WALK-IN TUNNEL WITH PASSIVE SOLAR HEATING (WATER TUBES)

An alternative for cucumber and squash production in North Florida

By Itzhak Secker, George Hochmuth and D.J.Cantliffe

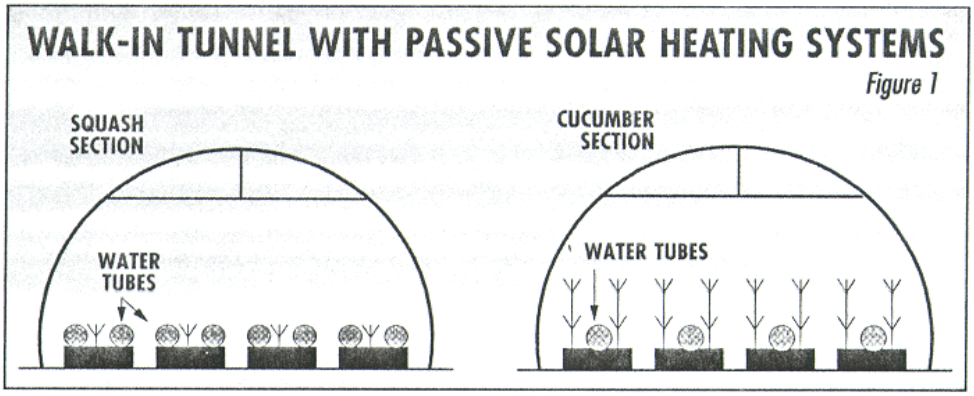
High tunnel (also called walk-in tunnel) is the most popular method for growing vegetables during the winter time around the world. They have been used extensively in Europe, Asia, and the mid-East for early production of vegetables, fruits, and flowers. Recently, tunnels have been tested for early cucumber production in Mexico. High tunnel is a low cost, plastic-covered greenhouse-like structure which has neither an electrical-powered ventilation system nor a permanent heating system. Florida, the leading state in the production of outdoor and indoor vegetable production, and the third largest populated state in United States, has the ultimate conditions for low cost indoor vegetable production during the winter. The high tunnel system could be suitable for large growers as well as small growers for various crops like tomatoes, bell pepper, cucumbers, melons, herb, strawberries, and other specialty crops. High tunnels improve growing conditions and give mechanical protection as well as good freeze protection which usually results in enhanced crop quality and increased total yield. Low cost passive solar heating system, like water sleeves, could be integrated into the system for additional heat for better freeze protection and improve growing conditions. The water increases night temperatures and reduces excess heat inside the tunnel during the day.

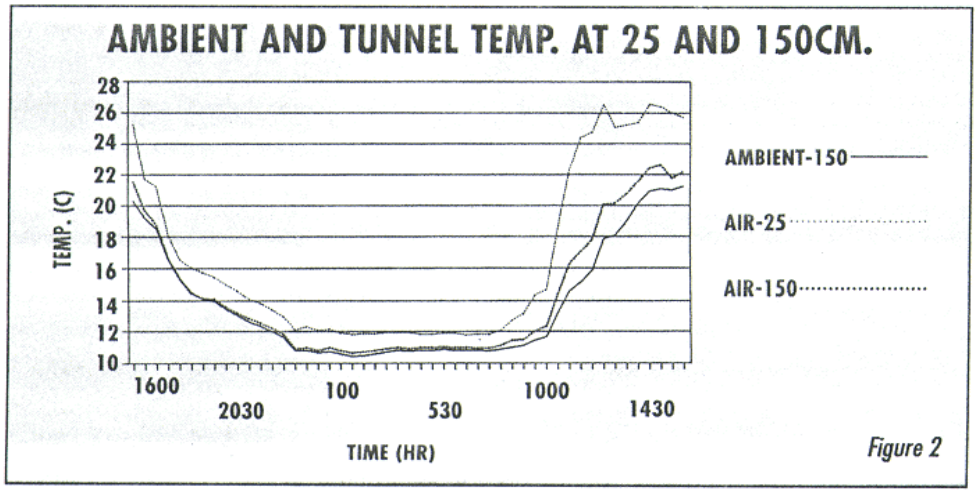
Florida is a leading state in the production of outdoor vegetables. In recent years, Florida greenhouse vegetable production has been increasing, especially in northern Florida.

The major vegetable crops produced in Florida greenhouses includes tomatoes, cucumbers, and lettuce (Hochmuth, 1990; Sweat, 1993). North Florida has a limited vegetable production season because of early freezes in the fall and unpredictable weather in the winter-spring season. Florida-grown cucumbers and squash normally are available from late September through early July with production somewhat limited during January through March (Florida Agricultural Statistics - 1990).

A tunnel is a plastic-covered greenhouse-like structure which utilizes solar heat and natural ventilation for temperature and humidity control. Unheated, low cost, high tunnel structures have been used extensively for many years in Europe (Castille, 1991), Asia (Takakura, 1993), and the Mideast (El-Aidy, 1991) for early vegetable production. Recently, tunnels have been tested for early cucumber production in Mexico (Martin et al., 1993). Recently, in the U.S., the use of high tunnels has been expanded for the production of tomatoes and other crops. Tunnels have been used mainly as overwintering structures for ornamentals (Wells, 1993).

After the oil crisis of 1973, many solar heating systems have been studied, and the passive solar heating system was found to be the cheapest and easiest to use by farm-





ers in the Mediterranean countries. In the mid-80s, water-filled transparent polyethylene (PE) tubes were used as a passive solar heating system in greenhouses in Greece (Grafiadellis, 1990; Mavroyanopoulos & Kyritsis, 1989), Israel [Esquira (Secker) & Segal, 1989], Tunisia (Verlodt, 1989), Turkey, Spain, Portugal, and Lebanon (Zabaltitz, 1989).

The passive solar system consists of polyethylene tube/tubes (150-200 microns), 25-35 cm in diameter, which are filled with water and placed on the ground between the plants. During the day, global radiation is absorbed by the tubes. When the ambient irradiation and temperature decrease, heat energy is released by radiation and convection (Zabeltitz, 1989). The passive solar system increases the air, soil, and plant temperatures by 3-50c. During the day, the system acts as a cooling system reducing the air and soil temperature in the greenhouse by 2-30c [Esquira (Secker) et al., 1989). The system also provides good freeze protection and considerably enhances plant production [Grafiadelis; 1990. Esquira (Secker); 1989. Mawardi and Stewart, 1993].

The purpose of this work was to observe the production of parthenocarpic cucumbers (Bet - Alfa type) and squash under unheated walk-in tunnels using passive solar heating system (water tubes) during the wintertime in North Florida.

Material and Methods

The experiments were conducted at the Horticultural Unit of the University of Florida, IFAS Gainesville, during the winter - spring season of 1992-1993. The soil was a typic loamy siliceous hyperthermic Grossarenic Paleudults (sandy soil). Preplant soil tests were taken and soil testing procedures involved the use of Mehlich-I extraction.

A walk-in tunnel, 8.5 m wide and 50 m length was built over four formed beds. The beds, 1.2 m wide, 0.2 high, and 2 m center to center were covered with clear polyethylene (PE) film (50 microns - Polyon - Barkai). The beds were fumigated with methyl bromide - chloropicrin (MBC) mixture [(67 - 33 percent) 15 gr/m2] five weeks before planting to achieve soil solarization effects combined with MBC. Plots were irrigated with drip irrigation tubing with emitters at 25 cm intervals (Typhoon - Netafim). Irrigation scheduling was aided with the use of tensiometers, and irrigation cycles were initiated as needed to maintain a soil moisture tension of -10 to -12 centibars at a depth of 25 cm. All fertilizer was applied using fertigation (irrigation and fertilization) through the drip system. The fertilizers were injected proportionally with each irrigation, using a Venturi pump. The fertilizer was a mixture of KNO3, NH4NO3 , and H3PO4. The system was monitored by an irrigation computer (Motorola MIR 5000F DC).The walk-in tunnel was covered with I.R. thermic film (150 microns, Thermofilm I.R. - Polyon - Barkai). The tunnel was naturally ventilated from both sides by using side curtains rolled up from the baseboard to the hip board. For rolling up the sides, a one-inch pipe running the length of the tunnel, attached to the edge of the plastic was used. The side curtains were kept open as much as possible for adequate ventilation to prevent moisture related diseases.

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The tunnel was divided into two sections, one for cucumbers (28m) and the second (22 m) for squash. Five parthenocarpic cucumber cultivars (Sahara, Picobello, Pigal, Cordito, Dina) all Bet Alfa type, were direct-seeded on 20 Nov. 1992. The plants were seeded in two rows on (60 cm) single bed, with 30 cm between plants, with 26 plants/plot resulting in 30,000 plants/ha. Polyethylene tubes (200 microns-Polyon-Barkai) 25.5 cm in di-

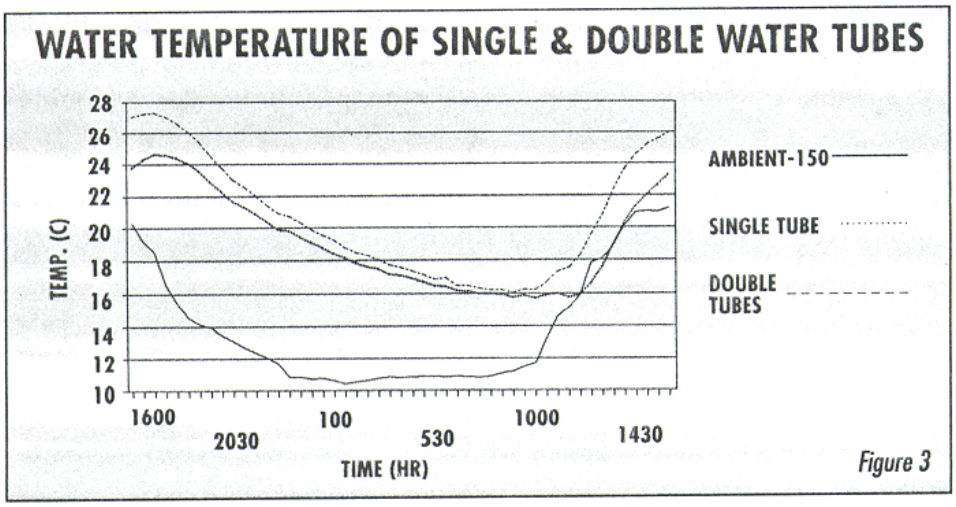

Figure 3

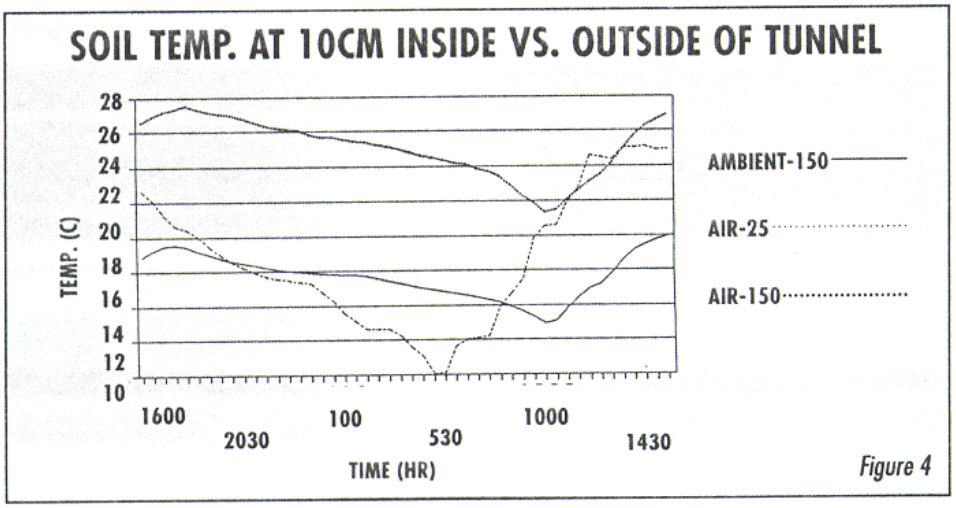

Figure 4

ameter were laid on each bed between the rows and were filled with water (43 liter/m2) and chlorine to prevent algae growth. The cucumber plants were trellised and pruned as needed.

Two zucchini/squash cultivars (Embassy and President) were direct-seeded on Dec. 7, 1992 on a single row with the plants 90 cm apart resulting in 5,600 plants/ha. The plants were seeded in between the parallel water tubes, [(Figure 1) 22.3 cm each (54 liter\m2)], 12 plants/plot. All treatments were replicated four times in a randomized block design. A data logger (Campbell CR-10) was set to collect the water tube, ambient air (150 cm),ambient soil (10 cm),indoor air (25 cm and 150 cm), and indoor soil temperatures. Disease severity was estimated visually for downy mildew on a scale of 1 (no disease) to 5 (high incident).

All marketable, mature fruits were harvested every other day from both experiments and data collected were: total and marketable yield, fruit length, fruit weight, and number of fruits per plant. Analysis of variance was used to determine statistical significance of data.

RESULTS AND DISCUSSION

Climate Data

During the winter growing season (Nov. through Mar.) of 1992-93, six events of air temperatures below 0°C occurred. The frequency of the events were approximately once a month. The normal range for air temperatures in Gainesville at this time of the year is a maximum of 20-27°C and a minimum of 5-10°C. The average solar radiation was 14-24 MJ/m2 per day. The soil temperature maxima and minima were 21-27°c and 10-15°c respectively.

Temperatures in the tunnel

Air and soil temperatures were monitored only during a portion of the growing season by the data logger. The air temperatures were 0.5-2°C and 2-4°C higher than ambient at 150 cm and 25 cm respectively (Fig.2). The tunnel was ventilated most of the growing season on both sides to prevent humidity accumulation and to reduce high-humidity related diseases. The soil temperature increase due to the water tubes and the clear plastic mulch was 6-8°C higher than the ambient soil (Fig. 3). The temperatures inside the tunnel did not drop below 0°C during freezes and the plants did not show any freeze or chill related injures.

Passive solar heating system

The single water tubes accumulated 10-12°C per day which translated to 430-516 Kcal/m2/day, or 40,000-50,000 Kcal/m2/day for the season. The double tubes accumulated 540-650 Kcal/m2/day, or 50,000-60,000 Kcal/m2/day for the entire season. The energy accumulated during the day was released during the night, resulting in higher night time soil and air temperatures in the tunnel.

TOTAL CUCUMBER YIELD, UNDER A WALK-IN TUNNEL USING PASSIVE SOLAR HEATING SYSTEM

CV	TOTAL HARVEST t\ha	AV. FR. LENGTH (cm)
1. Sahara	92a	13.8c
2. Picobello	89a	14bc
3. Pigal	89a	15.3a
4. Cordito	66b	14bc
5. Dina	86b	14.5b

Table 1

TOTAL SQUASH YIELD, UNDER A WALK-IN TUNNEL USING PASSIVE SOLAR HEATING SYSTEM

CV	TOTAL HARVEST t\ha
1. Embassy	42b
2. President	46a

Table 2

Yield-Cucumbers

All the five cultivars were Bet-Alfa type - short (15-18 cm), parthenocarpic, smooth (barbless), and dark green skin. The harvest began 45 days after direct-seeding. The total yield ranged from 66 t/ha for Cordito to 92 t/ha for Sahara for the 2.5-month harvesting period (Jan. to mid Mar.). No significant differences in earliness were observed between the cultivars. Fruit length averaged 13.5 to 15 cm, and fruit weight ranged from 200 to 250 gr/fr with significant differences among the cultivars (Table 1).

Zucchini\Squash

Two zucchini cultivars were tested - Embassy and President (PetoSeed). Harvest began 43 days after direct-seeding, and total yields were 42 and 46 t/ha for Embassy and President, respectively with significant differences between the cultivars (Table 2).

Diseases

Although the greenhouse climate is potentially favorable for insect and disease, the winter season and the insect-proof net around the tunnel kept the indoor insect population low. Humidity related diseases can be major problems when growing cucumbers in protected culture. The cucumber cultivars differed in their sensitivity to downy mildew. Keeping the sides rolled up for most of the growing season helped reduce the intensity of the diseases.

Florida is a leading state for outdoor and greenhouse vegetable production. The unheated greenhouse/high tunnel which is very popular in Europe and the Mid-East, was tested in North Florida for cucumber and squash production. Supplemental heating was supplied by a passive solar heating system (water tubes). Five cucumber cultivars (Bet -Alfa type) and two squash (zucchini) cultivars were direct seeded in Nov., 1992. Production of 66-92 t/ha and 42-46 t/ha of cucumber and zucchini squash, respectively, resulted during the early spring of 1993. The passive solar system increased the soil, air, and plant canopy temperatures by 3-50C.

Walk-in tunnels provided a protected growing system applicable to winter vegetable production in Northern Florida. The passive solar heating system provided freeze protection and increased air and soil temperatures. The walk-in tunnels combined with the passive solar heating system could provide a low-cost system for late fall and early spring production of several crops, mainly cucurbits. ○

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