Current Status of Drip Irrigation for Vegetables in the Southeastern and Mid-Atlantic United States

George Hochmuth[1]

Additional index words. microirrigation, irrigation, polyethylene mulch, water management, fertilizer management

Summary. Responses to a 1993 survey showed that drip irrigation was used on 36,400 ha of commercial vegetables in the southeastern and mid-Atlantic United States. Florida led with 44% of total drip-irrigated vegetable area, followed by Georgia, North Carolina, and Pennsylvania, with about 10% each. Drip irrigation was used most commonly on tomato, pepper, and watermelon crops. The most-important benefits of drip irrigation were improved water and fertilizer delivery efficiencies compared to other irrigation systems, such as overhead sprinklers and subirrigation. Challenges with drip irrigation included high installation cost, emitter clogging problems, need for filtration, overirrigation problems, disposal of tubing, and lack of readily available expertise. Most drip irrigation was used with polyethylene mulch and most tubing was thin-wall disposable rather than thick-wall reusable. Eighty-one percent of the drip-irrigated vegetable acreage was fertigated with N and K. Survey responses indicated that drip irrigation use for vegetables is increasing.

Extension personnel often are asked to supply statistics on use levels of certain production technologies. These statistics often are gathered by surveys of commercial grower organizations, or extension colleagues. State vegetable extension specialists in 14 states were asked to respond to 10 questions concerning the status of drip irrigation use for vegetables in their state. The survey results are summarized here. Relevant literature citations are included in the discussion of each topic to provide supporting documentation and to provide assistance for readers desiring additional information.

The term "drip irrigation" used here refers to the application of small volumes of water under low pressure from small-orifice emitters in a tube (usually polyethylene) placed on or just below the soil surface near the plant (Hochmuth et al., 1993). The first installation of a combined drip irrigation–polyethylene mulch system in the southeast / mid-Atlantic United States was made by Norm Smith, Professor, at Rutgers Univ., in a demonstration plot on Long Island in 1964 (Amer. Veg. Grower, 1993). The demonstration was conducted with the early drip irrigation tubing developed by Richard Chapin, and this tubing was used in several early research studies (Chapin and Chapin, 1971; Hall, 1977; Oebker and Kuykendall, 1971; Paterson and Smith, 1973; Voth, 1977). From these studies and demonstrations evolved wide adoption of drip irrigation for vegetable production in the southeastern and mid-Atlantic United States. This paper summarizes results of a 1993 survey of drip irrigation use on commercial vegetables in the southeastern and mid-Atlantic United States.

The survey covered 14 southeastern and mid-Atlantic states (Table 1). Drip irrigation was used on 36,400 ha, with Florida leading in usage with 16,230 ha (44%) (Table 1). North Carolina, Georgia, and Pennsylvania each had about 10% of the drip-irrigated vegetable area. New Jersey, Virginia, and South Carolina each had about 5% of the area, with 2230, 1840, and 1740 ha, respectively. Remaining states each had <1000 ha of drip-irrigated vegetables. The survey did not request the percentage of total vegetable area employing drip irrigation; however, for Florida, that figure would be 10% of total vegetable area or 30% of polyethylene-mulched vegetables.

Drip irrigation was used most extensively for tomatoes (50%), followed by peppers, watermelons, muskmelons, and cucumbers (Fig. 1). Strawberries, grown with production practices similar to vegetables, ranked in the top six crops for which drip irrigation was used.

Drip irrigation was combined with polyethylene mulch in 97% of the drip-irrigated area. Polyethylene mulch has been shown to improve early and total yields (Abdul-Baki et al., 1992; Bonanno and Lamont, 1987; Bryan, 1966; Emmert, 1957; Harmon and Worley, 1964; Knavel, 1966; Locascio and Thompson, 1960; Maiero et al., 1987; McEachern and Hawthorne, 1973; Schales, 1968), increase water and nutrient efficiency (Halsey, 1985; Hayslip and Iley, 1966; Jones et al., 1977; Locascio, 1961; Locascio et al., 1985; Sweeney et al., 1987), and improve vegetable quality (Jones, 1961; Menn, 1960). Black polyethylene mulch also controls weeds in the row (Courter and Oebker, 1964; Halsey, 1985; Thompson, 1959), providing a substantial benefit for drip-irrigated crops with mulch compared to use of drip irrigation without mulch. Other advantages for mulch were summarized by Lamont (1993).

There are two types of drip irrigation tubing based on longevity of use—reusable (thick-wall) and disposable (thin-wall). Eighty-five percent of drip irrigation in the southeastern and mid–Atlantic United States involved disposable tubing, according to survey results. Disposable drip irrigation tubing, with a wall thickness of up to ≈0.30 mm, can be used for up to three crops (without intervening tillage) and then discarded.

Leading benefits of drip irrigation identified in the survey were water conservation and improved fertilizer management (Table 2), two topics that have been studied since the 1970s by researchers in the southeastern United States. Research on water requirements of drip-irrigated vegetables in humid regions was summarized by Locascio et al. (1992).

Continued research is being conducted on water requirements of drip-irrigated vegetables, especially for Florida staked tomatoes and strawberries (Smajstrla et al., 1988). Crop water requirements for tomatoes ranged from ≈0.2 of pan evaporation (Class A Weather Bureau evaporation pan with appropriate pan coefficient) early in the season to ≈0.8 of pan evaporation during peak crop demand (Pitts and Clark, 1991). Water requirements av-

[1]*Professor, Extension Vegetable Specialist, Horticultural Sciences Department, University of Florida, Gainesville, FL 32611.*

Florida Experiment Station Journal Series number R-03716. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement *solely to indicate this fact.*

Table 1. *Drip irrigation use on commercial vegetables in the southeastern and mid-Atlantic United States.*

Ranking	State	Cooperator	Drip-irrigated area (ha)	Total drip-irrigated area (%)
1	Florida	G. Hochmuth	16,230	44
2	Georgia	D. Granberry	4,020	11
3	North Carolina	D. Sanders	3,850	10
3	Pennsylvania	M. Orzolek	3,850	10
4	New Jersey	C. Storlie	2,230	6
5	Virginia	C. O'Dell	1,840	5
6	South Carolina	W. Cook	1,740	5
7	Tennessee	A. Rutledge	800	2
8	Maryland	F. Schales	680	2
9	Alabama	J. Dangler	600	2
10	Mississippi	D. Nagel	300	1
11	Kentucky	J. Strang	160	0.5
12	Delaware	E. Kee	80	0.5
13	Louisiana	J. Boudreaux	20	0.5
Total			36,400	

erage ≈0.5 to 0.75 of pan evaporation over the season (Locascio et al., 1992; Olson and Rhoads, 1992). For drip-irrigated tomatoes in Florida, water should be applied in one to three applications per day on coarse-textured, sandy soils (Locascio et al., 1992). Tensiometers maintained at 10 to 15 kPa helped schedule irrigations (Smajstrla and Locascio, 1990; Smajstrla et al., 1988).

Improved nutrient delivery was another leading benefit for drip irrigation identified in the survey. Drip-irrigated tomatoes produced the same yield as subirrigated tomatoes, but with 33% less N and K fertilizer (Clark et al., 1991). Drip irrigation with fertilizer injection (fertigation) provided efficient fertilizer delivery, especially when coupled with polyethylene mulch (Hochmuth and Clark, 1991). On sandy soils, split applications of N and K with up to 80% of the N and K injected resulted in better yields than crops where no N or K was injected (Cook and Sanders, 1991; Dangler and Locascio, 1990; Hochmuth, 1992a; Locascio et al., 1977, 1989, 1992; Locascio and Myers, 1974). The exception to this occurs on medium- to fine-textured soils, where tomato yields with all fertilizer applied preplant were similar to yields of fertigated crops (Locascio et al., 1989; Cook and Sanders, 1991).

Improved nutrient delivery with drip irrigation probably results from nutrient applications timed more closely to crop demand. Schedules for N and K injection for crops such as watermelon (Table 3) have been presented for Florida (Hochmuth and Clark, 1991). Frequent daily or weekly nutrient injections were needed for sandy soils compared to more fine-textured soils (Cook and Sanders, 1991); however, when irrigation application was well-managed, weekly fertilizer injections were as effective as daily injections for yield enhancement (Cook and Sanders, 1991; Locascio and Smajstrla, 1989).

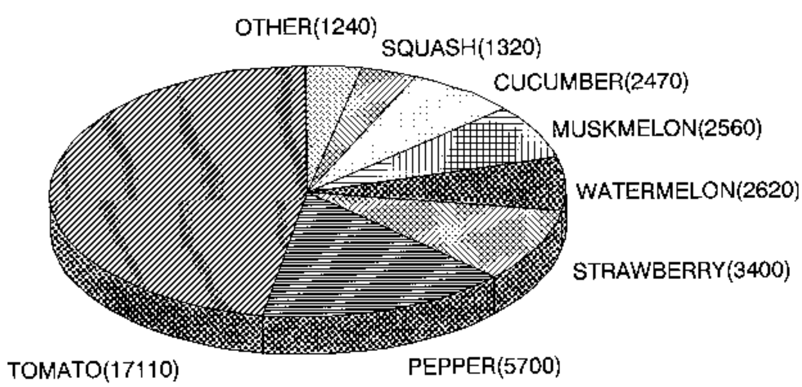

Fig. 1. *Distribution of drip-irrigated vegetable crops (hectares) in the southeastern and mid-Atlantic United States.*

Table 2. *Benefits of drip irrigation for commercial vegetables in the southeastern and mid-Atlantic United States.*

Ranking	Drip-irrigation benefit	Respondents (%)[z]
1	Water conservation	95
2	Better fertilizer management	60
3	Higher yields / quality	50
4	Better disease control	35
4	More convenient	35

[z]*Total number of respondents was 14.*

Survey respondents reported higher yields and better disease control with drip irrigation compared to other irrigation systems and production practices. Foliar diseases such as bacterial spot or early blight of tomatoes might be reduced with drip irrigation compared to overhead sprinkler irrigation.

Convenience was mentioned in the survey as a benefit of drip irrigation. Convenience results from the reduction in labor needed for moving pipe, and pumps required with sprinkler systems. Drip irrigation systems can be computerized to control application of water and nutrients to match crop requirements.

The most often-mentioned challenge with drip irrigation was the high cost of installation (Table 4). The annual total cost for drip irrigation is high, and similar to that for traveling gun and center pivot, but considerably more expensive than subirrigation (Prevatt et al., 1992). Annual cost per hectare was calculated to be \$1200, \$1045, \$955, and \$470 for traveling gun, center pivot, drip, and subirrigation, respectively (Prevatt et al., 1992).

Clogging problems were mentioned as challenges to successful drip irrigation by 45% of survey respondents (Table 4). Drip irrigation emit-

Table 3. *Schedule for N and K application with drip irrigation for watermelons in Florida.*

Crop development		Injection rate (kg / ha per day)[z]	
Stage	No. weeks	N	K
1	4	1.1	0.8
2	2	1.7	1.2
3	2	2.2	1.6
4	3	1.7	1.2
5	2	1.1	0.8

[z]*Rows on 2.4-m centers; total nutrients, 135 N and 110 K ($kg \cdot ha^{-1}$); after Hochmuth and Clark (1991).*

Table 4. *Challenges to drip irrigation use for commercial vegetables in the southeastern and mid-Atlantic United States.*

Ranking	Drip-irrigation challenge	Respondents (%)[z]
1	Expensive to install	55
2	Emitter clogging problems	45
2	Filtration needed	45
3	Tendency to overwater	30
3	Lack of available expertise	30
3	Disposal of tubing	30
4	Need for increased management	20
4	Insect / animal damage	20

[z]*Total number of respondents was 14.*

ters are prone to clogging when poor-quality, unfiltered water is used or when proper precautions for water treatment are not followed. Drip emitters can be clogged by physical (sand, clay, limestone), biological (bacteria, algae), or chemical (various precipitates) materials. Drip irrigation systems benefit from filtration (Sanders, 1992a). Biological and chemical clogging factors can be prevented by appropriate chemical treatment of water (Clark et al., 1988a; Pitts et al., 1990; Sanders, 1992b). Sodium hypochlorite commonly is injected to reduce clogging due to algal or bacterial growth (Clark and Smajstrla, 1992; Pitts et al., 1990).

Another challenge with drip irrigation systems, mentioned by 30% of survey respondents, was overirrigation. On sandy soils, water does not move laterally more than ≈25 cm (Clark, 1992; Clark and Smajstrla, 1993; Smajstrla and Locascio, 1990), so soil in the bed is not completely wetted laterally. Irrigation managers without sufficient information or training have a tendency to overwater in an effort to completely wet the soil in the bed. This effort usually results in water moving below the root zone. Work with several vegetables has shown that traditional bed widths (90 cm) can be narrowed (60 cm) for drip irrigation compared to other irrigation systems, especially subirrigation (Clark and Maynard, 1992). Use of tensiometers and evapotranspiration estimates can help maximize irrigation efficiency and minimize overirrigation (Clark et al., 1990, 1991; Smajstrla and Locascio, 1990).

Twenty percent of survey respondents mentioned that drip irrigation systems require increased management time compared to other irrigation systems due to need for water treatment, leak prevention, and fertilizer injection. Growers require training on proper management of drip irrigation, and sometimes expertise is not readily available. The survey respondents expressed concern that expertise for proper irrigation system design and management is not widely available. Proper system design is required for success with drip irrigation (Clark, 1992; Clark et al., 1988b; Sanders, 1992a).

Disposal of drip tubing was mentioned by 30% of the survey respondents as a challenge for drip irrigation use. Drip tubing is deposited in landfills or incinerated for energy recovery. More options for reuse or recycling will be required.

Thin-wall (0.15- to 0.25-mm) drip irrigation tubing is popular due to reduced cost compared to tubing with thicker walls. However, thin-wall tubing is subject to insect and rodent damage (Stansly and Pitts, 1990), which increases management costs. Insect and rodent damage was mentioned by 20% of the survey respondents as a challenge to successful drip irrigation use.

The survey revealed one-third of drip-irrigated vegetables was double-cropped. Growers are making multiple use of drip irrigation and polyethylene mulch investments where possible. Double-cropping spring-used beds with a fall crop (for northern growers) or double-cropping fall after spring or spring after fall (for southern growers) has been successful for several cropping systems (Clough et al., 1990; Hochmuth, 1992b; Kays et al., 1976; Stanley et al., 1991).

Conclusion

Drip irrigation has been widely adopted for vegetable crops in the southeastern and mid-Atlantic states. Although costs and management expertise requirements are high, 86% of the survey respondents reported that drip irrigation was increasing in their state, and 14% reported that use was remaining level. States with large areas of drip-irrigated vegetables were experiencing increases in drip irrigation use. Survey respondents pointed out that improved irrigation and fertilization application efficiencies were the two most-important benefits of drip irrigation. The most serious challenges for growers included high installation costs and a high level of expertise needed to properly operate drip irrigation systems. Emitter clogging is a common problem, and clogging control programs must be designed into the drip irrigation system. Benefits outweighed the potential problems leading to continued increase in drip irrigation use for vegetables.

Literature Cited

Abdul-Baki, A., C. Spence, and R. Hoover. 1992. Black polyethylene mulch doubled yield of fresh-market field tomatoes. HortScience 27:787–789.

American Vegetable Grower. 1993. Around the industry. Amer. Veg. Grower 41:9.

Bonanno, A.R. and W.J. Lamont. 1987. Effect of polyethylene mulches, irrigation method, and row covers on soil and air temperature and yield of muskmelon. J. Amer. Soc. Hort. Sci. 112:735–738.

Bryan, H.H. 1966. Effect of plastic mulch on the yield of several vegetable crops in north Florida. Proc. Fla. State Hort. Soc. 79:139–146.

Chapin, R.D. and R.E. Chapin. 1971. Double-wall tubing for drip irrigation of row crops. Proc. 10th Natl. Agr. Plastics Congr. 10:8–18.

Clark, G.A. 1992. Drip irrigation management and scheduling for vegetable production. HortTechnology 2:32–38.

Clark, G.A. and D.N. Maynard. 1992. Vegetable production on various bed widths using drip irrigation. Appl. Eng. Agr. 8:28–32.

Clark, G.A. and A.G. Smajstrla. 1992. Treating irrigation systems with chlorine. Fla. Coop. Ext. Serv. Circ. 1039.

Clark, G.A. and A.G. Smajstrla. 1993. Application volumes and wetting patterns for scheduling drip irrigation in Florida vegetable production. Fla. Coop. Ext. Serv. Circ. 1041.

Clark, G.A., D.Z. Haman, and F.S. Zazueta. 1988a. Injection of chemicals into irrigation systems: rates, volumes, and injection periods. Fla. Coop. Ext. Serv. Bul. 250.

Clark, G.A., C.D. Stanley, and A.G. Smajstrla. 1988b. Micro-irrigation on mulched bed systems: components, system capacities, and management. Fla. Coop. Ext. Serv. Bul. 245.

Clark, G.A., D.N. Maynard, C.D. Stanley, G.J. Hochmuth, E.A. Hanlon, and D.Z. Haman. 1990. Irrigation scheduling and management of micro-irrigated tomatoes. Fla. Coop. Ext. Serv. Circ. 872.

Clark, G.A., C.D. Stanley, D.N. Maynard, G.J. Hochmuth, E.A. Hanlon, and D.Z. Haman. 1991. Water and fertilizer management of microirrigated fresh market tomatoes. Trans. ASAE 34:429–435.

Clough, G.H., S.J. Locascio, and S.M. Olson. 1990. Yield of successively cropped polyethylene-mulched vegetables as affected by irrigation method and fertilization management. J. Amer. Soc. Hort. Sci. 115:884–887.

Cook, W.P. and D.C. Sanders. 1991. Nitrogen application frequency for drip-irrigated tomatoes. HortScience 26:250–252.

Courter, J.W. and N.F. Oebker. 1964. Comparison of paper and polyethylene mulching in yields of certain vegetable crops. Proc. Amer. Soc. Hort. Sci. 85:526–531.

Dangler, J.M. and S.J. Locascio. 1990. Yield of trickle-irrigated tomatoes as affected by time of N and K application. J. Amer. Soc. Hort. Sci. 115:585–589.

Emmert, E.M. 1957. Black polyethylene for mulching vegetables. Proc. Amer. Soc. Hort. Sci. 69:464–469.

Hall, B.J. 1977. Drip irrigation in row crops. Proc. Intl. Agr. Plastics Congr. 7:42–47.

Halsey, L.A. 1985. Cost comparison of conventional and direct-seeded plastic mulch watermelons in north Florida. Proc. Fla. State Hort. Soc. 98:278–281.

Harmon, S.A. and R. Worley. 1964. Effects of plastic mulch sheeting on cantaloupe production in south Georgia. Proc. Natl. Agr. Plastics Congr. 5:93–103.

Hayslip, N.C. and J.R. Iley. 1966. Use of plastic strips over fertilizer bands to reduce leaching. Proc. Fla. State Hort. Soc. 79:132–139.

Hochmuth, G.J. 1992a. Fertilizer management for drip-irrigated vegetables in Florida. HortTechnology 2:27–32.

Hochmuth, G.J. 1992b. Double-cropping vegetables on polyethylene-mulched beds. Fla. Coop. Ext. Serv. Circ. SP109.

Hochmuth, G.J. and G.A. Clark. 1991. Fertilizer application and management for micro (drip) irrigated vegetables in Florida. Fla. Coop. Ext. Serv. Spec. Ser. SS-VEC-45.

Hochmuth, G.J., S.J. Locascio, T.E. Crocker, C.D. Stanley, G.A. Clark, and L.R. Parsons. 1993. Impact of microirrigation on Florida horticulture. HortTechnology 3:223–229.

Jones, J.P. 1961. Control of soil rot of cucumber by plastic mulch and certain fungicides. Proc. Fla. State Hort. Soc. 74:180–182.

Jones, T.L., U.S. Jones, and D.O. Ezell. 1977. Effect of nitrogen and plastic mulch on properties of Troup loamy sand and on yield of 'Walter' tomatoes. J. Amer. Soc. Hort. Sci. 102:273–275.

Kays, S.J., A.W. Johnson, and C.A. Jaworski. 1976. Multiple cropping with trickle irrigation. HortScience 11:135–136.

Knavel, D.E. 1966. Comparison of black plastic, clear plastic, and aluminum foil mulches for vegetable crop production. Proc. Assn. South. Agr. Work. 63:218.

Lamont, W.J. 1993. Plastic mulches for the production of vegetable crops. HortTechnology 3:35–39.

Locascio, S.J. 1961. The retention of nutrients as affected by plastic mulch. Proc. Natl. Agr. Plastics Congr. 2:21.

Locascio, S.J. and B.D. Thompson. 1960. Strawberry yield and soil nutrient levels as affected by fertilizer rate, type of mulch, and type of application. Proc. Fla. State Hort. Soc. 73:172–179.

Locascio, S.J., G.A. Clark, A.A. Csizinszky, C.D. Stanley, S.M. Olson, F. Rhoads, A.G. Smajstrla, G. Vellidis, R.J. Edling, H.Y. Hanna, M.R. Goyal, S. Crossman, and A.A. Navarro. 1992. Water and nutrient requirements for drip-irrigated vegetables in humid regions. Fla. Agr. Expt. Sta. Southern Coop. Serv. Bul. 363.

Locascio, S.J., J.G.A. Fiskell, D.A. Graetz, and R.D. Hauck. 1985. Nitrogen accumulation by peppers as influenced by mulch and time of fertilizer application. J. Amer. Soc. Hort. Sci. 110:325–328.

Locascio, S.J., J.M. Myers, and F.G. Martin. 1977. Frequency and rate of fertilization with trickle irrigation for strawberries. J. Amer. Soc. Hort. Sci. 102:456–458.

Locascio, S.J., S.M. Olson, and F.M. Rhoads. 1989. Water quantity and time of N and K application for trickle-irrigated tomatoes. J. Amer. Soc. Hort. Sci. 114:265–268.

Locascio, S.J. and A.G. Smajstrla. 1989. Drip irrigated tomato as affected by water quantity and N and K application timing. Proc. Fla. State Hort. Soc. 102:307–309.

Maiero, M., F.D. Schales, and T.J Ng. 1987. Genotype and plastic mulch effects on earliness, fruit characteristics, and yield in muskmelon. HortScience 22:945–946.

McEachern, G.R. and P.L. Hawthorne. 1973. The influence of polyethylene mulch on the production and postharvest quality of 'Louisiana' strawberries. Proc. Natl. Agr. Plastics Congr. 11:131–132.

Menn, J.P. 1960. Plastic mulches. Proc. Fla. State Hort. Soc. 73:114–117.

Oebker, N.F. and J.R. Kuykendall. 1971. Trickle irrigation in horticultural crops in the desert southwest. Proc. Natl. Agr. Plastics Congr. 10:28–35.

Olson, S.M. and F.M Rhoads. 1992. Effect of water quantity on fall tomato production in north Florida. Proc. Fla. State Hort. Soc. 105:334–336.

Paterson, J.W. and N.J. Smith. 1973. Nitrogen, mulch, and trickle irrigation effects on eggplant production. Proc. Natl. Agr. Plastics Congr. 11:179–186.

Pitts, D.J. and G.A. Clark. 1991. Comparison of drip irrigation to subirrigation for tomato production in southwest Florida. Eng. Agr. 7:177–184.

Pitts, D.J., D.Z. Haman, and A.G. Smajstrla. 1990. Causes and prevention of emitter plugging in microirrigation systems. Fla. Coop. Ext. Serv. Bul. 258.

Prevatt, J.W., G.A. Clark, and C.D. Stanley. 1992. A comparative cost analysis of vegetable irrigation systems. HortTechnology 2(1):91–94.

Sanders, D.C. 1992a. Drip-irrigation system component design considerations for vegetable crops. HortTechnology 2(1):25–27.

Sanders, D.C. 1992b. Maintenance considerations for drip irrigation systems. HortTechnology 2(1):38–39.

Schales, F.D. 1968. Response of several vegetable crops when mulched with metallic and nonmetallic mulches. Proc. Natl. Agr. Plastics Congr. 8:119–122.

Smajstrla, A.G. and S.J. Locascio. 1990. Irrigation scheduling of drip-irrigated tomato using tensiometers and pan evaporation. Proc. Fla. State Hort. Soc. 103:88–91.

Smajstrla, A.G., B.J. Bowman, G.A. Clark, D.Z. Haman, F.T. Izuno, and F.S. Zazueta. 1988. Basic irrigation scheduling in Florida. Fla. Coop. Ext. Serv. Bul. 249.

Stanley, C.D., A.A. Csizinszky, G.A. Clark, and J.W. Prevatt. 1991. Sequential cropping for vegetable production using microirrigation on sandy soils in southwestern Florida. HortTechnology 1(1):72–75.

Stansley, P.A. and D.J. Pitts. 1990. Pest damage to micro-irrigation tubing: Causes and prevention. Proc. Fla. State Hort. Soc. 103:137–139

Sweeney, D.W., D.A. Graetz, A.B. Bottcher, S.J. Locascio, and K.L. Campbell. 1987. Tomato yield and nitrogen recovery as influenced by irrigation method, nitrogen source, and mulch. HortScience 22:27–29.

Thompson, B.D. 1959. Response of strawberries to mulching with plastic. Proc. Fla. State Hort. Soc. 72:179–185.

Voth, V. 1977. Ten years of drip irrigation on California strawberries from 1967–1976. Proc. Intl. Agr. Plastics Congr. 7:90–96.