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CLOGGING OF TRICKLE IRRIGATION EMITTERS UNDER FIELD CONDITIONS[1]

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Abstract. **Monthly clogging percentages were measured during a 5-yr study of trickle irrigation of citrus. Clogging percentages were found to be much greater for drip emitters as compared to spray-jets. Most drip emitters were clogged by iron deposits whereas most spray-jets were clogged by insects. Drip emitters clogged much more frequently during low-use winter months as compared to high-use summer months. Clogging percentages also increased annually, from 2.5% in 1979 to 21.3% in 1983. Clogging percentages of spray-jets were low (<2.5%) and unaffected by time or season throughout this study. Two types of electromagnetic water treatment units evaluated had no effect on emitter clogging percentages during the course of this study.**

Trickle irrigation systems have become increasingly popular for citrus irrigation in Florida, for at least three reasons: 1) yield increases have been demonstrated as compared to nonirrigated trees (17); 2) they are less costly as compared to conventional irrigation systems (14); and 3) spray-jet systems have been shown to provide a measure of protection for citrus when operated under freezing conditions (4, 15, 23, 24, 25).

Clogging of emitters has been and continues to be a major problem with the use of trickle irrigation systems (1, 16), especially when fertilizers are applied through the system (18), or when poor quality water is used in trickle irrigation (22). This problem is not unique in Florida. Rather it is a universal characteristic of trickle system applications (13, 20, 26). However, the more difficult problems with trickle emitter clogging in Florida have been those associated with biological growths, especially in the presence of iron and sulfur in water supplies (1, 7, 8, 9, 12, 16).

Emitter clogging affects the uniformity of water application with trickle irrigation systems. Although proper system design can help to compensate for some of the effects of emitter clogging (2, 3) uniformity of water application is greatly reduced when only 1%-5% of the emitters are clogged with 2-8 emitters per plant (21). Uniformity would be even further reduced if only one emitter was used per tree. The effect of nonuniformity on production would be greater if fertilizer was being injected through the system.

Reclaiming of clogged or partially clogged emitters is a difficult and expensive process (19). Therefore clogging problems should be addressed from a preventative point of view, rather than from the point of view of reclaiming systems which are already clogged. Ford (5) stated that sodium hypochlorite in water will form a powerful oxidizing agent which can be effective in preventing sludge and slime formations in trickle irrigation systems. He also presented a method for estimating chlorination requirements and procedures for using a test kit to evaluate the effectiveness of chlorination (6, 10, 11).

Clogging problems are at least partially dependent upon the type of emitters used. Koo (18) found that drip emitters were clogged approximately 5 times as often as spray-jet emitters. Nakayama et al. (20), studied the effects of time on emitter clogging when systems were subject to various water treatments. No known research has been conducted on the effects of different types of emitters and time of year on emitter clogging under citrus field conditions in Florida. Therefore, this was a primary objective of this research.

A second objective of this research was to determine the effectiveness of two types of electromagnetic water treatment units on emitter clogging. These types of water treatment units have previously been found to be effective for the prevention and removal of scale and precipitates from pipes and vessels in such applications as boilers and cooling towers for large air conditioning systems.

Materials and Methods

Research site. This research was conducted at the IFAS Lake Alfred Citrus Research and Education Center, where an irrigation and fertigation study of citrus was conducted during the past 5 yr. Fifteen yr-old 'Valencia' orange trees (*Citrus sinensis* (L.) Osb.) were irrigated with 2 types of trickle irrigation systems, 1-gal/hr drip emitters and 10-gal/hr spray-jet emitters. Drip treatments included 2 and 4 emitters per tree, and spray-jet treatments included 1 and 2 spray-jets per tree. Mature trees spaced 15 ft x 30 ft were produced on Astatula Fine Sand.

The irrigation water supply system consisted of a submersible pump and a 4-inch well. The pump operated automatically to maintain pressure in a 250 gal airless bag pressure tank. During trickle irrigation, water was used from the tank to prevent frequent cycling of the pump.

Water was filtered for use in the trickle irrigation systems. An 80-mesh screen filter and two parallel 10 μm paper cartridge filters were used on the mainline downstream from the pressure tank. This degree of filtration exceeded the requirements of the emitters used in order to assure that clogging would not occur from particulate matter from the water source.

Both the 1-gal/hr drip emitters and the 10-gal/hr spray-jets were operated at 10 psi water pressure. The minimum orifice diameter was 0.024 inches for the drip emitters. The spray-jets had orifice diameters of 0.05 inches.

Research treatments. Irrigation treatments included both timer and tensiometer-controlled water applications. Fertigation treatments included monthly injections of solutions of ammonium nitrate and potassium sulfate. Concentrations were calculated so that annual amounts of N-P_2O_5-K_2O injected were 50-0-50 and 25-0-25 lb. Also, one-third of the trees were non-fertigated controls. For control trees all fertilizer was applied twice annually using conventional (granular application) methods.

The emitter clogging data reported *in this paper* were composites from all of the irrigation and fertigation research

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treatments. No attempts were made to study clogging as a function of specific irrigation or fertigation treatments.

Evaluation of emitter clogging. Clogged emitters were counted monthly as part of normal maintenance of the irrigation system. That maintenance consisted of the following procedures. First, all of the irrigation systems were turned on and injected with chlorine (liquid sodium hypochlorite). The solution concentration was 10 ppm chlorine in the mainline near the injector pump.

While chlorine was being injected, each of the emitters was visually inspected. Clogged emitters were cleaned or replaced, and counted. Lateral lines were flushed when emitters were cleaned. Chlorine injection was continued until all emitters were inspected and functioning properly. Then chlorination was discontinued and fertilizer solutions were injected. When fertilizer injections were complete, chlorine injections were reinitiated. Chlorine injections continued for one-half hour after all of the fertilizer solution had been purged from the irrigation system. The irrigation system was then shut off, and the chlorine solution was allowed to remain in the system until the next scheduled irrigation.

Emitter clogging percentages were calculated on a monthly basis as the ratios of the number of clogged emitters to the total number of emitters of each type. In our research plots there were a total of 216 drip emitters and 72 spray-jet emitters.

Water quality. Because water quality affects emitter clogging, water quality samples from the irrigation water supply system were analyzed. Samples were taken downstream from the pressure tank and upstream from the filter system. There was little variation among water quality parameters for six samples analyzed. Table 1 presents averages of the water quality parameters analyzed. Most notable of these is iron, which was high at 0.2 ppm.

Table 1. Analysis of irrigation water quality.

Iron	= 0.2 ppm	Chlorine	= Trace
Magnesium	= 6 ppm	Hardness	= 97 ppm
Calcium	= 30 ppm	Soluble Salts	= 133 ppm
Soduim	= 3 ppm	pH	= 7.9
Na_2SO_3	= Trace	H_2S	= 0.12 ppm

Electromagnetic water treatment units. Two different types of electromagnetic water treatment units were installed on the water supply at different times to determine if they would be effective in reducing emitter clogging. These units both operated on the same basic principles. They induced a magnetic field through which the water flow was directed. For one unit, the magnetic field was parallel to the direction of flow. For the other, the magnetic field was perpendicular. Also, the second unit used an impeller to create additional turbulence as the water flowed through the magnetic field.

Electromagnetic water treatment units of this type have been used successfully for water treatment in boilers and cooling towers where excessive scale buildup reduces the efficiency of those facilities. In those applications, the induced electromagnetic fields have caused a reduction or a complete elimination of scale formation, and thus have reduced labor costs for cleaning.

The first electromagnetic water treatment unit studied was installed in June, 1982. It was located between the irrigation system pressure tank and the filter system. In January, 1983, it was moved to a position downstream from the filter system to study its effectiveness in that position. In May, 1983, it was removed from the irrigation system, and the second electromagnetic unit was installed. The second unit was installed upstream from the pressure tank. It remained in that position through October, 1983. All trickle irrigation water pumped was directed through the electromagnetic treatment units while they were in operation.

Both electromagnetic water treatment units were installed with the advice and instruction from the manufacturers' representatives. Both installations were inspected by the manufacturers' representatives. Only the second unit required routine maintenance and service. Service procedures as given in the manufacturer's literature were followed. Basically, this consisted of cleaning and inspection on a monthly basis.

Results and Discussion

Monthly emitter clogging percentages observed during the 5-yr period, 1979-1983, are shown in Fig. 1-5. There was considerable variation from month to month, especially in the later years of this study as clogging percentages increased. In 1979, clogging percentages were low (below 5%) and approximately equal for both the drip and spray-jet emitters. In 1980 and later years, clogging percentages increased for the drip emitters, while they remained relatively low for the spray-jets.

Part of the month-to-month variability probably occurred because of the method of data collection. Emitters were classified as either clogged or not clogged for our recording purposes. In practice, however, we sometimes cleaned emitters which were only partially clogged. Spe-

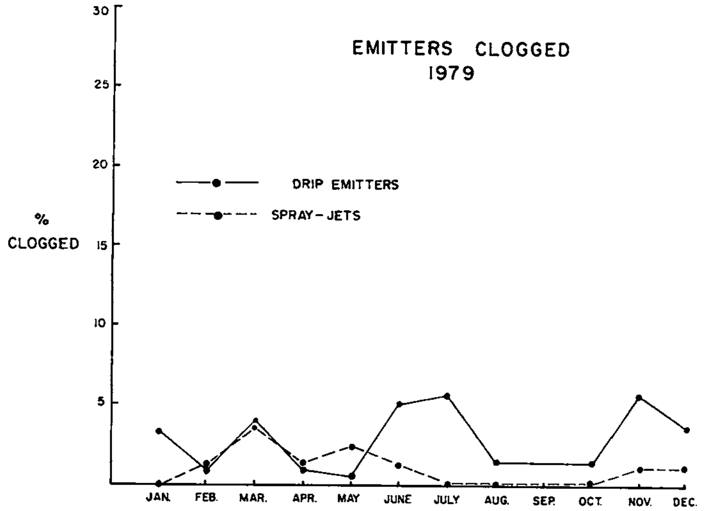

Fig. 1. Monthly average emitter clogging percentages, 1979.

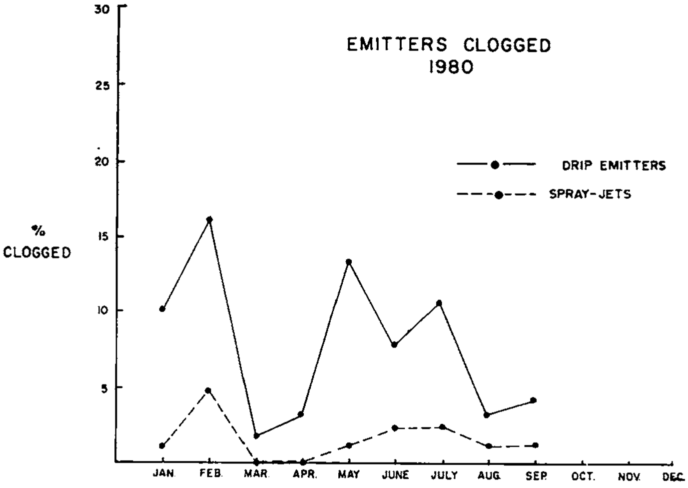

Fig. 2. Monthly average emitter clogging percentages, 1980.

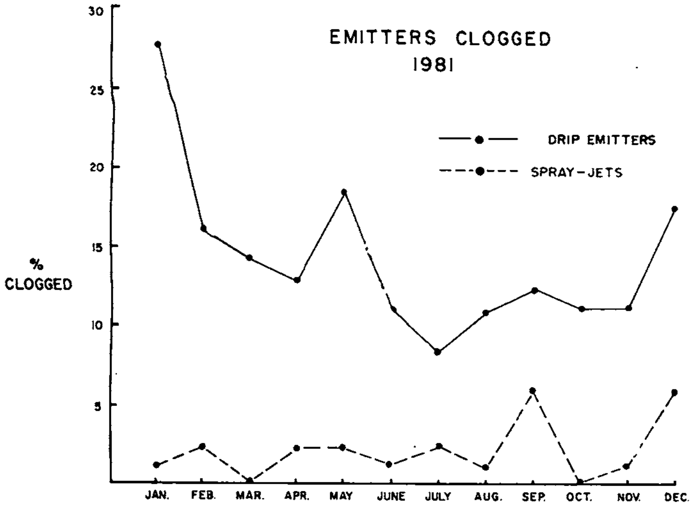

Fig. 3. Monthly average emitter clogging percentages, 1981.

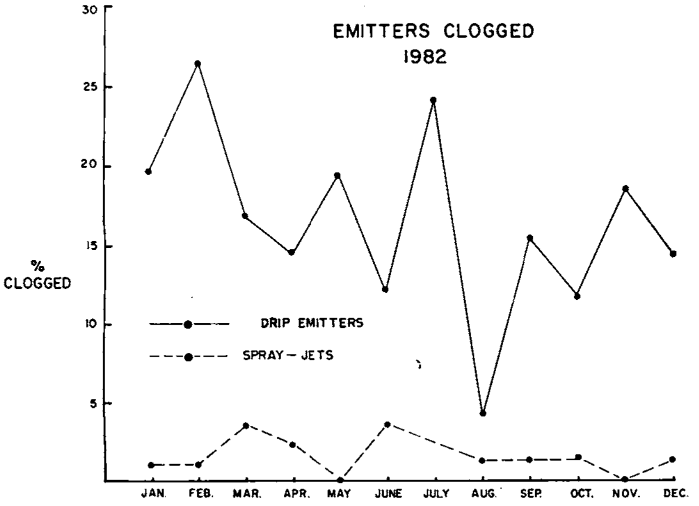

Fig. 4. Monthly average emitter clogging percentages, 1982.

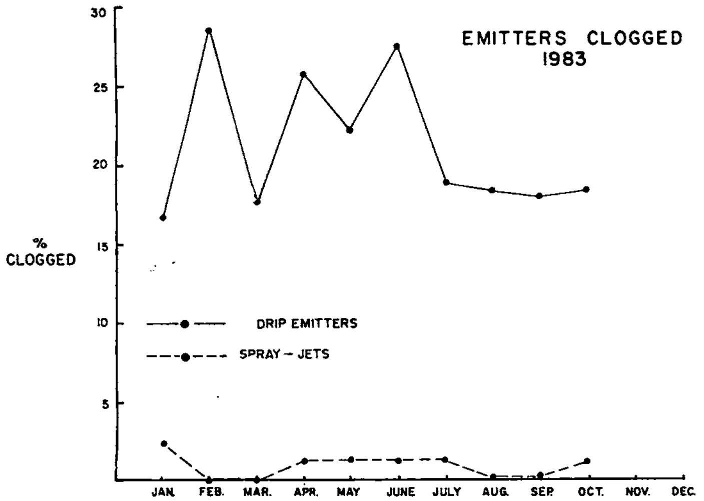

Fig. 5. Monthly average emitter clogging percentages, 1983.

cifically, emitters were cleaned if their flows had been reduced to only a small fraction of the normal flow as determined by visual inspection. Some variability in our data probably occurred because of individual decision-making concerning whether or not an emitter's flow rate was sufficiently clogged that it should be cleaned and classified as clogged. Some variability was also undoubtedly due to the random nature of the clogging process.

To smooth some of the variability in our monthly data, data were averaged on a seasonal and on an *annual basis.* Seasonal emitter clogging percentages are presented in Fig. 6. When averaged in this manner, variability was greatly reduced, and very definite patterns emerged with respect to clogging of drip emitters. From Fig. 6, drip emitter clogging percentages were greatest during winter months. They were lowest during summer months. This pattern correlated well with time of operation of those systems. The drip systems were all operated daily. However, they were operated either in proportion to long-term pan evaporation data or in response to tensiometer controls. Therefore, drip systems were operated many more hours per day during the summer months as compared to the winter months, and the longer periods of operation of the systems during the summer months are postulated as the reason for the fewer emitters clogged during those months. From Fig. 6, spray-jet clogging percentages were small and fairly constant throughout this study. The maximum monthly value recorded was 2.8% and the 5-yr average value was 1.7%.

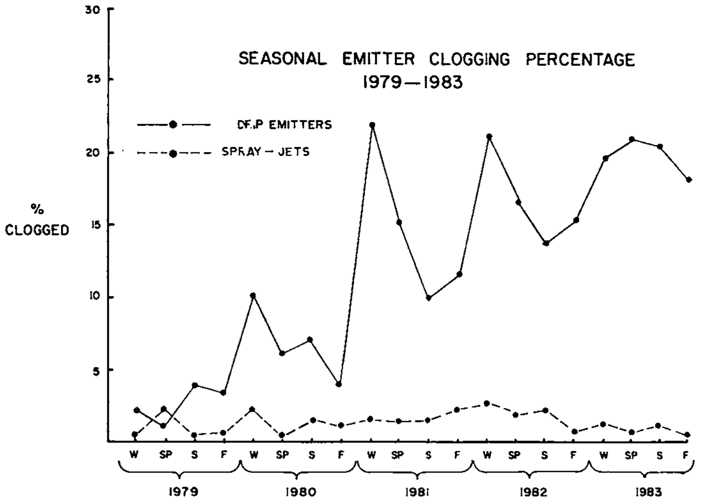

Fig. 6. Seasonal averages of monthly emitter clogging percentages. W = winter; SP = spring; S = summer; F = fall.

A general continuous increase in clogging percentage also occurred with time from 1979 to 1983. This trend is even more apparent in Fig. 7, where annual summaries of monthly clogging percentages are shown. As shown in Fig. 7, there was an almost linear increase in clogging percentage from about 2.5% in 1979 to 21.3% in 1983. During this same time period, the spray-jet clogging percentages remained almost constant at approximately 1.7%.

The causes of clogging were different for the drip and spray-jet emitters. The drip emitters were clogged almost exclusively by iron deposits and slime or sludges formed as a result of iron bacteria. The spray-jet emitters were primarily clogged by small insects, including ants and small wasps which entered the emitters and then became lodged as the irrigation system was operated, and by spiders which deposited egg sacs in the risers of the spray-jets.

The reasons that the spray-jets were not as readily clogged by iron deposits is thought to be the result of at least two factors. First, the spray-jet orifice size used was considerably larger (0.05 inch diameter) than the drip emitter orifice size (0.024 inch diameter). We believe this factor allowed non-rigid masses such as slimes and sludges to be more easily discharged without clogging the spray-jets. Second, the spray-jets were more quickly drained after each irrigation, thus allowing less resident time for the growth

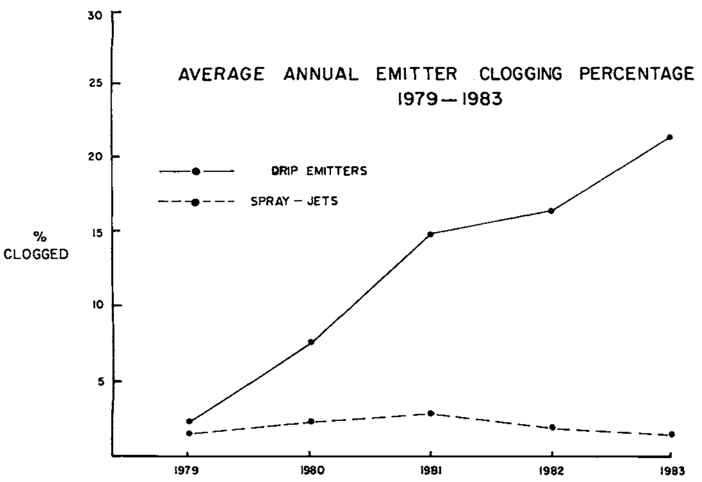

Fig. 7. Annual averages of monthly emitter clogging percentages.

of bacteria or for solids deposition by evaporation directly from the emitter. This was aided by the fact that spray-jets were mounted above ground level on 8-inch vertical risers, whereas the drip emitters were directly connected to lateral pipes, and were placed directly on the soil surface.

From Fig. 7, average annual emitter clogging percentages increased for the duration of this study. This was probably due to a buildup of iron deposits on the walls of pipes. When these deposits become dislodged, they are evidently of sufficient size that they clog the drip emitters, but not the spray-jets. This conclusion was supported by the fact that iron deposits were discharged from the lateral pipes whenever the pipes were flushed as the emitters were cleaned.

From Fig. 6 and 7, it can be seen that the use of the electromagnetic water treatment units had no effect on emitter clogging. After operation of the irrigation system since 1978, the electromagnetic units were installed beginning in June, 1982, and remained in operation through October, 1983. From 1982 through 1983, there were no appreciable changes in the long-term patterns of emitter clogging that had previously been established.

The normal seasonal patterns of emitter clogging demonstrate the need for long-term evaluation of instrumentation of this type. Short-term evaluations may be misleading because of fluctuations in emitter clogging that may occur for other reasons.

In summary, monthly emitter clogging percentages of 1-gal/hr drip and 10-gal/hr spray-jet emitters were measured during a 5-yr study of trickle irrigation of citrus. Clogging percentages were found to be much greater for the drip emitters as compared to the spray-jets. The mechanisms of clogging were also different. Most of the drip emitters were clogged by iron deposits from precipitates or bacterial action. Most of the spray-jets were clogged by insects or spiders becoming lodged in the emitters. The lower incidence of clogging of spray-jets by iron deposits was apparently due to their larger orifice diameters and the more rapid drainage of water from them after each irrigation.

Definite seasonal patterns and long-term trends in drip emitter clogging were observed. Drip emitters clogged much less frequently during summer months as compared to winter months. This observation correlated well with hours of operation of the irrigation system. Clogging percentages of drip emitters also increased annually, from 2.5% in 1979 to 21.3% in 1983. Clogging percentages of spray-jets were relatively unaffected by time or season. They remained constant at about 1.7% throughout this study.

Two types of electromagnetic water treatment units were evaluated in this research. These units were tested for 17 months in 1982 and 1983. They were installed at our field research site and operated in accordance with manufacturer's specifications in an attempt to reduce emitter clogging. The electromagnetic water treatment units evaluated had no observable effect on emitter clogging percentages during the course of this study.

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TIMING OF SPRAY TREATMENTS FOR CITRUS GREASY SPOT CONTROL[1]

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Abstract. **Spray-timing experiments on grapefruit trees for the control of greasy spot, caused by** Mycosphaerella citri **Whiteside, showed that a single copper fungicide treatment was more effective when applied in the summer than in April or May. Only in some years did a copper spray in June or August control the disease as well as one applied in July. Even in 1982, when the greatest monthly release of ascospores was in April, 2 months ahead of normal, a single spray treatment in July of 0.5% oil plus 0.4 lb. copper/100 gal, controlled greasy spot as well as a 2-spray program consisting of 0.8 lb. copper/100 gal postbloom followed by a 1% oil in July. With oil, time of spraying from April to August had little or no effect on levels of greasy spot control obtained on leaves of the spring growth flush. Oil, unlike copper, often gave no control of greasy spot rind blotch and in some years it was much less effective than copper for greasy spot control on leaves. The results are discussed in relation to the behavior of the greasy spot pathogen and the action of the spray materials.**

In Florida, the number of spray treatments used to control greasy spot, caused by *Mycosphaerella citri,* is economically limited. Many citrus growers apply only an oil spray in the summer to control this disease. Copper fungicides are more reliable than oil for greasy spot control (7), but are normally used only if heavy disease pressure is expected.

Some citrus groves receive a copper fungicide spray postbloom (April or May) for the control of melanose, caused by *Diaporthe citri* Wolf, if the crop is intended for the fresh market. In the past, when most of citrus in Florida was marketed fresh, nearly all groves received a copper spray postbloom. This practice continues in many groves grown solely for processing in the belief that copper sprays so-timed help to control greasy spot. Thompson et al. (4) reported that a postbloom copper treatment sometimes protected the leaves from greasy spot. Griffiths (2), Cohen (1) and Whiteside (5) obtained better control of greasy spot with copper sprays applied in June or July than with those applied in May or August. Clearly, more study was required to determine to what extent greasy spot control might be sacrificed by eliminating a postbloom copper spray.

This paper summarizes data from spray-timing experiments on 'Marsh' grapefruit (*Citrus paradisi* Macf.) trees with copper fungicide and spray oil. Also, these studies were designed to develop a more reliable recommendation for the control of greasy spot rind blotch (GSRB), which is a major problem on grapefruit for the fresh market. More comprehensive reports of some of the experiments described here have been published (9, 10).

Materials and Methods

Experimental designs. Experiments 1, 2, 3, 5, and 6 were conducted in a 'Marsh' grapefruit grove at the Citrus Research and Education Center, Lake Alfred. The trees were 10 to 12 ft high and spaced 25 x 15 ft. The spray treatments were applied by handgun, using 8 gal/tree, to single-tree plots replicated 6 or 8 times in a randomized complete block design. Experiment 4 was conducted in an older 'Marsh' grapefruit grove about 2 miles from the other location. In this grove, the trees were 20 ft high and spaced 30 x 25 ft, and the spray treatments were applied by handgun at 15 gal/tree to 4- tree plots replicated 6 times in a randomized complete block design.

The spray materials used were basic copper sulfate, 53% Cu (Tribasic copper sulfate, Cities Service Co., Atlanta, GA 30302) and spray oil (Sunspray 7E, Sun Oil Co., Philadelphia, PA 19103), containing 99% refined petroleum distillate and meeting FC435-66 specifications (3). The only other material sprayed on the trees during the tests was ethion, which was applied separately from other treatments and up to 3 times a year to control rust mites.

Disease assessments. The severity of greasy spot on leaves was based on the amount of defoliation caused by the disease or, when the defoliation on untreated trees was less than 5%, on the number of leaves with disease symptoms. In the latter instance, any missing leaves were assumed to have abscised because of greasy spot and were added to the count of diseased leaves.

Assessments of disease severity were confined to the current year's spring growth flush. Shortly after this growth flush had expanded, the shoots to be sampled were labeled with white plastic tags, in groups of 10, at 4 locations arranged equidistantly around the canopy, at the same compass points on each tree. The total number of leaves on each shoot was then recorded.

In all experiments except Experiment 5, the greasy spot severity assessments were made in late February or March, just as the new spring growth flush was beginning to emerge. In Experiment 5, the assessment was made immediately after the freeze of January 12-14, 1981, before freeze-induced leaf drop began.

To determine greasy spot severity on fruit, about 150 fruit were picked randomly from each tree. After washing, the rind on each fruit was examined for the presence or absence of GSRB.

Spore trapping. A Kramer-Collins 7-Day Drum Spore Sampler was operated continuously from *April 1 to September 30* each year in the grove where all experiments except

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