

THE EFFECTS OF SOIL WATER MOVEMENT ON ONIONS  
GROWING IN A PLASTIC-COVERED GREENHOUSE

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Abstract. Onions were raised in a plastic-covered, quonset greenhouse with 1 m high open sides in polyethylene-lined soil beds (2.7 x 1.5 x 0.5 m deep). Total salable yields increased from 20 to 110 tons/ha as irrigation rates increased from 2.3 to 20.6 liters/plant/growing season. Onions in the control plots yielded higher than those in the polyethylene-lined plots at low irrigation rates because lateral and upward soil water movement supplemented irrigation water. However, at high irrigation rates, onion yields from the unlined plots were lower since the additional soil water contributed to leaching of nitrogen from the root zone. These effects were more pronounced near the edges of the greenhouse than towards the center. Therefore, in order to achieve a more uniform soil moisture condition in a greenhouse located in a high rainfall area, the edges should be irrigated at a lower rate than the centers, particularly during rainy periods.

INTRODUCTION

The Volcano Agricultural Experiment Station is located at 1200 m elevation on the Island of Hawaii and receives over 250 cm of rainfall per year. Plastic-covered greenhouses or rainselters enable the successful production of gourmet-grade sweet onions in this high rainfall area. Irrigation rate strongly affects both the total salable onion yields and bulb size (1). Excessive water application reduces yields and quality; this is at least partially caused by nutrient leaching, particularly N and K. During rainy periods, an unknown amount of water moves laterally through the soil from outside the greenhouse and upwards from under the soil beds. Thus, a soil irrigated with an optimum irrigation rate can be excessively moist during rainy weather.

This study was conducted to determine the amount of lateral and upward soil water movement in a greenhouse and its effects on onion production.

METHODS AND MATERIALS

A study was conducted in a polyethylene-covered Criterion greenhouse (9 m x 29 m) with 1 m high open sidewalls. Plots, 2.7 m x 1.5 m x 0.5 m deep, were excavated with a tractor

front-end bucket. The cavities were lined with 2 layers of 0.15 mm black polyethylene and the Manu silt loam soil was back-filled by adding subsoil first and then adding topsoil, thus approximately maintaining the original soil profile. The subsoil was very hard and chunky. Plastic-lined plots were alternated with control plots (i.e. non-excavated plots). 'Yellow Granex' onions were seeded on Dec. 20, 1989 and transplanted (February 7, 1990) into 4 rows spaced 23 cm apart; onion spacing within rows was 15 cm.

Plots were irrigated 3 times per week with Drip-In 2 L irrigation tubing from a day prior to transplanting until May 28, 1990, which was 36 days before harvest (July 3, 1990). Water application rates were 2.31, 4.20, 6.93, 9.99 15.82 and 20.55 liters of water per plant for the whole growing cycle. Individual treatments were controlled by an automatic timer and solenoid apparatus and the water was measured with water meters. Treatments were replicated 3 times and the experiment was arranged as a randomized complete block. The only water source for the plastic-lined plots was drip irrigation. However, control plots received both irrigation water and laterally and upwardly moving capillary soil water.

Dolomite (2240 kg/ha) and 16-16-16 (1120 kg/ha) were broadcast and incorporated to a 7 cm depth prior to transplanting. Care was taken not to compact the soil by walking on the plots from the time after the soil was rototilled until harvesting. There was a total of 110 cm rainfall during the growing season and the rainfall exceeded 5 cm on five individual days. In the week preceding transplanting, there was 36 cm of rainfall.

Onion harvest data were collected from the 1 m section of rows nearest the outside edge of the greenhouse and also from the 1 m section nearest the center of the greenhouse. Onions were graded as greater than 10 cm diameter, 7.5 to 10 cm, 5 to 7.5 cm, less than 5 cm, doubles and cull. Data are expressed as kg/m<sup>2</sup> of bed with onions (i.e. based upon the 0.9 m, 4-row bed width rather than the 1.5 m plot width).

## RESULTS AND DISCUSSION

Onion size and total yield from the plastic-lined plots increased with increasing water application rates (Figure 1). Yields of double onions were greatest in the highest irrigation treatments. Yields near the center of the greenhouse were similar to those near the outside edges since soil moisture was fairly uniform throughout these plots.

Early in the growing season, plots with the highest irrigation accumulated as much as 10 cm of gravitational water. However, no gravitational water was observed by the mid-crop

growth stage. Apparently, the amount of water loss by transpiration plus evaporation was nearly equal to the highest irrigation rate. Additional irrigation would have caused a saturated soil condition (because the gravitational water could not drain away) and may have resulted in reduced yields.

Although plots were protected from direct rainfall by the plastic greenhouse, soil moisture was visibly greater in the control plots than in the plastic-lined plots, especially after a heavy rainfall. The soil near the outside edge of the greenhouse was wetter than soil near the center of the greenhouse and differences in onion growth were observed. These phenomena may be explained by vertical and lateral capillary water movement from outside the plots.

Onion yields near the outside edge of the greenhouse did not appear to respond to irrigation rates (Figure 2), but there are possible explanations for this. Onion yield in the control plot with 2.3 liters water/plant was equal to the yield from the plastic-lined plots with 8.8 liters water/plant. Assuming that yield was proportional to total water supplied, these onions received an additional 6.5 liters of water/plant. This calculates to 11.6 cm of water on a whole plot basis which is about 10 per cent of the total outside rainfall (110 cm) during this period.

Yields of onions growing in the control plots with low irrigation rates near the center of the greenhouse were higher than those growing in the corresponding plastic-lined plots. However, the reverse was true at the highest irrigation rate (Figure 2). At the 2.3 liters water/plant irrigation rate, onions from the control plots yielded as well as those from the plastic-lined plots receiving 5.1 liters water/plant. This suggests that these plots received an additional 2.8 liters water/plant by capillary water movement, and this calculates to 5 cm of additional water over the whole bed area.

Onion yields near the outside edge of the control plots with the highest two irrigation rates were significantly lower than in the corresponding plastic-lined plots. It is likely that at least during the early crop stage, there was excessive leaching loss of N from the control plots. The foliage was noticeably lighter green in color and the percentage N in onion tissue from the control plots was lower than from plants growing in the plastic liner (Figure 3.) Sweet corn was planted after the onions were harvested. The tissue N from sweet corn in the control plots was higher than that from the plastic-lined plots (Figure 4). Sweet corn is deeply rooted and was able to absorb some of the N which had leached below the onion root zone in the control plots. Sweet corn yields in the control plots were also higher than those from the plastic-lined plots.

During the early crop stage, the plastic liner prevented the leaching of gravitational water and the loss of soluble nutrients, especially N. Since this gravitational water was reused during the later crop stages, N was effectively recycled. The effective N application rate was 294 kg N/ha of solid onion beds. An onion production rate of 107 tons/ha of beds would absorb this amount of N (2). The actual onion yield of the highest irrigation plots was 110 tons/ha of beds; thus, all of the applied N was absorbed into plant tissue.

This experiment demonstrates that a substantial amount of water can enter a greenhouse via lateral and vertical capillary soil movement. Significantly more water enters near the edge of the greenhouse than near the center of the greenhouse. The timing and amount of rainfall would greatly magnify this effect. Thus, irrigation studies in greenhouses should specify the plot area harvested and the outside rainfall conditions if the responses to irrigation rates are to be meaningful.

Growers normally would install drip irrigation tubing along the length of the greenhouse. During periods of heavy rainfall, increased uniformity of water application to the crops could be gained by irrigating the outer rows at a lower rate than the inside rows.

The concept of lining a greenhouse bed with plastic sheeting could provide some worthwhile advantages. Leaching losses of water and nutrients could be eliminated. This increases water and fertilizer efficiency and protects the environment. Irrigation timing could be greatly simplified; a grower could check for the presence of gravitational water in drainage pipes and schedule irrigation when the water level was very low. Gravitational water could be examined for nutrients, electrical conductivity and pH by rapid tests and provide timely information for the grower.

#### ACKNOWLEDGEMENT

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#### LITERATURE CITED

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## ONION IRRIGATION TRIAL SALABLE WEIGHT

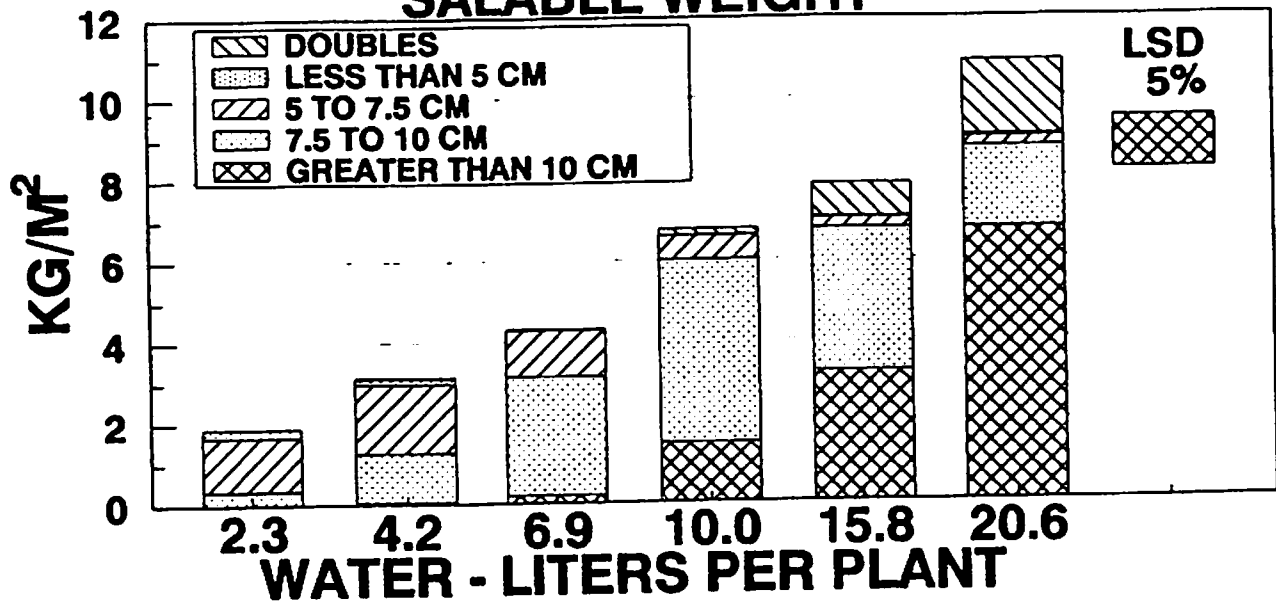


FIGURE 1. Effects of irrigation rates on bulb yield and quality of onions growing in soil lined with plastic.

## ONION IRRIGATION TRIAL SALABLE WEIGHT

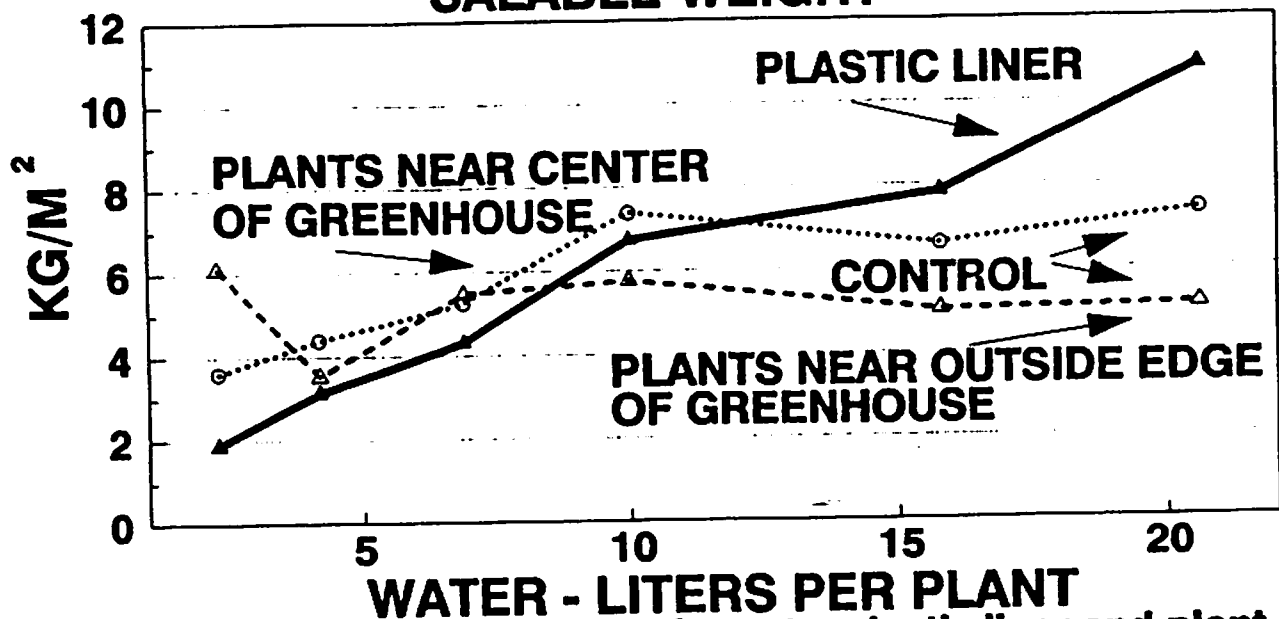
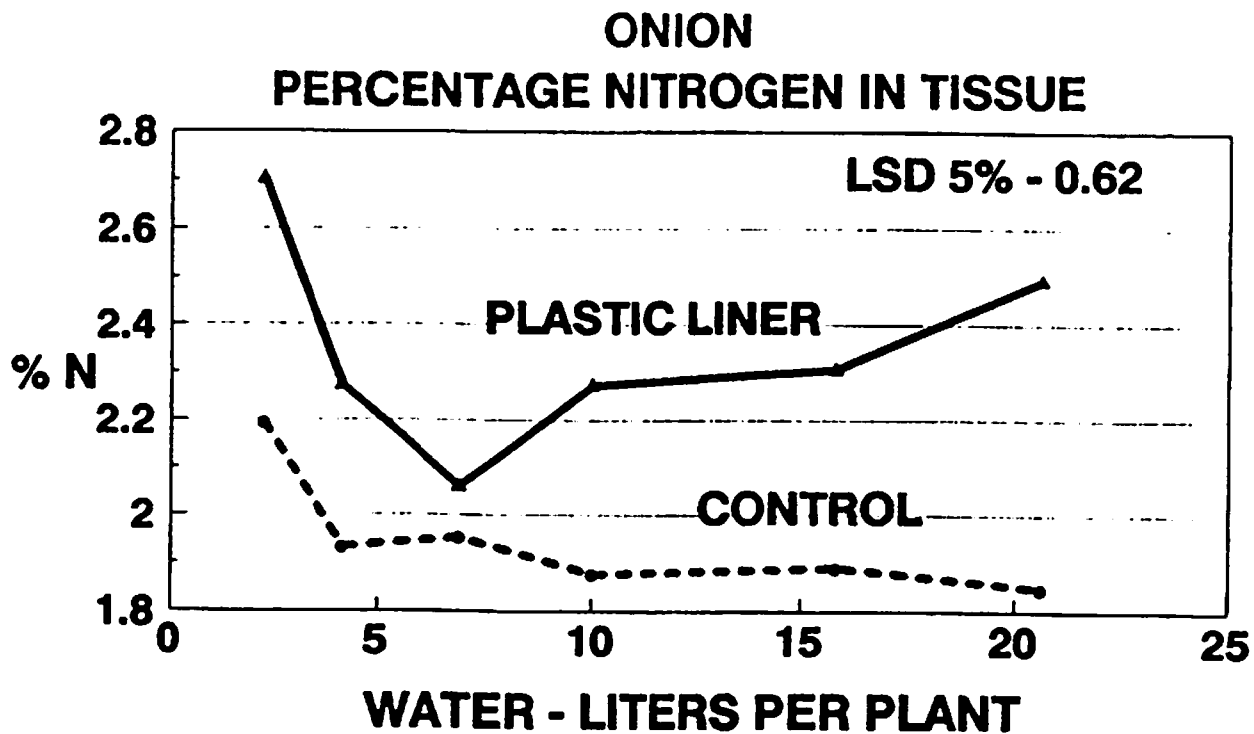
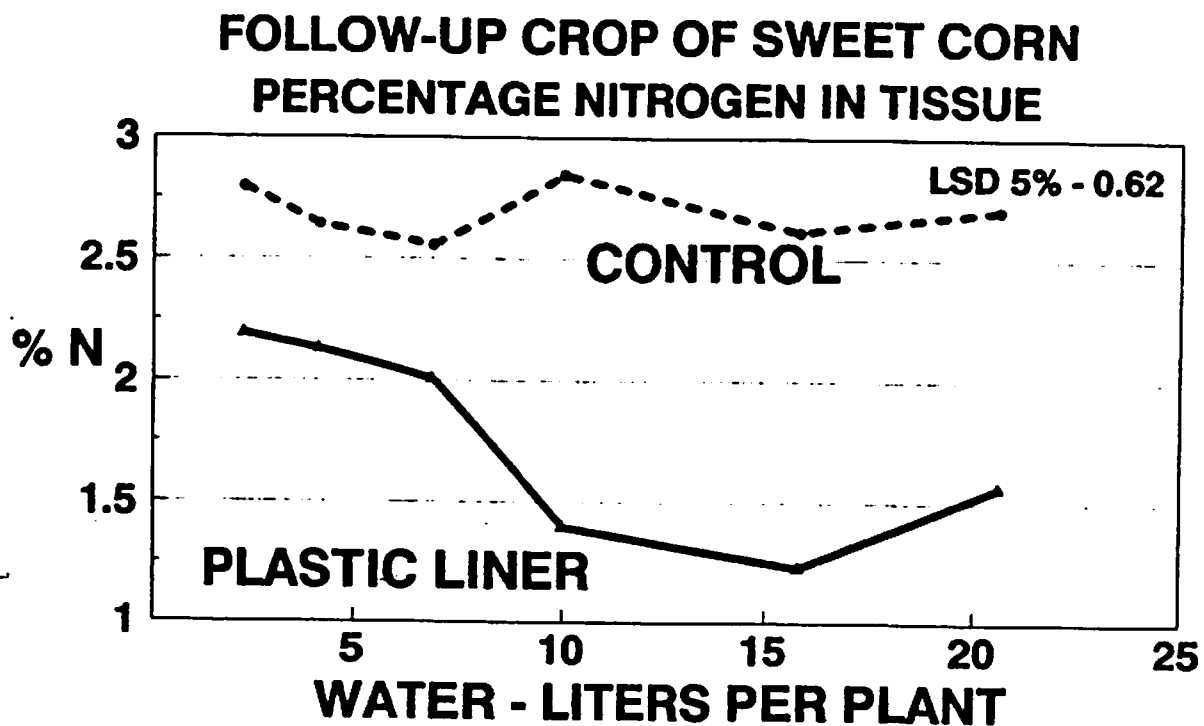


FIGURE 2. Effects of irrigation rate, plastic liner and plant location in the greenhouse on salable onion yield.



**FIGURE 3.** The effects of irrigation rate and a plastic liner on the percentage N in onion tissue.



**FIGURE 4.** The effects of irrigation rate and a plastic liner on the percentage N in sweet corn following an onion crop.