# Impact of Aerated Subsurface Irrigation Water on the Growth and Yield of Crops.

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## Abstract

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 in which air was injected into the root zone of bell peppers via the subsurface drip irrigation (SDI) system justified follow-up fieldwork on larger plots approaching commercial scale. We present a review of current research aimed at evaluating the technical and economic feasibility of air injection into a SDI as a best management practice for fresh-market tomato, melon and bell pepper production. Generally, the incorporation of high efficiency venturi injectors in SDI systems increased root zone aeration and can add value to grower investments in SDI.

## Introduction

Modification of root zone environments by injecting air has continued to intrigue investigators. The concept of aerating the irrigation water increases the potential for the air to travel with water movement within the root zone more generally and affect crop growth. 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. For example, a soil that is well aerated will favor increased root respiration and aerobic microbial activity. Conversely, in waterlogged soils typical of poor drainage, anaerobic conditions prevail. Since oxygen is essential for root respiration, then immediately after the roots have been surrounded by water they can no longer respire normally.

Through work in other areas, the Mazzei® Corporation has developed high efficiency venturi injectors capable of aerating water with fine air bubbles. 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 been funded as part of the *Governor's Buy California's Initiative,* to work 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). Furthermore, a group of scientists at Queensland, Australia, who are in contact with researchers in Germany, have indicated that they are currently compiling a review on the topic of aeration within the root zone (Professor David Midmore, Plant Sciences Group, Central Queensland University- personal communication). Hence, it is obvious that the issue of aeration of subsurface irrigation water is of interest worldwide as growers continue to look for ways to optimize crop production and water use efficiency.

In this paper, we present some of the findings from our current research, being conducted in California, aimed at evaluating the impact of air injection into a SDI as a best management practice for fresh-market tomato, melon and bell pepper production.

## Review of Current Research

The major goal of the current research is to evaluate the technical and economic feasibility of injection of ambient air into a subsurface drip tape irrigation system, 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, over the next two years. In this phase 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 can be found in Goorahoo et al., (2001a,b). Briefly, the basic principle of the Mazzei® (patented) injector is as follows: 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.

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

## Significant results and Accomplishments to Date

Much of the data collected to date is still being processed.

### Melons

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

Most of the tomato and pepper experiment data sets are still being processed.

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 yield (both numbers and weights) 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. This data is currently being processed and will be presented at the meeting.

## Conclusions and Future Research

- Recent and on-going research has shown that the incorporation of high efficiency venturi injectors in SDI systems 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 the SDI-air injection technology primarily as tool for increasing crop productivity.
- The work conducted to date has been aimed at evaluating the SDI-air injection system 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.

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**References**

Adhikari D., and Goorahoo D. 2004. Effect of air injection through subsurface drip irrigation on the growth and yield of crops. Proceedings of California Chapter of Plant and Soil Conference Feb.3-4, 2004 in Visalia, CA.

Bhattarai S, McHugh J, Lotz G, Midmore D J. 2003. Physiological responses of cotton to subsurface drip irrigation on heavy clay soil. Proc.11th Australian Agronomy Conference, 2-6 February, 2003, Geelong, Victoria, Australia: Australian Society of Agronomy. pp.1-2. htpp://www.regional.org.au/au/asa/2003/p/4/bhattarai.html.

Bhattarai S., Huber S., Midmore, D J. 2004. Aerated subsurface irrigation water gives growth and yield benefits to zucchini, vegetable soybean and cotton in heavy clay soils. Annuals of Applied Biology. **144**:285-298.

Goorahoo D, Carstensen G, Zoldoske D F, Norum E, Mazzei A. 2001a. Using air in subsurface drip irrigation (SDI) to increase yields in bell pepper. In Proceedings of The IrrigationAssociation Technical Conference, San Antonio, Texas, pp. 95-102.

Goorahoo D., G. Carstensen and A. Mazzei. 2001b. A Pilot Study on the Impact of Air Injected into Water Delivered through Subsurface Drip Irrigation Tape on the Growth and Yield of Bell Peppers. California Agricultural Technology Institute (CATI) Publication # 010201.

**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.**

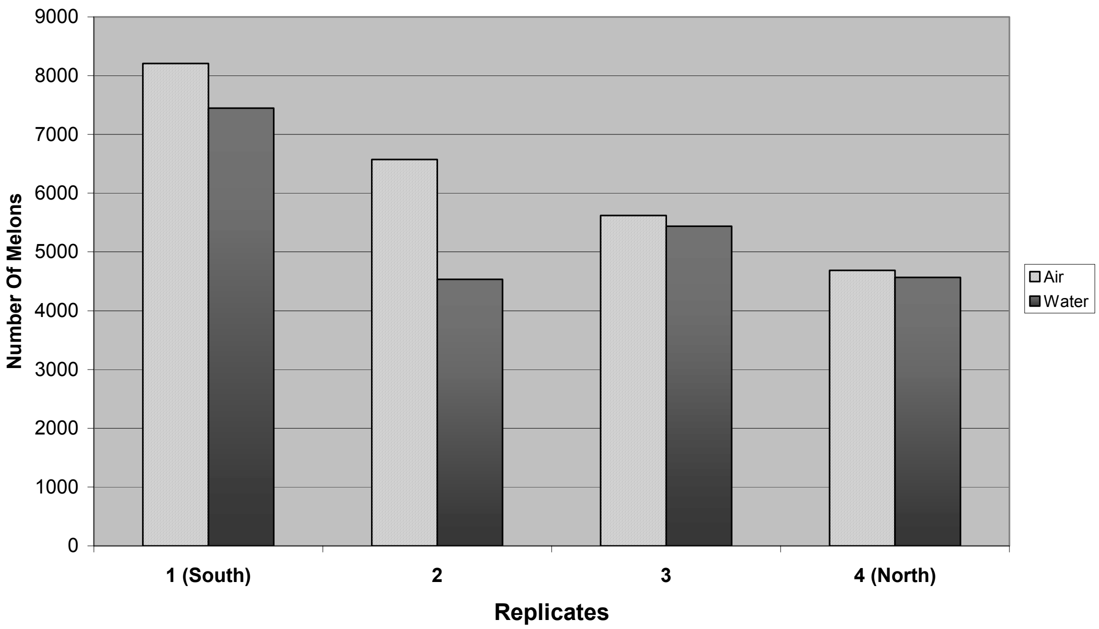


**Figure 3: Total Number of Melons in Air versus Water Plots-2003**

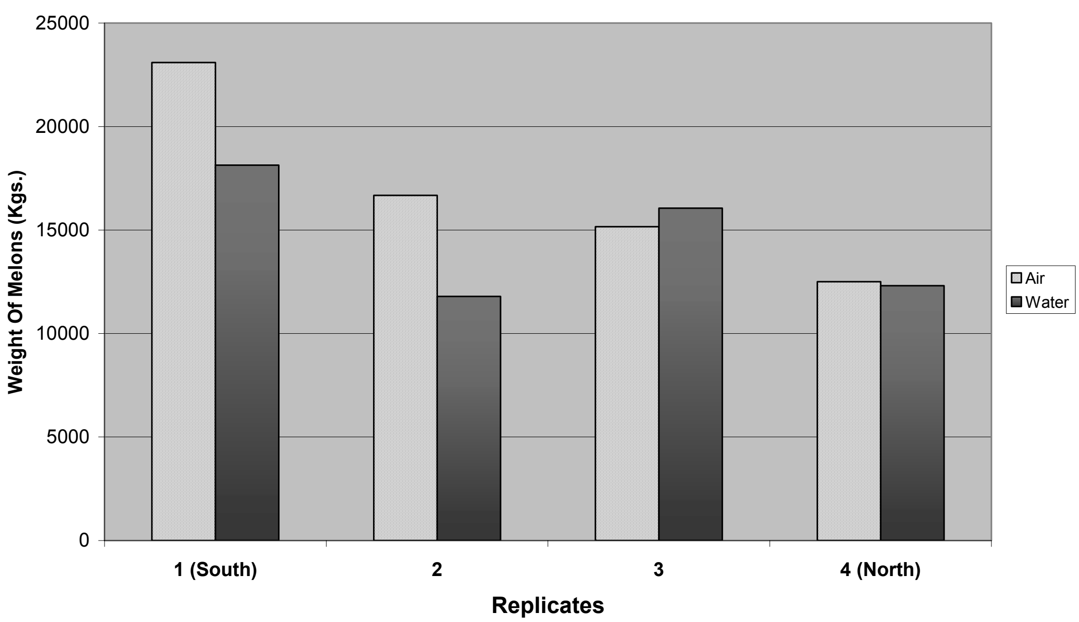


**Figure 4: Total Weight of Melons in Air versus Water Plots- 2003**

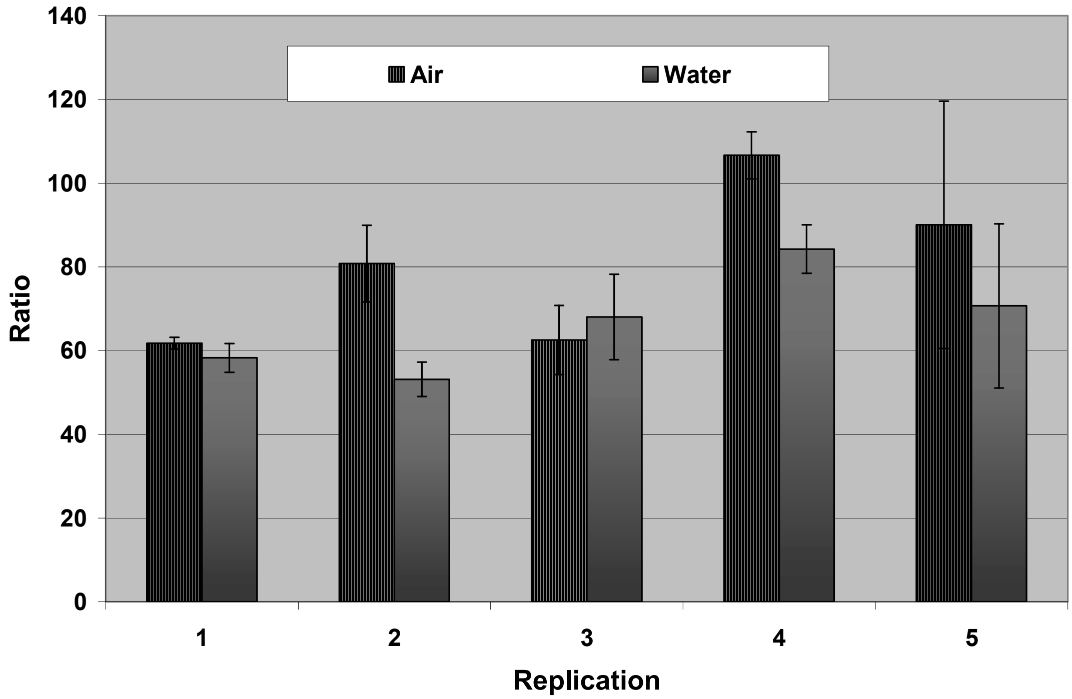


**Figure 5: Shoot to root dry weight ratio for melon plants harvested in 2004.**

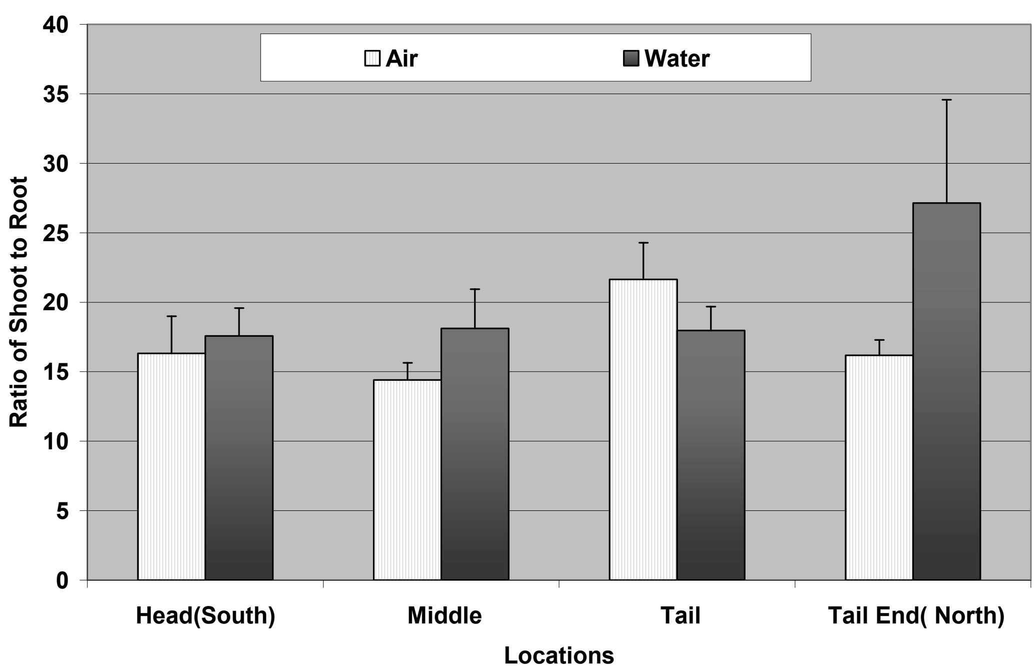


**Figure 6: Shoot to Root Ratio along the Tape Length for Peppers in 2004.**