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# FIELD SOILLESS CULTURE AS AN ALTERNATIVE TO SOIL METHYL BROMIDE FOR TOMATO AND PEPPER

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*Abstract.* **Soil fumigation with methyl bromide is an important agricultural practice in the United States for controlling soil-borne diseases, insects, nematodes, and weeds. The use of methyl bromide as a soil fumigant in agriculture will be forbidden in the U.S. after 2005, because of its negative effect on the stratospheric ozone layer. With the impending loss of methyl bromide as a soil fumigant, there has been much effort placed on searching for alternative soil treatment systems. One approach to dealing with the loss of methyl bromide, for selected crops, might be the use of cultural systems that do not depend on the native soil. Soilless culture of vegetables is commonplace in greenhouse production around the world, and the same production system might also be adaptable to outdoor culture of certain vegetables. Research on outdoor soilless culture of crops has been conducted at the University of Florida North Florida Research and Education Center in Live Oak, Florida, for several years. In the spring of 2001, research was conducted to compare tomato (*Lycopersicon esculentum* Mill.) and pepper (*Capsicum annuum* L) in an outdoor soilless culture system with the standard plastic mulched, methyl bromide fumigated soil-based system. Two basic production systems were compared: 1) the standard tomato and pepper cultural system and 2) soilless production using perlite-filled lay flat bags. 'Sunpride' tomato and 'Brigadier' pepper were planted. The irrigation water and nutrients were delivered to plants in both systems by drip irrigation. This paper describes our experiences with outdoor soilless culture of tomato and pepper and summarizes the benefits and challenges with soilless culture for commercial-scale use.**

There were 287,000 acres of vegetables produced in Florida and valued at $1.5 billion dollars for the production season of 1999-2000. On the basis of value, tomato and pepper production accounted for 28% and 15.3%, respectively, of the state's total value (Maynard, 2001). Vegetable production in Florida is a very technological business involving high-cost inputs that include polyethylene mulch, drip irrigation, fertilizer, pesticides, and use of methyl bromide as a soil fumigant (Hochmuth, 1994). Soil fumigation with methyl bromide is an important agricultural practice in the United States for controlling soil-borne diseases, insects, nematodes, and weeds. However the use of methyl bromide as a soil fumigant in agriculture will be forbidden in the U.S. after 2005, because of its negative effect on the stratospheric ozone layer. Vegetable producers are losing a valuable pesticide because the Environmental Protection Agency has found that it contributes to the destruction of the earth's protective ozone layer in the atmosphere. Faced with a 2005 ban on a widely used chemical that controls soil pests, University of Florida researchers and many others researchers around the world are working to develop new high-technology growing methods and tools that substitute for the use of methyl bromide soil fumigant. An alternative for soil fumigation might be to move production of some high value crops out of the native soil and into soilless culture (Woods, 2000).

During several years of recent research, many chemical products have been evaluated as potential replacements for methyl bromide. The results indicate that no one alternative pesticide can provide the consistent broad-spectrum control provided by methyl bromide (Hansen et al., 2000; Larson and Shaw, 1995, 2000; Locascio et al., 1997; Noling and Becker, 1994; Shaw and Larson, 1999).

Another approach to dealing with the loss of methyl bromide, for selected crops, might be the use of cultural systems that do not depend on the native soil. Soilless culture of vegetables is commonplace in greenhouses around the world, but the same production system might also be adaptable to outdoor culture of certain vegetables (Hochmuth and Crocker, 1997; Hochmuth and Hochmuth, 1996; Hochmuth et al., 1998; Schon and Peggy, 1997). Soilless systems for outdoor culture have been studied for several years at the University of Florida. Results have shown that several soilless systems can be used successfully and yields have been excellent, sometimes much greater than with traditional, soil-based cultural systems. Soilless systems would be more expensive to install compared to soil-based, methyl bromide systems, therefore increased yields, greater quality, certain reduced inputs, and special crops and markets will be needed for profitability.

The early results in northern Florida suggest, that with the use of the perlite lay-flat bag culture system, it is possible to get higher yields from plants in bags of perlite than from a standard mulched, drip-irrigated production system. The technical aspects of soilless culture mainly consist of an outdoor hydroponics system, supplying all the nutrients in the irrigation water. The bags of perlite provide an inorganic growing medium for plant roots, but the perlite has no nutrients or any of the harmful organisms that infest regular soils. This paper describes some of the work we have been conducting with outdoor soilless culture for vegetables and some suggestions for scaling this work up for commercial-scale use of this system.

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Tomatoes and peppers have been grown in perlite hydroponic culture at the University of Florida North Florida Research and Education Center-Suwannee Valley near Live Oak, Florida. Researchers have been comparing standard, soil-based culture systems with soilless culture with perlite-filled lay-flat bags. Soil for the soil-based system was prepared by plowing and disking and was then fumigated with methyl bromide and covered with black polyethylene film for the standard production system. In the soilless system, perlite lay-flat bags, 10 ft long and 6 inches in diameter were filled manually with horticultural perlite. Bags were placed end to end on a polyethylene- mulched row (bed) with 5 ft between the centers of each bed to facilitate the normal crop operations. Bags were arranged in a single row for tomato and in pairs of rows for pepper.

Irrigation was supplied via 0.5-inch polyethylene tubing connected to a 0.5-inch drip tape with emitters spaced 4 inches apart. Root intrusion of the drip tape emitters can be a problem in perlite bag culture. Due to more aggressive root growth habit in tomato bags, the drip tape was placed on the bag surface, and pinned down with wires (Fig. 1). Holes were mechanically punched in the top surface of the bags to enable nutrient solution to run from the tape into the perlite media through the holes. For pepper, the drip tape was placed inside the bag as the bags were filled with perlite (Fig. 2). The tape ran continuously out of the end of one 10-ft bag and into the end of the next bag in the row.

Planting holes, 18 inches apart for tomato and 12 inches apart for pepper were made in the bags. The same varieties, 'Sunpride' tomato and 'Brigadier' pepper, as used commercially in Florida, were used in these tests. Production systems and pest management were the same with the soilless and soil-based systems. Nutrients were supplied through three injectors and three electrical valves connected to the irrigation system. One injector supplied the soil-based system with fertilizer from a single stock tank, on a weekly basis (Maynard et al., 2001a; 2001b). The N and K were applied at 1 to 2 lb·acre$^{-1}$ per day, depending on the growth stage. Two stock tanks of concentrated nutrient solutions were used to supply the nutrient for the soilless system (Hochmuth, 1990). The final delivered nutrient solution concentrations for the soilless system were 150 ppm N, 50 ppm P, 200 ppm K, 150 ppm Ca, 50 ppm Mg, 60 ppm S, 2.8 ppm Fe, 0.2 ppm Cu, 0.8 ppm Mn, 0.3 ppm Zn, 0.7 ppm B, and 0.05 ppm Mo.

Fig. 1. Outdoor soilless culture of tomato in perlite-filled, lay-flat bags, showing placement of drip irrigation tubing on the surface of the bags.

Fig. 2. Outdoor soilless culture of pepper in perlite-filled, lay-flat bags at the University of Florida North Florida Research and Education Center-Suwannee Valley, near Live Oak, Florida, 2001. Note drip tubing emerging from inside the bags.

Irrigation water and nutrients were delivered to plants by drip irrigation, controlled automatically by the use of a timer. For the soil-based system, the irrigation was operated to maintain the soil moisture tension at -10 centibars in the root zone as indicated by tensiometers. The number of irrigations and the length of an irrigation event varied from several 15-min irrigations early in the season to several 45-min irrigations later in the season. In hydroponic vegetable production, it is important to allow some fraction of the media solution to leach from the bags after each irrigation event. This leaching portion prevents accumulation of soluble salts in the most active root area (Smith, 1987). In our study, the irrigation frequency and duration were determined based on an irrigation criterion of 20% of the leaching fraction (LF). To determine the LF of 20%, leached samples were collected periodically during the week. The frequency of operation and the length of operation of the soilless irrigation system were adjusted to maintain the acceptable leach fraction. This resulted in from one to 12 irrigations per day, depending on the growth stage of the crops.

In the research plots, the tomato and pepper plants in the soilless system grew faster and the plants were larger, compared with their soil-based counterparts. Leaf samples were collected to determine any differences in plant nutrition between the two systems. While leaf nutrient contents for N, K, P, and Mg were usually greater with the perlite system, the concentrations were always adequate with both systems. Fruit yield and fruit quality are being measured since the economic practicality of soilless culture will depend on high yields of high-quality fruits. For some crops the yields and quality will need to be greater than from standard soil culture. The economic analysis is being conducted to determine if the increases in yield and fruit quality can overcome the extra costs associated with soilless culture.

## Some Suggestions for Commercial Use

Project staff members have been working with a commercial vegetable grower in southern Florida who is interested in adopting soilless culture for his farming operation. This grower started with 5 acres of combined tomato and pepper, using this system developed at NFREC-Suwannee Valley. One of the biggest challenges with this system for commercial scale is the design of the irrigation system so that proper irrigation and nutrient application can be made. The perlite bags hold only a small portion of the needed nutrient solution for the day. The grower needs the capability of delivering several to many, short irrigations per day. Growers who want to use perlite lay flat bags system should be careful to use drip tape with emitters no more than 4 inches apart in order to assure that nutrient solution is within the plant root zone. Placement of the drip tape on the outside of the bags is important for crops like tomato that have vigorous roots or the roots may enter the tape emitters, clogging them. It is important to maintain a leaching fraction of 15 to 20% and to make drain cuts close to the bottom of the bag (0.5 inches from the bottom) so that the solution does not accumulate in the bags and flood the roots. Flushing of the irrigation system is needed at least every 2 weeks to remove solid particles and organic matter from the system.

Several crops can be grown continuously with the perlite bags. Winter squash (*Cucurbita maxima* Duchesne ex Lam.) and cucumber (*Cucumis sativus* L.) have successfully been grown following tomato and pepper. Yields of the second-crops also were greater than the yields of the same vegetables grown in double-crop fashion with standard, soil-based systems. Multi-cropping with soilless systems will help make the economics more acceptable.

Outdoor culture of vegetables using a soilless system is possible and might serve as an alternate system for methyl bromide-fumigated soil systems. The extra cost for the soilless system would have to be offset by increased yields, increased crop quality, increased prices for the crops, or combinations of these factors. From work so far, it appears that the outdoor soilless culture of vegetables could be profitable for farmers, especially those with direct sales, or in situations where yields and quality can be increased significantly.

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