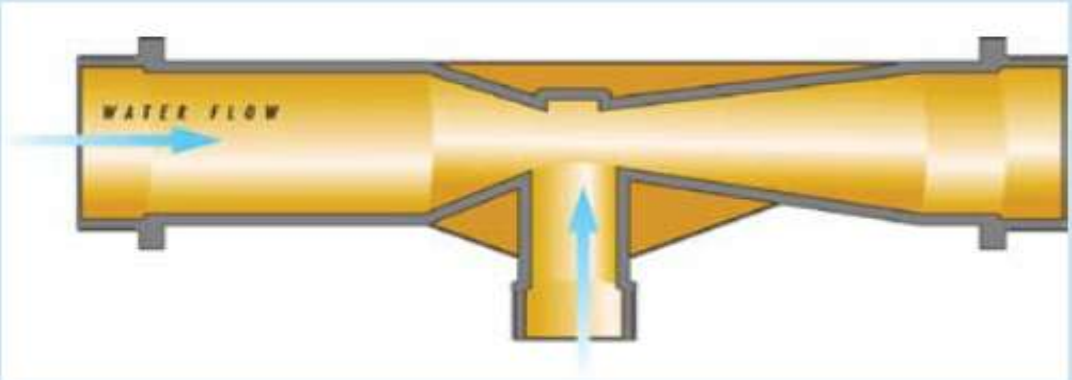
Evaluating the impact of air via subsurface drip irrigation (SDI) system through the incorporation of high efficiency venturi injectors, referred to as AirJection® Irrigation, has been the focus of our research over the past six years. To date, our major objective has been to assess the technical and economic feasibility of AirJection® Irrigation as a best management practice for various crops in the San Joaquin Valley (SJV). So far, we have tested the technology on bell peppers, fresh market tomatoes, cantaloupes, honeydews, broccoli and sweet corn. Recent and on-going research has shown that AirJection® Irrigation can increase root zone aeration and add value to grower investments in SDI. For example, in Summer 2004, for cantaloupes grown on 20-acre plots, there was a 13% increase in the number of melons and a 18% increase in the weight of melons harvested due to air injection. The increases in yield and improvement in soil quality associated with the root zone aeration augers well for the adoption of AirJection® Irrigation primarily as tool for increasing crop productivity. The work conducted to date has been aimed at evaluating the AirJection® Irrigation on conventional farms. However, because AirJection® Irrigation uses ambient air, there exists the potential to use this system on organic farms. In 2007, we intend to evaluate the AirJection® Irrigation system on land designated for transition to organic vegetable production at California State University-Fresno. In addition to yield and fruit quality, future studies should focus on the impact of air injection on water use efficiency, soil respiration, insect/pest resistance and rooting characteristics of the various crops.

Introduction

The concept of aerating the irrigation water increases the potential for the air to travel with water movement within the root zone. Physical, chemical, and biological soil characteristics that influence crop growth and yield depend on the relative proportions of the liquid and gas phases within the root zone. The findings of a pilot study conducted in 2000 at the Center for Irrigation Technology (CIT) in which air was injected into the root zone of bell peppers via the subsurface drip irrigation (SDI) system, referred to as AirJection® Irrigation, justified follow-up fieldwork on larger plots approaching commercial scale. In this presentation, we review the concept of AirJection® Irrigation, our current research aimed at evaluating the technical and economic feasibility of AirJection® Irrigation as a best management practice for fresh-market tomato, melon and bell pepper production. We also s discuss the potential for the application of the technology to other high valued crops such as strawberry and organic farming systems.

Concept of AirJection® Irrigation

Through work in other areas, the Mazzei® Corporation has developed high efficiency venturi injectors capable of aerating water with fine air bubbles. The principle of operation for the AirJection® is described in the box below.



Injector Technology

As water under pressure enters the injector inlet it is constricted in the injection chamber (throat) and its velocity increases. The increase in velocity through the injection chamber, according to the Bernoulli equation, can result in a decrease in pressure below atmospheric in the chamber. This drop in pressure enables air to be drawn through the suction port and be entrained into the water stream. As the water stream moves toward the injector outlet, its velocity is reduced and the dynamic energy is reconverted into pressure energy. The aerated water from the injector is supplied to the irrigation system. The fluid mixture delivered to the root zone of the plant is best characterized as an air/water slurry.

Review of Work Conducted to Date

In 2000, a pilot study was conducted at the Center for Irrigation Technology (CIT) in which air was injected into the root zone of bell peppers via the subsurface drip irrigation (SDI) system (Goorahoo et al., 2001a,b). In that study an increase of 33% in bell pepper count, and a 39% increase in bell pepper weight was noted for the aerated plots versus the plots receiving only water. When the roots were examined, there was a significant difference between the root weight to total plant weight ratios for the aerated plants and the non-aerated plants. The findings from the 2000 CSU-Fresno study justified follow-up fieldwork on larger plots approaching commercial scale.

Since the 2000 small-scale study, CIT researchers have worked with commercial vegetable growers in evaluating the feasibility of the air-injection system in crop production systems utilizing SDI. In addition to our research in the San Joaquin Valley (SJV) in California, similar work is being conducted by scientists in Australia (Bhattarai et al., 2003 and 2004) and Japan (Professor Hitoshi Ogawa, Tamagawa University, Tokyo, Japan, personal communication).

The major goal of the current research is to evaluate the technical and economic feasibility of AirJection® Irrigation, as a best management practice for crop production. Ideally, the technology should be applied to and tested on as many crops as possible. Realistically, we plan on assessing the practice on as many vegetable and fruit crops commonly grown in the SJV. In this report of the research, our focus is on three crops: bell peppers, fresh-market tomatoes and melons.

Details on the design and theory of operation of the air injection system employed in the research is described above and can be found in Goorahoo et al., (2001a,b). The commercial size plots were located in Firebaugh (tomatoes) and Mendota (melons and peppers) in the SJV. The air injection systems used in the melons and pepper project were different from the set-up in the tomatoes project in that in the melon and pepper fields, each drip tape had its own air injector, whereas in the tomato fields there was a single larger injector servicing twenty four drip lines (Figures 1 and 2).

Soils in this region range from sandy loams to clay loams. Some of the measurements performed to date include:

1. Pre-Plant Soil sampling
2. Crop Growth and Irrigation Monitoring
3. Harvest and Yield Data Collection
4. Photosynthesis and transpiration
5. Plant Height and width measurements
6. Root and Shoot Post Harvest
7. Post Harvest Soil Sampling

<u>Significant Results and Accomplishments to Date</u>

<u>Melons</u>

In Fall 2003, we conducted comparative tests between air injection and water only treated melons (honey dews) on 13acres plots with a drip tape run length of over 400m. There was a 14% increase in the number of melons and, a 16% increase in the weight of melons harvested due to air injection. These figures translate into a projected increase of $260 to $350 per acre for the farmer depending on the wholesale price of melons which can range from $3 to $4 per box. Generally, there was a decrease in yield of melons in moving from the South to the North end of the experimental plot (Figures 3 and 4). This trend was for both the air injected and water treated plots. It is noteworthy that the irrigation manifold was at North end (replicate #4) of field, and the vent valve was at South end (replicate #1). With respect to quality, there was no significant difference between the sugar levels measured for the air treated and the water only treated melons. The average Brix level for the air treated and water-only melons were 11.0 and 12.9, respectively.

In Summer 2004, for cantaloupes grown on 20-acre plots, there was a 13% increase in the number of melons and, a 18% increase in the weight of melons harvested due to air injection (Tables 1 and 2). More importantly, the increase in the number and weight of large air–injected melons, which were shipped in 9 per box, exceeded that of the water-only melons by 43% (table 1) and 39% (Table 2), respectively. The larger melons are the most desirable grade for the grower. There was a greater shoot to root dry weight ratio for plants subjected to air injection (mean 80 ±7) than those receiving water only ((mean 67 ±5) (Figure 5).

Tomatoes and Peppers

In the tomato experiment grown on 20 acre plots with drip tape run lengths of approximately 300m, so far we have observed that for the air treated plants there were greater yields from the plants located at the "head" of the drip line versus the plants down at the "tail". Our initial findings seem to indicate that in the case of the tomato crop, there may have been earlier fruit maturity for the air treated plants.

In the 2003 experiment with peppers grown on 40acres with run of over 400m, we observed that although there was a trend of decreasing yields in terms of both numbers and weights. Generally, in moving away from the source of the air and water injection, there was still a positive effect of the air injection towards the tail end of the irrigation tape (Table 3).

One constraint of conducting the experiment on the on the commercial farm was that it was not possible to carry out excessive destructive plant sampling during various growth stages in an effort to examine the impact of the air injection on the roots. In 2004, a bell pepper research plot (0.25 acres) was been set up at CIT in which the destructive sampling was carried out. Figure 6 shows the shoot to root ratio along the tape length for peppers in 2004. Generally, there was more root weight per shoot weight for the plants subjected to air injection than those plants receiving only water. For the 2004 experiment, photosynthesis and transpiration rates were also measured using a CIRAS 2 photosynthesis analyzer.

Strawberries

In addition to the scientific studies mentioned above, we have done some observational studies on Strawberries planted on in October 2003 in Oxnard, CA. Both the Non-Aerated Control and AirJection® Aerated plots used the following design:

- Two lines of sub-surface drip tape (0.667 gpm / 100 ft) per row
- 64" bed x 15" spacing x 4 rows per bed x 315' row length (25,500 plants per acre)
- Drip tape was operated with approximately 10 psi of inlet pressure

The AirJection® aerated test plot used the following configuration to supply the air/water mixture:

- Model A-14 Mazzei AirJection® Irrigation units
- 100% of the water for each row flows through the injector.
- The AirJection® units were operated with approximately 25 psi of inlet pressure.
- The gas to liquid ratio was approximately 11%.

The strawberry results indicate that there was a 18.3% increase in #1 Grade fruit in the Aerated plot vs. the Control plot. There was a 6.9% increase in #2 Grade fruit in the Aerated plot vs. the Control plot. There was a 33.7% increase in Freezer Grade fruit in the Aerated plot vs. the Control plot.

Conclusions and Future Research

- Recent and on-going research has shown that the incorporation of high efficiency venturi injectors in SDI systems, referred to as AirJection® Irrigation, can increase root zone aeration and add value to grower investments in SDI.
- The increase in yields and improvement in soil quality associated with the root zone aeration augers well for the adoption of AirJection® Irrigation technology primarily as tool for increasing crop productivity.
- The work conducted to date has been aimed at evaluating AirJection® Irrigation on traditional farms. However, because the air injection system with the venturi devices uses ambient air, there exists the potential to use this system on organic farms. We intend to evaluate the SDI-air injection system on land designated for transition to organic vegetable production at California State University-Fresno.
- In addition to yield and fruit quality, future studies should focus on the impact of air injection on water use efficiency, soil respiration, insect/pest resistance and rooting characteristics of the various crops.
- In addition to yield and fruit quality, future studies should focus on the impact of air injection on water use efficiency, soil respiration, soil salinity, soil microbial activity, insect/pest resistance and rooting characteristics of strawberries.
- In 2007, we intend to evaluate the AirJection® Irrigation system on land designated for transition to organic production at CSU-Fresno.

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Table 1: Comparison of Count for Melons- 2004

Treatment	Large	Medium	Small	Total Harvestable	Non Harvestable
Air	96	203	447	746	696
Water	67	180	411	658	667
Difference	29	23	36	88	29
% increase	43%	13%	9%	13%	4%

Table2 Comparison of Weight for Melons-2004

Treatment	Large	Medium	Small	Total Harvestable Wt.
Air	207.4	331.6	603.0	1142.0
Water	149.31	325.44	491.56	966.3
Difference	58.05	6.13	111.49	175.66
% increase	39%	2%	23%	18%

Table 3: Summary of Pepper yield along the drip lines grown in 2003.

Replicates	**No. of Peppers**	**No. of Peppers**	**Wt. of Peppers**	**Wt. of Peppers**
	Air	**Water**	**Air**	**Water**
Head (West)	100	57	13	10.72
Middle	80	84	12.26	14.03
Tail (East)	47	45	7.18	7.52
Total	**227**	**186**	**32.44**	**32.27**
Difference	**41**	**0.17**		
% Difference	**22.04%**		**0.53%**	

Figure 1: Single injector for each drip line.

Figure2: Relatively larger injector servicing 24 drip lines.

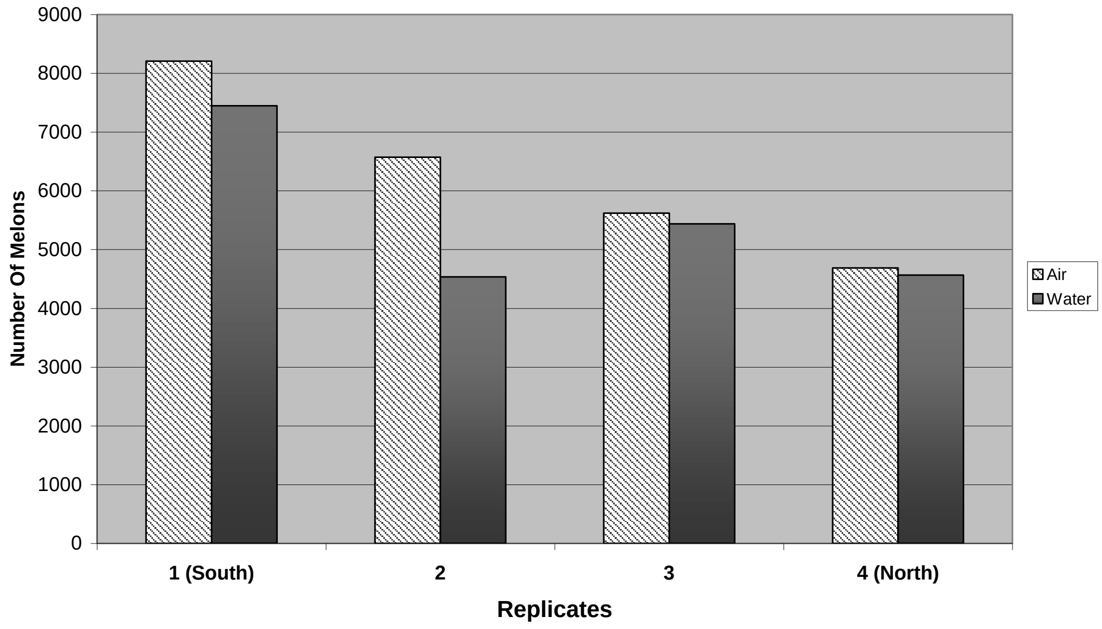

Figure 3: Total Number of Melons in Air versus Water Plots-2003

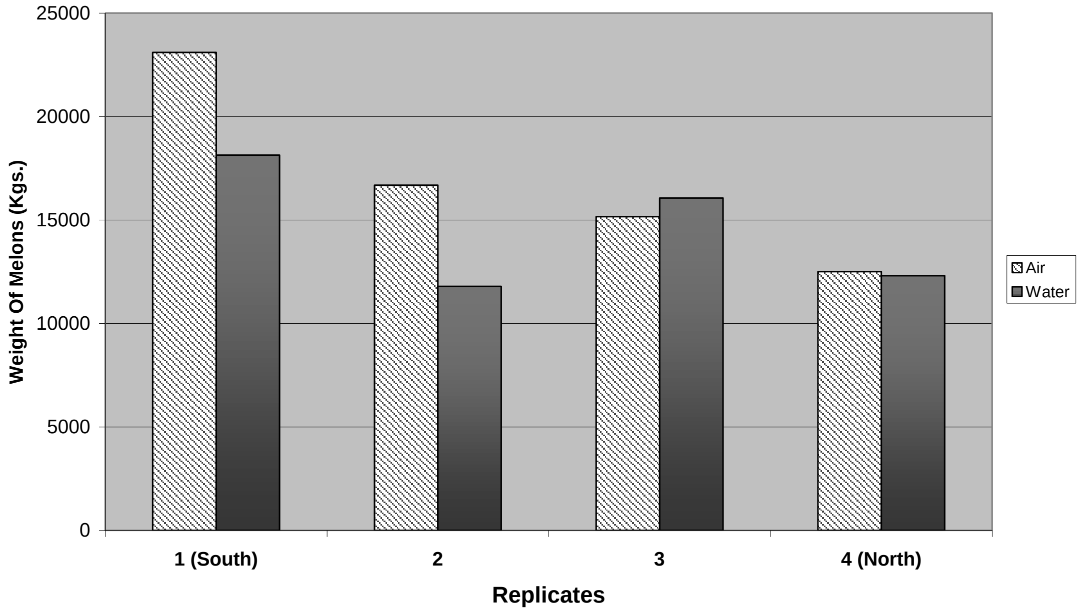

Figure 4: Total Weight of Melons in Air versus Water Plots- 2003

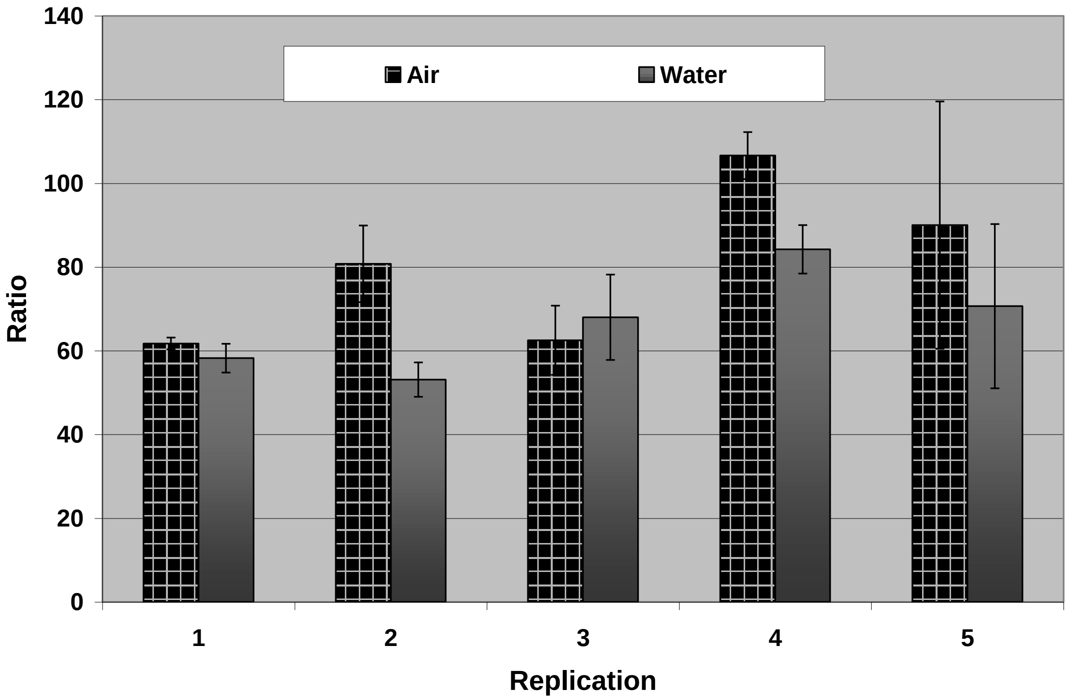

Figure 5: Shoot to root dry weight ratio for melon plants harvested in 2004.

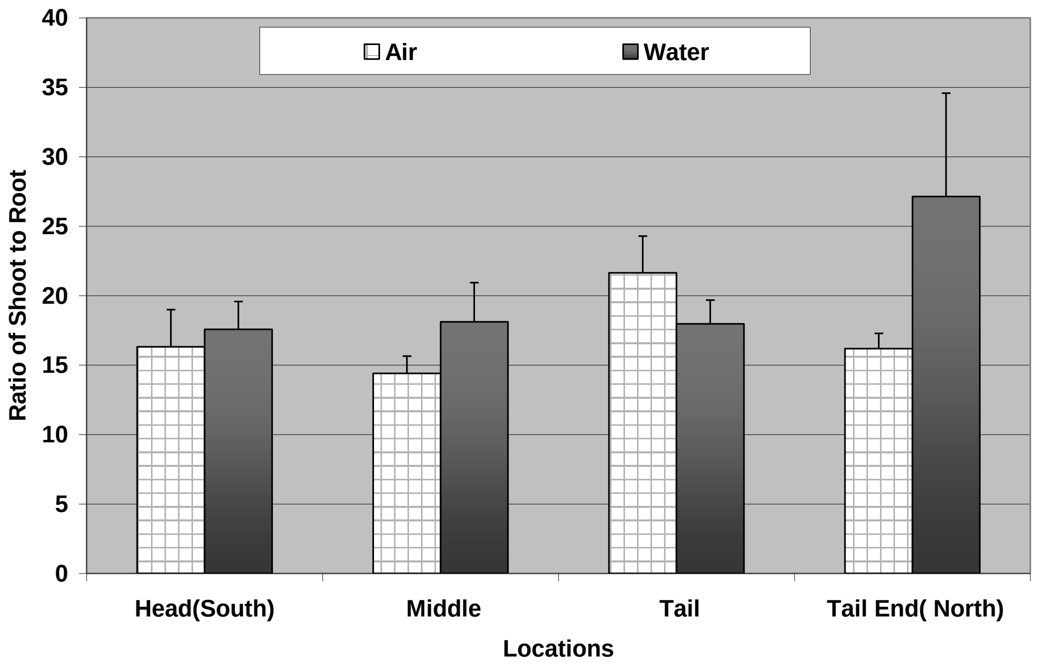

Figure 6: Shoot to Root Ratio along the Tape Length for Peppers in 2004.