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CLOGGING CHARACTERISTICS OF VARIOUS MICROSPRINKLER DESIGNS IN A MATURE CITRUS GROVE

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Abstract. **The clogging rates for 10 models of microirrigation emitters were observed over a 3.5-year period to determine if the emitter design could influence maintenance requirements. The emitters were located in a block of mature Temple orange trees on single beds with a 30 ft between-row x 23 ft within-row spacing. The irrigation system used a surface water supply with a 50 mesh screen as the primary filter. The experiment used 5 spray emitter models and 5 spinner models in a randomized complete block design with 5 replications. All emitters were on the same irrigtion zone, received water of the same quality, were irrigated at the same time and for the same duration. Emitters were examined twice per year, at which time the condition of each emitter was recorded. Clogging was generally caused by ants, spiders, or bacteria and algae. The average clogging rate per inspection period ranged from 2% to 38%, averaging 19%. The emitter design which used an enclosed cap to disperse water had the highest clogging percentage. The emitter which had a relatively large orifice and a mechanism to plug the orifice when not in use had the lowest clogging rate.**

The use of microirrigation in Florida agriculture has increased dramatically in recent years. Over 400,000 ac are now micro-irrigated in the state (3), with most of these systems associated with citrus production. Microirrigation emitters generally have operating pressures less than 30 psi, discharge rates from 5 to 25 gal h^{-1}, and throw diameters ranging from 5 to 30 ft (7). Growers can choose emitters from the many designs offered by manufacturers. Emitters vary in their performance under ideal conditions (1). Poor field performance can be caused by full or partial emitter clogging due to wind-blown particles, insect, biological growth, or chemical encrustation. Other major maintenance problems associated with the microsprinkler assemblies include dislodging of the emitter from the stake assembly and deterioration or destuction of the spaghetti tubing due to insects and rodents. These problems occur even with properly designed and maintained filtration systems.

Most recent microsprinkler field installations for citrus in Florida have used emitters discharging from 10 to 20 gal h^{-1} combined with stake assemblies and spaghetti tubing. One of the main factors that has caused growers to adopt microsprinkler systems has bee the demonstrated freeze protection that the systems provide for young trees (5). Over 80% of the citrus groves that utilize freeze-protection measures use irrigation for that purpose (4).

Many growers prefer spray or spinner emitters over drip systems because they provide a larger wetted area. The large pattern diameter is especially desirable in areas with coarse textured soils where lateral movement of soil water is limited. Stake assemblies raise the emitter 8 to 12 in above the ground and offer several advantages over emitters installed directly in the polyethylene (PE) lateral tubing or installed on risers plugged directly into the lateral. The stake assembly allows the emitter to remain in a fixed position when temperature extremes or other factors cause movement of the lateral tubing. Performance of the emitters is also enhanced since they stand on a firm base and do not rotate from vertical positions when the lateral tubing moves or twists. The added elevation can also increase the coverage diameter of many emitter models and allows water to be distributed above low-growing grass and weed species.

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The three main causes of emitter plugging are from physical particles, biological growths such as bacteria and algae, or from chemical reactions in the water causing scale buildup (6). Clogging is often caused by a combination of these factors. Unlike drip systems, which may have several outlets per tree, a microsprinkler that malfunctions results in a tree that receives little or no water. The economic impact resulting from crop stress and reduced fruit quality or yield due to a high percentage of malfunctioning emitters can be considerable.

This study was conducted to evaluate the maintenance problems associated with several different emitter designs under field conditions in a mature citrus grove. The primary goal was to determine if specific design characteristics could decrease the effort required to maintain the microirrigation system. This report concludes the study and summarizes results for the 3.5 years (1985 to 1990) of field observations on microirrigation emitter maintenance requirements.

Material and Methods

The experiment was conducted in a mature 'Temple' orange block in the Ft. Pierce Agricultural Research and Education Center (AREC) grove. The block consisted of 28 rows of trees, each row with 23 trees. The trees were planted in 1955 on single-row beds, with rows spaced 30 ft apart and a within-row spacing of 23 ft, resulting in a density of 63 trees ac^{-1}. The block encompassed an area of slightly more than 10 ac, with a total of 644 tree spaces. The trees had not been pruned to remove the skirts, and canopy diameters ranged from 16 to 23 ft.

The water supply for the irrigation system was an unlined combination supply and drainage canal managed by the North St. Lucie River Water Control District. An axial-flow pump was used to lift water from the supply canal to a center ditch in the grove. Once filled, the center ditch and a small connected pond provided enough storage to operate the microirrigation system for 8-10 hr. During wet periods, the outlet for the center ditch was opened for drainage.

A microirrigation system was installed in the block during the winter of 1987 as part of a system that serviced about 70 ac of grove at the AREC. The system was designed to allow simultaneous irrigation in any two of the eight blocks in the grove. The pump station was electrically powered and capable of discharging 500 gal min^{-1} at a pressure of 30 psi. The pump withdrew water from the center supply ditch through 40 ft of 6-in diameter canal strainer with 0.020 inch openings and 80 slots per ft.

The primary filter for the system was a 6-in diameter manual flush screen filter with a 50 mesh stainless screen. Pressure gauges on the filter inlet and outlet allowed monitoring of pressure drop through the filter. Chlorine injection to control biological growth was performed on an intermittent schedule, usually just prior to shutting the system down for extended periods. During 1989 and 1990, zones were also chlorinated on a once per month schedule during the spring irrigation season.

The pump discharged into a 6-in mainline that serviced the 8 blocks of citrus. Water delivery to each block was controlled with a 4-in butterfly valve. Pressure gauges at each block turnout allowed operators to regulate the zone pressure. The turnout for the 'Temple' block was located 700 ft downstream from the pump station. The submain servicing the block was buried along the east side of the block with pipe diameters ranging from 4 in down to 2.5 in. Risers from the submain to the ground surface were 18 to 30 in long and made of 1-in diameter flexible PVC. A slip X compression elbow on the riser was used to connect the 1-in polyethylene tubing. Laterals were 515 ft long, each lateral serving 23 trees. All emitters were on stake assemblies connected to the PE lateral with 24 in lengths of 4-mm diameter spaghetti tubing. Normally, the block was operated with 28 psi pressure at the zone turnout.

Table 1. Emitter specifications and characteristics.

ID No.	Manu- facturer	Model name	Base color	Orifice diam. (in)	Flow rate[z] (gal h^{-1})	Dispersal mechanism
1	Maxijet	360 x 12 Cap	green	0.040	18.0	cap
2	Plastro	Ray Jet Sprayer	green	0.067	16.9	vortex
3	Plastro	Mini-Sprinkler	green	0.067	18.0	spinner
4	Rain Bird	Micro bird Spinner	green	0.048	19.4	spinner
5	Hardie	Microsprinkler III	blue	0.079	35.9	spinner
6	Solcoor	Microsprayer	grey	0.044	17.2	deflector
7	Solcoor	Round Spinner	grey	0.044	17.2	spinner
8	Bowsmith	Fan Jet II	green	0.040	18.6	deflector
9	Irridelco	Fan Spray	green	0.050	20.5	deflector
10	Ein-Tal	L. P. Minisprinkler	black	0.050	16.0	spinner

[z]Manufacturer's specified emitter discharge rate at 25 psi operating pressure.

A total of 10 models of emitters (5 spinners and 5 sprays) were included in the experiment (Table 1). The spinners used a moving part which rotated to disperse the water stream. The spray emitters, which typically distribute water in distinct streams, had slotted caps, deflector plates, or a vortex action (Fig. 1). Half othe emitters were attached to the stake assembly with threaded connections (Nos. 1, 4, 5, 8, and 9), while the other emitters (2, 3, 6, 7, and 10) used a friction fit connection.

The emitters were installed in a randomized complete block design with 5 replications. Each replication contained

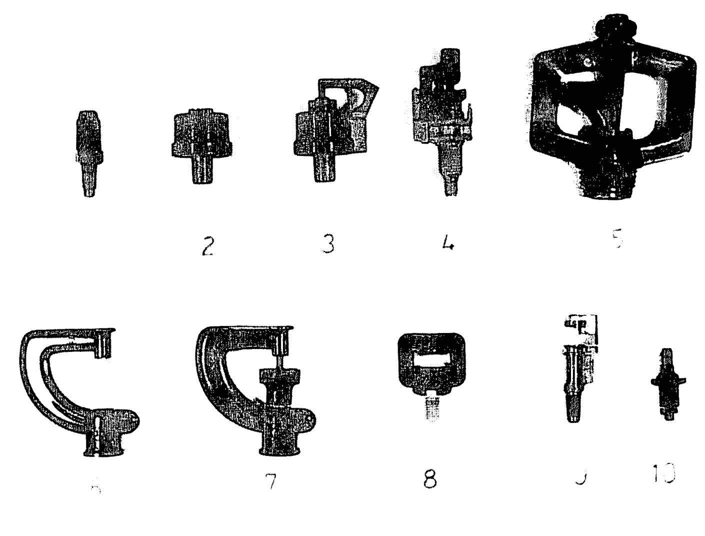

Fig. 1. The dispersal mechanisms of emitters used in experiment included: spinners (Nos. 3, 4, 5, 7, and 10), and spray emitters with cap (No. 1), with vortex (No. 2), and with deflector plates (Nos. 6, 8, and 9).

5 rows with 2 emitters models per row. Each plot consisted of 10 emitters of the same model. The first and last trees in each row served as buffer trees to eliminate the effects of edge exposure. Similarly, edge rows were excluded from the experiment.

The emitters were initially installed in April 1987. They were first examined for fouling in April 1988. At that time, all faulty emitters were cleaned or replaced. Subsequent inspections of all the emitters were made in October 1988, May and October 1989, and May and October 1990. During these inspections, problems with any of the emitters were noted and recorded. Emitter problems were either classified as fouled (full or partial clogging) or dislodged from the stake assembly. Any emitters that had problems were then cleaned or replaced.

During the course of the experiment, trees that died were replaced with resets. Since the resets provided less shade and a slightly different micro-environment, emitters on reset trees were excluded from the analysis. The percentage of the fouled emitters on mature trees were analyzed by ANOVA procedures.

Results and Discussion

The rainfall patterns during the summers of 1987, 1989, and 1990 supplied sufficient moisture so that irrigations were not required in these years during most of the period from July through October (Table 2). However, due to infrequent rains during the summer of 1988, irrigations were required in the summer months as well as during the winter and spring dry months. In the first survey period (4/87-4/88), 20 irrigations totaling 86 hours were made. The totals for subsequent periods were: 4/88-10/88, 8 irrigation events for 47 hours; 10/88-5/89, 15 irrigation events for 73 hours; 5/89-10/89, 11 irrigation events for 43 hours; 10/89-5/90, 12 irrigation events for 56 hours, and 5/90-10/90, 8 irrigations for a total of 51 hours.

With the exception of emitters 6 and 7, dislodging was a relatively insignificant problem (Table 3). Emitters usually can become dislodged from pressure surges when the later lines were filling or from knockdowns during picking or other cultural operations. Many growers feel that the friction fit attachment feature is desirable since it allows easy exchanges of problem emitters in the field. Friction fit emitters 2, 3, and 10 dislodged at the same rates as those with threaded connections. However, one or both of the other friction fit emitter models (6 and 7) were more often dislodged (p = 0.05) than the other models during all inspections except April 1988 and October 1989 (Table 3). Their average dislodging rates for the 6 inspection dates of 6.6% (No. 6) and 8.7% (No. 7) were significantly higher than the rates for all other other models.

Table 2. Monthly irrigations by number of events and total hours of operation from April 1987 to October 1990.

	1987		1988		1989		1990	
Month	(No.)	(hr)	(No.)	(hr)	(No.)	(hr)	(No.)	(hr)
Jan	–	–	0	0	3	14	1	5
Feb	–	–	2	10	4	14	2	6
Mar	–	–	0	0	2	10	1	5
Apr	3	12	2	8	3	12	3	21
May	3	15	4	23	4	15	5	29
Jun	9	14	0	0	4	16	2	13
Jul	2	9	0	0	0	0	1	9
Aug	0	0	1	5	0	0	0	0
Sep	0	0	1	8	0	0	0	0
Oct	0	0	3	19	0	0	0	0
Nov	0	0	1	3	1	3	–	–
Dec	1	4	4	18	4	16	–	–
Total	18	54	18	94	25	97	15	88

Orifice fouling was the most frequent maintenance problem encountered for most of the emitters. All models except No. 2 had fouling rates in excess of 10% for at least one of the inspections (Table 4). Fouling generally was caused by orifice blockage by ants and spiders or from biological growth in the orifice. The mean fouling percentage for the 6 inspection dates ranged from a low of about 2% for No. 3 to nearly 38% for No. 1, averaging 19.3% for all models combined (Fig. 2). The mean emitter fouling rates typically averaged about 2% greater than that reported after 2.5 years (2).

The emitters with the largest orifice openings generally had the least fouling (Fig. 3). Emitters 2 and 3, which had the lowest clogging percentages, had orifice areas 2 to 3 times greater than most of the other emitters. Emitter No. 5 was the exception. It had the largest orifice area, but had clogging rates similar to emitters with half the orifice area.

Emitter 1, which used a slotted cap to disperse water streams, had a significantly higher clogging percentage than the other emitters. The closed lower portion of the cap apparently provided a more favorable environment for

Table 3. Percent of emitters dislodged from stake assembly by emitter type and inspection date.

	Percent of emitters dislodged						
ID No.	Apr 1988	Oct 1988	May 1989	Oct 1989	May 1990	Oct 1990	Mean
1	0.0	0.0 a[z]	0.0 b	0.0	0.0 b	2.0 b	0.3 b
2	0.0	0.0 a	2.0 b	0.0	2.0 b	0.0 b	0.7 b
3	2.0	0.0 a	0.0 b	0.0	4.0 b	6.2 ab	2.0 b
4	0.0	0.0 a	0.0 b	0.0	0.0 b	12.2 a	2.0 b
5	0.0	0.0 a	2.2 b	0.0	2.0 b	0.0 b	0.7 b
6	0.0	10.2 b	16.4 a	0.0	6.2 b	6.4 ab	6.6 a
7	0.0	12.0 b	8.0 b	0.0	20.0 a	12.0 a	8.7 a
8	0.0	0.0 a	4.0 b	0.0	4.4 b	2.2 b	1.2 b
9	0.0	0.0 a	2.0 b	0.0	0.0 b	0.0 b	0.3 b
10	0.0	0.0 a	0.0 b	2.0	2.2 b	0.0 b	0.7 b
mean	0.2	2.2	3.5	0.2	4.1	4.1	2.4

[z]Means within columns followed by the same letter are not significantly different (P = 0.05) according to the Duncan's Multiple Range Test (n = 50).

Table 4. Percent of emitters fouled by emitter type and inspection date.

ID No.	Percent of emitters dislodged						
	Apr 1988	Oct 1988	May 1989	Oct 1989	May 1990	Oct 1990	Mean
1	36.0 a[z]	38.0 a	40.0 a	50.0 a	40.0 ab	22.0 a	37.7 a
2	16.4 c	8.2 bc	6.0 de	16.2 cd	6.0 c	4.0 ab	9.5 de
3	4.0 de	2.0 c	0.0 e	2.0 d	6.6 c	0.0 b	2.4 e
4	0.0 e	18.9 b	28.7 abc	46.0 a	28.4 abc	16.4 ab	23.1 bc
5	22.9 bc	10.4 bc	8.7 cde	27.3 bc	14.4 bc	20.2 ab	17.3 bcd
6	18.4 bc	16.4 b	32.9 ab	12.0 cd	18.2 abc	12.2 ab	18.4 bcd
7	38.0 a	12.0 bc	32.0 ab	40.0 ab	12.0 c	24.0 a	26.3 b
8	22.9 bc	8.2 bc	12.4 bcde	27.3 bc	32.0 abc	16.9 ab	20.0 bc
9	14.7 cd	10.0 bc	26.9 abcd	26.9 bc	42.7 ab	18.2 ab	23.2 bc
10	29.1 ab	14.7 bc	12.7 bcde	2.2 d	18.0 abc	10.7 ab	14.6 cd
mean	20.2	13.9	20.0	25.0	21.8	14.5	19.3

[z]Means within columns followed by the same letter are not significantly different (p = 0.05) according to the Duncan's Multiple Range Test (n = 50).

ants and spiders than the open-style designs. It was also more prone to trap particles than the other designs due to the closed sides. In contrast, the spinning mechanism on emitter 2, which slides up the shaft during operation and drops down over the orifice when the water pressure drops, resulted in a low clogging rate (averaging 2.4%).

It was apparent that emitter design and operation conditions could influence maintenance requirements. Shielding the orifice when the emitter is not in use appears to be an effective method of reducing clogging problems. The shielded orifice prevents the entry of ants and spiders and makes the emitter less susceptible to malfunctioning due to windblown particles of sand. In addition, the shielded orifice excludes sunlight, necessary for the growth of most algae species, from entring the internal areas of the emitter. Larger diameter orifices were more effective in flushing out particles, insects, or algae than smaller orifices.

Designs which incorporate shielded orifices with relatively large orifice diameters and which also provide secure attachment of the emitter to the stake assembly should reduce maintenance requirements. These results were obtained from a surface water source in combination with a screen primary filter. Chemical encrustations, which are more common to groundwater systems, were not encountered. Proper system filtration, flushing, chlorination, and operation procedures should be followed to minimize maintenance problems, regardless of the emitter design and water source.

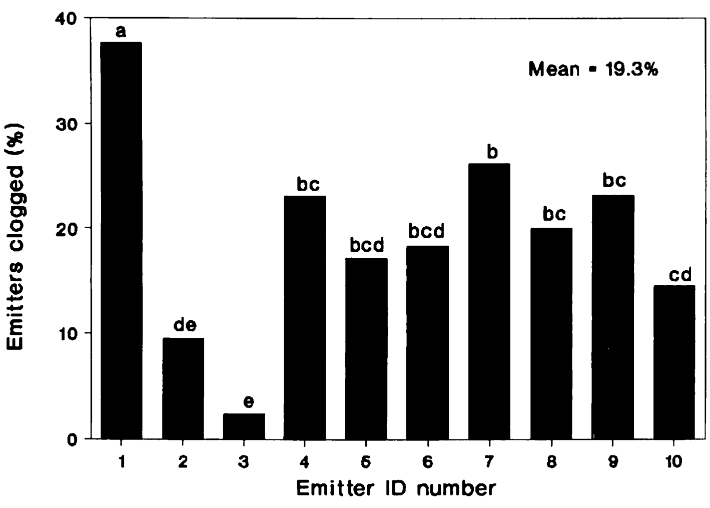

Fig. 2. Mean clogging rate by emitter for the 6 inspection dates. Means between emitters with the same letter above the bar are not significantly different (p = 0.05) according to the Duncan's Multiple Range Test.

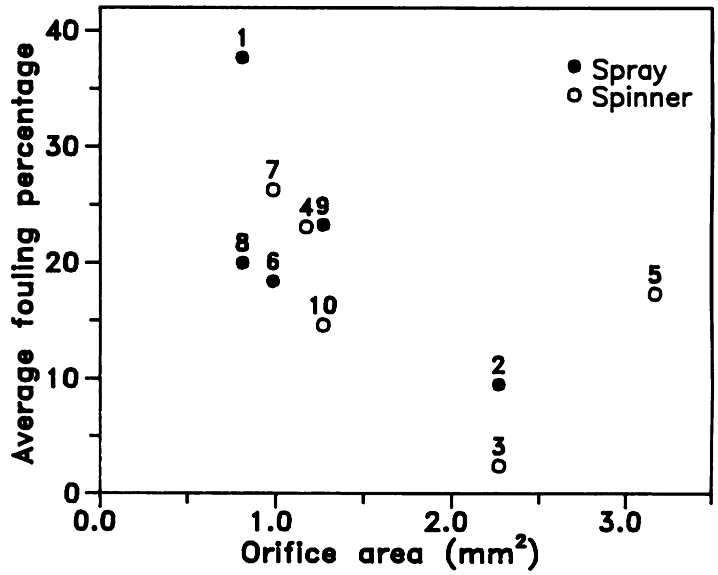

Fig. 3. Mean clogging percentage relative to orifice area for spinner and spray emitters.

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