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A COMPARISON OF MICRO TO SUBSURFACE IRRIGATION OF TOMATOES

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Abstract. **A study was conducted to evaluate the practical and economic feasibility of using drip (a form of micro irrigation) as an alternative to seepage (semi-closed) irrigation for polyethylene mulched and staked tomatoes (*Lycopersicon esculentum* Mill. cv. Sunny). Water table levels and soil water status were monitored, and tomato yield and quality were measured. Irrigation water used by the 2 irrigation systems was measured; fixed and variable costs for each system were computed. Results of the two-year study indicated that yield and quality of fruit with the micro irrigated tomatoes were comparable to that with seepage irrigation, but there was a significant reduction in water applied by the micro irrigation system (ratio 10:1). However, over 80 percent of the water usage by seepage irrigation can be attributed to downward percolation and therefore was returned to the groundwater reserves. Reduction in pumping costs compensated to some extend for the additional cost of the micro irrigation system. The seasonal additional costs for micro irrigation (excluding labor) was $136 per acre.**

Southwest Florida is experiencing both a rapidly growing urban population and expanding acreage of irrigated agriculture. These conditions are resulting in an increasing demand on available water supplies, making efficient irrigation essential to the long-term viability of the area's agriculture.

The region is a major vegetable producing area with a large percentage of this acreage devoted to tomatoes. The predominant irrigation method currently used is seepage (subsurface). The efficiency of this irrigation method is dependent on soil characteristics and on depth to the water table.

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Micro irrigation, on the other hand, is a method of providing water through a network of plastic pipe directly to the plant's root zone. Since water can be applied with a high degree of control, greater application efficiencies are possible. The benefits of micro irrigation have been reported by Locascio et al. [2, 3] and others [1, 6, 7]. However, due to the sandy soils that have a low water holding-capacity, practical problems exists in the management of micro irrigation for commercial tomato production.

Therefore, the objectives of the study were: 1) to measure the water consumption and plant yield response from the 2 irrigation methods, and 2) to evaluate the practical and economic feasibility of micro irrigation as a *production alternative* to seepage irrigation.

Materials and Methods

The study was performed at the Southwest Florida Research and Education Center (IFAS) in Immokalee on an Immokalee fine sand (sandy, siliceous, hyperthermic Arenic Haplaquods).

The two irrigation systems were each installed on 1.5 acre fields separated by a 360 ft wide buffer zone and a 4 ft deep perimeter rim ditch. This buffer zone was required to reduce the influence of the high water table in the seepage irrigated field on the drip irrigated field. Due to the size of the field study and the requirement to maintain a large buffer zone between the fields, the study was not replicated spacially but year was considered as replication.

A seepage system was also installed in the drip irrigated field to provide a means of wetting the field prior to bedding, fumigating, and mulching with plastic. The seepage system installed on both fields was the 'semi-closed' type, which used underground PVC pipe to convey water from the well to the lateral ditches within the field. Lateral irrigation ditches were spaced on 100-ft centers in 1987, but the spacing was reduced to 50-ft in 1988 to improve irrigation uniformity. Field row lengths were approximately 300 ft. Plant beds were placed between lateral ditches on six foot centers, and plants were set in the single row beds on 18 inch centers.

In the drip irrigated field, a single line source type of drip tubing was placed on top of the bed (under the polyethylene mulch) approximately 9 inches from the plant row. The lateral tubing used in 1987 had fixed emitters on an 18-inch spacing, and in 1988 a 12-inch emitter spacing was used. The emitter discharge was approximately 0.5 gal/hr at 15 psi.

Irrigations were scheduled on the seepage irrigated field to maintain the water table between 16 and 20 inches from the top of the bed. Tensiometers were located at 2 depths (6 and 12 inches) and at 3 locations within the drip irrigated field. The tensiometers were placed in the plant row (approximately 9 inches from the lateral line). Irrigations were scheduled in the drip irrigated field to maintain bed moisture above (–) 15 cbar of soil-water potential as measured by tensiometers.

Tomato seedlings (cultivar: Sunny) were planted in Jan. of each year. Fertilizer was applied at a rate of 235-48-327 lb./acre of N-P-K to each field. In the seepage field, all fertilizer was applied pre-plant under the plastic mulch; while in the drip field, all the P was applied pre-plant, but only a portion of the other fertilizer requirements (45 lb./acre N and 79 lb./acre K) were applied then. The remainder was injected into the irrigation system (see Table 1).

A water budget was maintained to account for inflows and outflows of water from the two fields. The water budget equation is given:

$$P + I_{in} + F_{in} + U = ET + CS + R_o + F_{out} + D \quad EQ[1]$$

where,

P = precipitation,
I = irrigation,
F = lateral flow (surface or subsurface),
CS = change in water stored,
R_o = runoff (irrigation tailwater)
ET = evapotranspiration,
U = upward flux for the preexisting water table,
D = deep percolation.

Equation [1] was simplified by the following assumptions: 1) lateral flows were minimized by maintaining equal water table depths at the boundaries, 2) over the growing season, the change in storage was insignificant in comparison to other parameters and was omitted, and 3) upward flux from the naturally occurring water table was small because of the normally deep water table maintained in the drip irrigated field. Therefore, the primary water budget data for this study were: irrigation inflow (metered), runoff (irrigation tailwater), evapotranspiration (estimated by pan evaporation), and rainfall (gauge at site). Irrigation water outflow was measured by a Parshall flume with a continuous recorder.

A 'controlled zone' within the seepage irrigated field was established for determining the water budget (see Fig. 1). On both sides of this zone a water table was maintained at approximately the same level as the water table within the zone. The purpose was to minimize subsurface lateral movement of water from this zone in which water use was measured. Runoff was subtracted from metered inflow into the control zone; the difference was considered to be water used be seepage irrigation. This included consumptive use (ET) and deep percolation.

Table 1. Fertigation schedule—drip irrigated tomatoes spring 1987 (5-0-8 liquid fertilizer was injected two times per week).

Age—week after transplanting	Nutrient (lb./acre/wk) N	K	Injected (% of total)
2	3.8	5.0	2
3	5.7	7.5	3
4	7.6	10.0	4
5	9.5	12.5	5
6	9.5	12.5	5
7	9.5	12.5	5
8	15.2	20.0	8
9	15.2	20.0	8
10	15.2	20.0	8
11	22.8	30.0	12
12	22.8	30.0	12
13	22.8	30.0	12
14	15.2	20.0	8
15	15.2	20.0	8

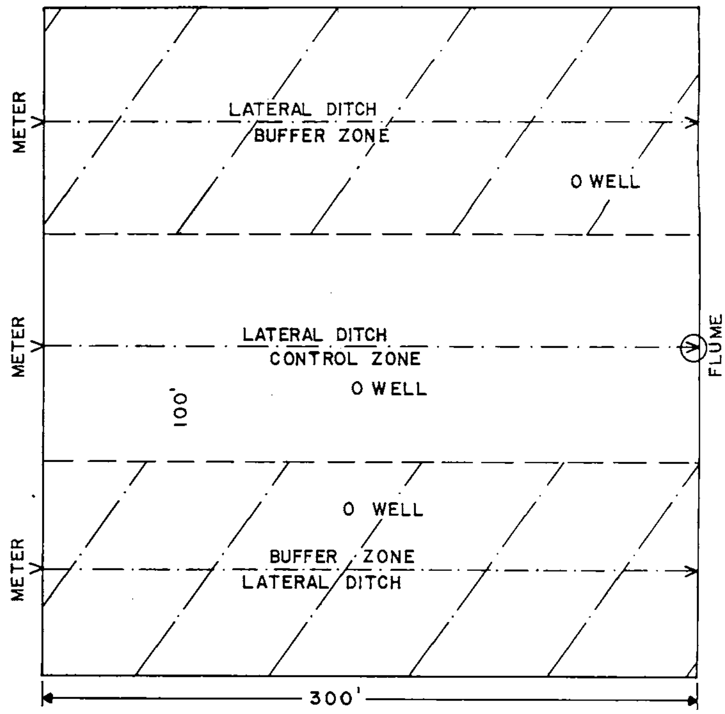

Fig. 1. Layout of seepage field to measure components of the water budget.

Results and Discussion

There were 2 harvests from the 1987 crop for both seepage and drip irrigated fields, but in 1988 there was a single harvest due to a problem of "uneven ripening". Since a primary objective of the study was to evaluate micro irrigation as a production alternative to seepage irrigation, the harvesting was done by commercial picking crews, and tomatoes were graded and sized by a commercial packinghouse. Yield and fruit size are shown in Table 2 were taken from commercial pack-out results. The combined yield from the 2 years showed no statistical difference between the 2 irrigation methods. Both fields were also sampled for yield and quality prior to the commercial harvest, and sample means were within statistical agreement with commercial packouts.

Fig. 2a and 2b show the accumulated water-budget for the 2 fields during the 2 seasons. Pan evaporation was presented as a rough estimate of ET since crop coefficients under drip irrigation were not known. Crop coefficients account for the influence of plant age, row spacing, and soil surface (polyethylene) on actual ET. The relationship of the graphs for each of the years were similar with total water applied by the seepage irrigation method as 66 and 88 inches for 1987 and 1988, respectively. Rainfall during the crop season in 1987 was about 10 inches while in 1988

Table 2. Average yield by size of tomatoes grown under drip and seepage irrigation (Spring 1987 and 1988) (25 lb boxes/ac).

Irrigation Method	Fruit size 6x7	6x6	5x6	Total[z]
Drip	136	379	854	1369
Seepage	183	438	766	1386

[z]Totals were not statistically different.

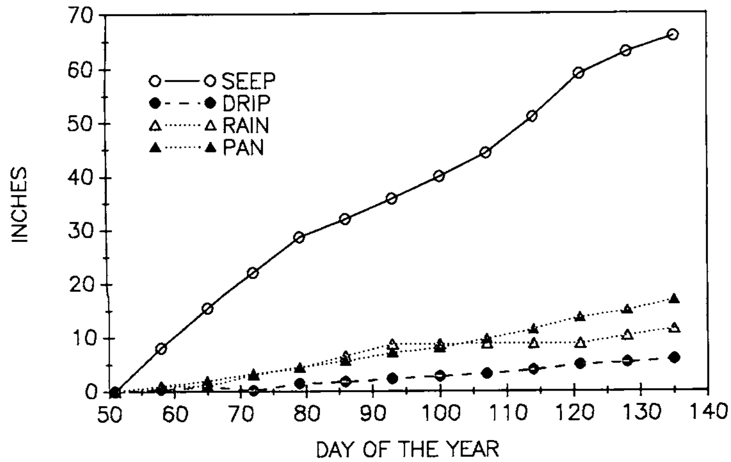

Fig. 2a. Cumulative water-budget for drip irrigated tomato field in 1987 (pan = pan evaporation).

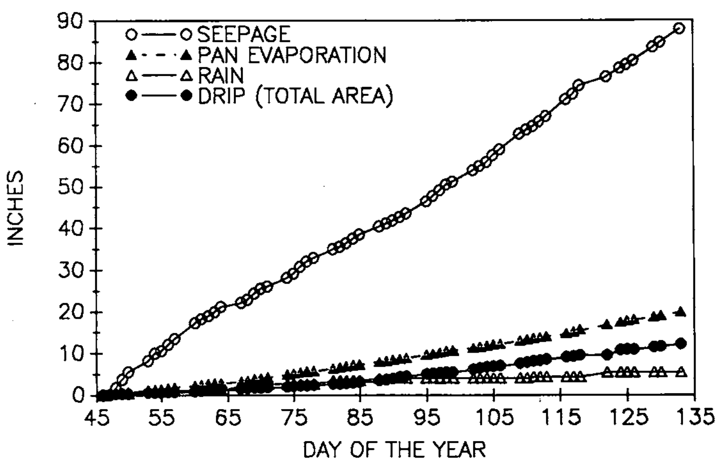

Fig. 2b. Cumulative water-budget for drip irrigated tomato field in 1988 (pan = pan evaporation).

it was less than 5 inches; 1987 was a wetter than normal year, while 1988 was a drier than normal year.

The total water applied on an area basis through the drip irrigation system was approximately 5 inches in 1987 and 10 inches in 1988. Pan evaporation also differed significantly between the 2 seasons, but not nearly to the extent of that of the water applied by the drip irrigation system. In 1987 pan evaporation during the growing season totalled about 16 inches, while in 1988 the total pan evaporation as 18 inches. The ratio of water applied to pan evaporation was close to the ratios reported by Locascio et al. [3]. Though more water was applied in 1988 than in 1987, more crop water stress (afternoon wilt) was observed in 1988, due to the dry and hot conditions that occurred during that season. It was observed that tomatoes grown under drip irrigation will show water stress on this soil during periods of high ET demand if soil-water potential becomes less than (–) 15 cbar.

The measured water application on an area basis by seepage irrigation for the 80-day growing season may have been more than the some commercial field operating under seepage irrigation. The efficiency of seepage irrigation on the flatwoods soils is directly dependent on the permeability of the spodic horizon or depth to the water table. It is well known that this permeability is variable from one field to the next.

In 1987, soil-water potential (Fig. 3a) for the drip irrigated field as measured by tensiometers was *maintained* from 0 to (–) 15 cbar at both the 6 and 12 inch depth for the majority of the observation period. In 1988, although about twice as much water was applied as was in 1987, tensiometer values dropped below (–) 15 cbar for a significant portion of the fruiting period (Fig. 3b).

In both years the water table in the drip irrigated field was maintained below 36 inches from the surface of the soil for a majority of the growing season. At that depth there was little water contributed from the water table to meeting ET demand [4]. However, in 1987 for a period of 10 days during which significant rainfall occurred, the water table was above 36 inches and probably contributed some to meeting crop water requirements. In 1988 the water table was continuously maintained at or below a 36-inch depth.

Economic Analysis: In evaluating irrigation methods, it is important to determine the potential economic benefit and cost of each method. Table 3 provides a listing of the estimated initial capital outlays for both a 100-acre drip and 100-acre seepage irrigation system. The 100-acre system

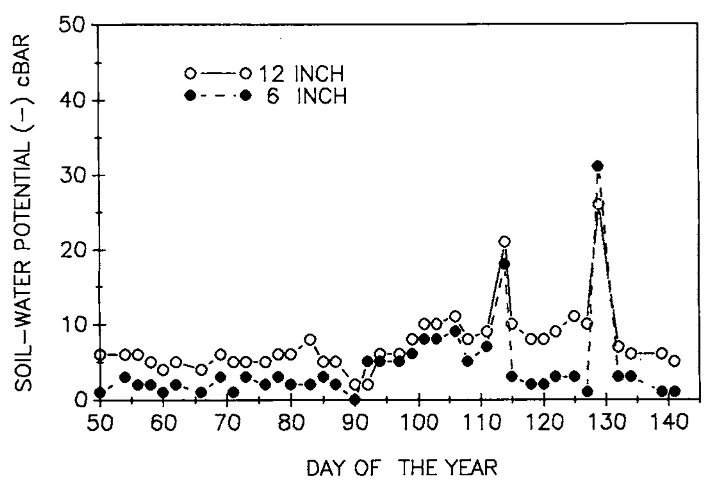

Fig. 3a. Tensiometer readings in drip irrigated tomato field in 1987 (average of three locations).

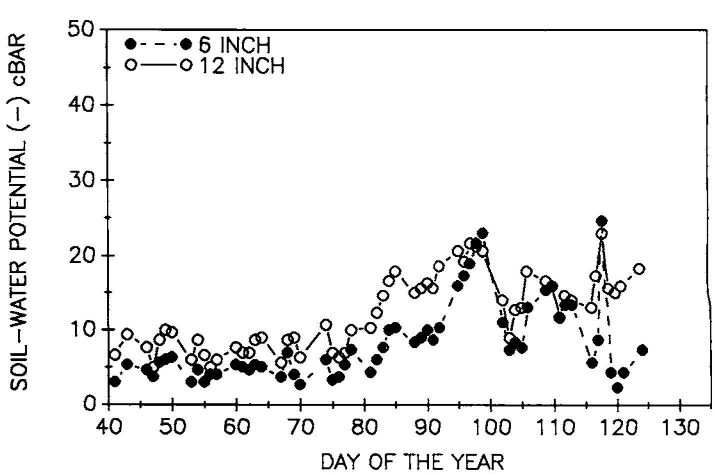

Fig. 3b. Tensiometer readings in drip irrigated tomato field in 1988 (average of three locations).

Table 3. Initial capital investment for 100-acre tomato drip and seepage irrigation systems, Southwest Florida, 1987.

Item	Drip System	Seep System	Added Cost
	Dollars		
Water supply system:	(1 well)	(2 wells)	
Well: 10" 140 ft deep	6,000	12,000	
Pump: 700 gpm 160 @ ft TDH[z]	6,000	12,000	
Power unit: 40 hp motor	3,000	6,000	
Sub Total	15,000	30,000	−15,000
System layout:			
PVC:			
6" 10000 ft.	30,000	15,000	
8" 1000 ft.	4,500	4,500	
Valves: (@ $2000)	8,000	4,000	
Filtration	3,000	0	
Chemical Injection	2,000	0	
Meters, backflow prev.	3,500	500	
Controller	2,000	0	
Sub Total	53,000	24,000	29,000
Total	68,000	54,000	14,000
Additional initial cost of drip over seepage irrigation (per acre)			$140

[z]TDH = Total dynamic head

size was assumed to achieve reasonable production economies of scale. Well depth, pump capacity and power requirements were assumed based on common water yielding characteristics of the water bearing formation underlying southwest Florida. Pumping capacities were based on estimates of irrigation application efficiency for the 2 irrigation methods. It was assumed that the drip system could be designed with zones, thus the required pumping capacity would be 7 gpm/acre (based on total acreage). The drip system must have seepage irrigation capacity since the field must often be wetted to allow for bed formation. In this example, however, there is only sufficient water to wet one half of the field at a time. The seepage system, because of lower application efficiency, would require more pumping capacity. Two wells, pumps and power units with a total capacity of 1400 GPM, were assumed for the seepage irrigation system. Thus, the assumed initial capital investment was $680 per acre for drip irrigation and $540 per acre for seepage irrigation. The seepage system being compared was a 'semi-closed' system, where water is conveyed to the field through underground pipe.

Table 4. Fixed cost differences for 100-acre drip and seepage irrigation systems for tomatoes, Southwest Florida, 1987.

Irrigation	Item	Water supply system[z]	System layout[z]	Total
		Dollars		
Drip	New cost	15,000	53,000	
	Average costy	7,500	26,500	
	Years of life	10	10	
	Depreciation[x]	1,500	5,300	6,800
	Interest[w]	750	2,650	3,400
	Insurance[v]	150	530	680
	Taxes[u]	150	530	680
	Repairs[q]	150	530	680
	Total[p]	2,700	9,540	12,240
Seep	New cost	30,000	24,000	
	Average cost[y]	15,000	12,000	
	Years of life	10	10	
	Depreciation[x]	3,000	2,400	5,400
	Interest[w]	1,500	1,200	2,700
	Insurance[v]	300	240	540
	Taxes[u]	300	240	540
	Repairs[q]	300	240	540
	Total[p]	5,400	4,320	9,720
				$2,520
Added cost of drip over seepage (per acre)[o]				$25.20

[z]See Table 9 for a description of the systems.
[y]New cost + salvage value divided by 2 (assumes no salvage value)
[x]New cost − salvage value divided by years of life.
[w]Average cost x 10%.
[v]New cost x 1%
[u]Average cost x 1%
[q]New cost x 1%
[p]Sum of depreciation, interest, insurance, taxes and repairs.
[o]Divided by 100 acres.

Table 5. Annual fixed and variable costs of equipment for 100-acre drip and seepage irrigation system for tomatoes, Southwest Florida, 1987.

Item	Drip	Seep	Added cost
	Dollars		
Fixed cost[z]	12,240	9,720	2,520
Variable costs:			
Irrig. tubing[y]	13,750	0	13,750
Interest[x]	1,375	0	1,375
Total	27,365	9,720	17,645
Total per acre[w]			$ 176

[z]From Table 4.
[y]550,000 ft. @ $25/1000 ft.
[x]On the irrigation tubing at 10%.
[w]17,645 divided by 100.

The fixed costs of the 2 irrigation methods are compared in Table 4. For both irrigation systems, annual depreciation was measured based on 10 years of useful life and no salvage value. The lateral irrigation tubing for the drip system was disposable; therefore, it was included in annual operating costs. Average annual interest cost was based on a 10 percent interest rate. Annual insurance and repair costs for each system was estimated based on one percent of new cost. Given these assumptions and those listed in Table 4, the annual difference in fixed costs would be $25 per acre greater for drip irrigation.

Table 5 provides a summary of annual fixed and variable cost of equipment for the two irrigation systems. The annual cost of the drip irrigation system over the cost of the 'semi-closed' seepage system was $176 per acre.

A summary of operating costs and for the two systems was estimated based on the assumptions listed in Table 6. The pumping costs were based on a seasonal pumping requirement for the drip irrigation system of 7.5 inches and 77 inches for the seepage system. The assumption of pumping requirements for the two systems was based on

Table 6. Assumptions used in estimating pumping costs.

Parameter	Drip	Seep
Static water level	10 ft[z]	10 ft[z]
Specific yield	35 gpm/ft	35 gpm/ft
Pumping friction	4 ft[z]	4 ft[z]
Working pressure	70 ft[z]	23 ft[z]
Pump efficiency	70 %	70 %
Motor efficiency	88 %	88 %
Horsepower required	26 HP	15 Hp
Electric cost	$ 0.08/KWH	$ 0.08/KWH

[z]Given in feet of water

Table 7. Summary of electric costs and for drip and seepage irrigated tomatoes, Southwest Florida, Spring crop of 1987.

Item	Drip	Seep	Added[zyx] cost
	$/acre		
Variable costs:			
Electric energy	8.50	48.50	–40.00

[z]No machinery variable and fixed cost were considered since they are similar in both alternatives.
[y]Management and labor cost differences are not quantified.
[x]Based on a seasonal pumping requirements of 77 inches for seepage irrigation and 7.5 inches for drip irrigation.

the average for the two seasons of the observed water requirements for the two systems. This resulted in savings of $40 per acre in energy consumption due to reduced pumping requirements for the drip irrigated field (see Table 7). Therefore, lower pumping costs covered some of the additional fixed and variable costs of the drip irrigation system. The increase in total irrigation cost (excluding labor) was $136 per acre for the micro irrigation system. The high level of management required with drip irrigation may have economic significance.

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SILVER-LEAF OF SQUASH IN SOUTH FLORIDA

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Abstract. **A previously unrecognized disorder of squash (*Cucurbita pepo* L.) in Florida appeared in Palm Beach County during Sept. 1987. Mild symptoms included silvering along the main and secondary veins of the upper leaf surface resulting in an etched appearance. Severe foliar symptoms included complete silvering of the upper leaf surface. The lower leaf surface appeared normal. Additional symptoms include blanching of flowers and fruit of green cultivars (acorn and zucchini) and a scalding of the upper fruit surface of yellow cultivars. The most serious outbreaks have been in southern Palm Beach and northern Broward Counties. The condition has also been observed in Collier, Dade, DeSoto, Hendry, Monroe, and St. Lucie Counties. The condition developed within 24 hours in most fields indicating an episodic nature of the symptom development. Plants appeared to be more susceptible when they were growing luxuriantly and when they were under moisture stress.**

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The first observation of leaf silvering in a commercial squash planting in Florida was made during late Sept. 1987 in Palm Beach County. The squash was *Cucurbita pepo* L., cv. Multipik. The squash plants were initiating flowers and growing very luxuriantly 1 week prior to the expression of leaf silvering symptoms. There were no immidiate indications of any physiological disorder, insects, or diseases in the planting. Within a week after flower initiation, the grower indicated that the upper surface of leaves turned a silvery color. Nearly every upper leaf surface had a silvery color with an exception being where one leaf had overlaid another. The lower leaves had the silvering symptom only where the upper leaves were not overlapping each other. This pattern of injury first suggested the possibility of spray injury. The planting had been sprayed recently with a boron solution (1 lb. Solubor per 100 gal of water). The grower disagreed with the diagnosis of boron injury since the concentration of Solubor used had no adverse effects on many previously grown squash plants. Also, the pattern of silvering was too uniform within the field to be attributed to a toxic spray application since a uniform spray coverage with one application could not have been obtained. Two days after the initial leaf silvering symptoms, the grower reported that several volunteer squash plants in another area of the farm which had not been sprayed with any chemical also had severe leaf-silvering symptoms.

During the next 2 months, observations of leaf-silvering were made on commercial squash plantings in Palm Beach and Broward Counties. Commercial squash fields