average minimum temperature in the mechanically tilled block was 29.4°F and in the herbicide-treated block 30.1°F. The severe freezes of 1970 and 1971 resulted in striking differences in tree damage. Foliage kill was 27 percent less in the herbicide block than in the tilled block. This reduced freeze injury was related to larger tree size, greater vigor, soil condition prior to the freeze, and slightly higher soil temperatures. Two years after the freezes the canopy area of trees in the herbicide block was nearly twice that of those in the tilled block. The herbicide block produced 83 lb./acre of solids more than the tilled block the first year after the freeze and 256 lb./acre solids more the second year.

Periodic freezes since, although not as severe, have continued to contribute partially to tree size and yield differences between blocks.

Before chemical nontillage weed control programs can be recommended under certain Florida citrus grove conditions, we must determine: 1) the moderating effects of weeds on the microenvironment and their possible role in determining the diversity and stability on insect populations and disease organisms in their ecosystem, 2) the degree to which the beneficial contributions of weeds *to pest problems* in citrus crop management systems compensate for their considerable competitive and other undesirable effects, and 3) the influence of declining organic matter levels on tree growth, mineral nutrition and microbial populations.

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RESULTS OF CITRUS FERTIGATION STUDIES[1]

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Abstract. **Fertilization of citrus through low volume and sprinkler irrigation systems was examined. No difference in the mineral contents of leaves, fruit quality and fruit production was found between dry fertilization applied in the conventional manner and liquid fertilization through permanent overhead sprinkler systems. Comparisons of liquid fertilization through low volume irrigation systems and dry fertilization revealed results ranging from no difference to substantial differences. Absorption of nutrients by the trees from fertigation through low volume irrigation systems was influenced by the extent of ground coverage. The feasibility of fertigation in citrus with certain precautions concerning these operations is discussed.**

Recent advances in agrotechnology make it possible to apply fertilizer materials through the irrigation systems, a practice referred to as fertigation (1, 2, 4, 5, 6). This practice has several advantages including: 1) savings in cost of fertilizer application and labor; 2) fertilizer elements are already in solution and become available to plant roots more quickly than dry materials placed on soil surface; and 3) the high flexibility in irrigation timing makes it easier to schedule fertilization. Possible disadvantages to fertigation are: 1) poor results with improperly designed irrigation systems which will not give satisfactory coverage of fertilizer materials. This is especially true with drip and other low volume irrigation systems where only a portion of ground is irrigated; and 2) inability to always use the least expensive materials in fertigation. This paper reports findings of fertigation experiments conducted with both low volume irrigation and permanent overhead sprinkler irrigation systems.

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Materials and Methods

The low volume fertigation study was conducted in a bearing 'Valencia' orange block planted in 1963 at the Davenport grove of AREC, Lake Alfred. The experiment which involved both timing and methods of application had 12 treatments arranged in a 3 x 4 factorial design with dry fertilizer applied twice a year and liquid fertilizers 3 and 10 times a year. Application methods included drip irrigation with 2 and 4 drippers per tree and under tree sprays with 1 and 2 jets per tree. Each treatment was replicated 4 times in randomized 6 tree plots making a total of 48 plots in the experiment. There were no guard trees between plots. A venturi suction device was used to incorporate the fertilizers. The irrigation operating pressure was maintained at 25 psi which discharged 16.5 gal from the dripper per hour.

Fertigation through sprinkler irrigation systems was conducted in 3 groves in Lake, Hillsborough and Highland counties. These groves varied from 10 to 25 acres and all have permanent overhead irrigation systems discharging water at .12 to .15 inches per hour between 60 to 80 psi operating pressure. In each grove one-half of the block was fertilized with conventional dry fertilizer and the other half fertilized through the irrigation systems. The fertigation cycle usually required 6 to 8 hr with 1 hr to wet the trees, 1 hr to inject the fertilizer, and 4 to 6 hr to rinse the fertilizer from the tree foliage. The quantities and formulations of the dry fertilizer used in different groves varied with cooperator's preferences. It was not always possible to match the liquid and the dry fertilizers with the same formulation, but the trees were fertilized with the same quantities of plant nutrients in both the liquid and dry fertilizers.

Experimental blocks are described in Table 1. Leaf and fruit samples were collected annually and analyzed to measure treatment effects. Fruit production data were collected from grove A and D. Data from the low volume fertigation study (grove A) were analyzed. Data from the sprinkler-fertilization studies were compared but not analyzed because they were side by side demonstration tests and not replicated.

Table 1. Treatments, locations and cultivars of groves used in fertigation studies.

Irrigation system grove	Low volume Drip & jet A	High volume Permanent overhead sprinkler B	C	D
Location	Polk	Lake	Hillsborough	Highlands
Soil series	Astatula	Eustis	Tavares	Paola
Cultivar	Valencia orange	Pineapple orange	Ruby Red grapefruit	Hamlin orange
Rootstock	R. lemon	S. orange	R. lemon	R. lemon
Spacing (ft.)	25 x 25	25 x 25	20 x 25	15 x 30
Fertilization (lb/A/yr)				
N	160	240	160	225
P	17	0	35	33
K	133	124	133	187
Mg	48	0	48	66
Application/ yr.	3 & 10	3	2	3

Compounds used: ammonium nitrate (21% N), urea-ammonium nitrate (32% N), phosphoric acid (23% P), polyphosphate (10-15-0), muriate of potash (50 K), potassium sulphate (42% K), potassium nitrate (13-0-37), calcined kisserite (20% Mg), magnesium nitrate (7-0-0-7), complete solutions: 10-4-8, 15-2-4 and 9-8-8.

Results

Leaf Analysis. The mineral composition of leaves shown in Table 2 was used to evaluate the treatment effects of fertigation. In overhead sprinkler irrigation studies very little difference was found between leaves from trees that were fertilized with dry fertilizer in the conventional manner and liquid fertilizer through the irrigation systems. This was expected because both methods of applying fertilizer covered essentially similar ground area. Differences in the leaf N content found in groves B, C and D reflected different quantities of N used in the fertilizer programs of these groves (Table 1).

In low volume fertigation no difference in the mineral composition of leaves was found the first year except for Ca and Mg. Presumably trees were still receiving residual nutrients from previous fertilizations. Differences due to fertigation treatments were observed for N, P and Mg contents the second and third years. Trees receiving liquid fertilizer had higher leaf P and lower leaf Mg than trees receiving dry fertilizer. Leaf N was influenced more by methods of irrigation than forms of fertilizer. Significant interactions were found between fertilization and irrigation treatments in leaf N.

To explain the fertilization-irrigation interactions, leaf N was catagorized by year, type of irrigation and fertilization (Table 3). No difference in leaf N content was found the first year, but trends were observed the second and third year. Leaf N was influenced by the extent of ground coverage of irrigation treatments. Ground coverage by irri-

Table 3. Influence of fertigation x irrigation interaction on leaf N content.

Year	Irrigation	Fertilization Dry	L-3	L-10	Fert. x Irrig. interaction[y]
		%	%	%	
1st	2 emitters	2.43	2.41	2.51	
	4 emitters	2.51	2.44	2.52	
	1 jet	2.45	2.57	2.50	
	2 jets	2.40	2.54	2.54	ns
2nd	2 emitters	2.48	2.37	2.32	
	4 emitters	2.47	2.49	2.52	
	1 jet	2.36	2.61	2.59	
	2 jets	2.41	2.65	2.58	**
3rd	2 emitters	2.65	2.46	2.36	
	4 emitters	2.65	2.47	2.41	
	1 jet	2.58	2.72	2.51	
	2 jets	2.50	2.76	2.66	**

[y]Significant: ns—not significant; *—significant at 5% level; **—significant at 1% level.

Table 2. Effects of fertigation on mineral composition of leaves.

Element	Year	Low volume irrigation (Grove A) Fertilization[z, x] Dry	L-3	L-10	Irrigation[y, x] E-2	E-4	J-1	J-2	Sprinkler irrigation Grove B Liquid	Grove B Dry	Grove C Liquid	Grove C Dry	Grove D Liquid	Grove D Dry
N	1st	2.45	2.49	2.50	2.45	2.49	2.51	2.48	3.22	3.23	2.66	2.63	2.90	2.99
	2nd	2.43	2.50	2.51	2.39b	2.49a	2.52a	2.50a	3.08	3.10	2.63	2.78	2.99	3.02
	3rd	2.60a	2.61a	2.47b	2.48b	2.51b	2.61ab	2.65a	—	—	—	—	2.86	2.99
P	1st	.12	.12	.12	.12	.12	.12	.12	.15	.14	.17	.17	.15	.15
	2nd	.13b	.14a	.14a	.14	.15	.14	.14	.16	.15	.12	.12	.15	.15
	3rd	.11b	.13a	.13a	.13	.13	.13	.13	—	—	—	—	.16	.16
K	1st	1.12	1.07	1.03	1.10	1.13	1.02	1.05	1.65	1.73	1.71	1.68	1.31	1.54
	2nd	1.77	1.70	1.72	1.73	1.74	1.73	1.72	1.55	1.55	1.28	1.39	1.19	1.43
	3rd	1.60	1.57	1.56	1.62	1.56	1.57	1.57	—	—	—	—	1.35	1.53
Ca	1st	2.76c	2.92b	3.19a	2.92	2.97	2.84	3.09	3.83	3.23	3.53	3.44	3.75	3.63
	2nd	2.82	2.86	2.97	2.76	2.81	2.99	2.99	3.13	3.06	5.55	5.75	3.50	3.38
	3rd	2.84	3.00	3.02	3.03	2.93	2.87	2.98	—	—	—	—	3.13	3.19
Mg	1st	.45a	.41b	.40b	.43	.42	.42	.41	.51	.41	.36	.34	.61	.59
	2nd	.39a	.36b	.36b	.36	.37	.37	.38	.57	.47	.35	.37	.45	.45
	3rd	.40a	.37b	.36b	.37	.36	.39	.38	—	—	—	—	.45	.43

[z]L-3 & L-10 liquid fertilizer applied through irrigation system 3 & 10 times a year.
[y]E-2 & E-4, 2 & 4 drippers per tree; J-1 & J-2, 1 & 2 green jets per tree.
[x]Means not followed by the same letters are different at 5% level of significance. Absence of letters after means indicate differences are not significant. Data for sprinkler irrigation were not analyzed.

gation treatments from small to large increased in the following order: 2 drippers, 4 drippers, 1 jet and 2 jets per tree. In the fertigation treatments, leaf N content increased proportionately with ground coverage with 2 drippers per tree having the lowest leaf N content and 2 jets the highest. Highest leaf N was found in irrigation treatments where jets were used for liquid fertilization. Opposite trends were found where dry fertilizer was used, with leaf N being lower in plots irrigated with jets. This may be partially explained by more rain-induced leaching loss where a larger ground area was already moistened by irrigation from the jets. Frequency of fertigation did not influence the mineral composition of leaves as there was no difference between fertigation 3 or 10 times a year.

Fruit Quality and Production

Fruit quality measurements showed that fertigation lowered the acid content in juice, resulting in higher Brix-acid ratio compared to dry fertilization (Table 4). The trend was more apparent in the low volume than sprinkler fertigated groves. Higher ratios were found with fertigation than dry fertilizer in Groves A, B and D. Grove C which had 'Ruby Red' grapefruit was the only exception. No consistent difference was found in juice content, Brix, yield of solids and fruit size between dry and liquid fertilization from the experimental groves.

Fruit production showed no difference between fertigation and dry fertilizer in overhead sprinkler irrigated blocks (grove D). Lower fruit production was found in the fertigated plots in low volume irrigation experiment (grove A). Reasons for the lower fruit production in low volume fertigation treatments are not clear, and are being further investigated. Two year's fruit production data should not be considered as conclusive.

Discussion and Conclusions

It is feasible to fertigate citrus with sprinkler or low volume irrigation systems. Savings in labor and energy can be realized in fertigation. Economic conditions and management practices will determine if it is advantageous to fertigate. A number of pertinent observations made during the course of these experiments should serve as guidelines for the improved efficiency of fertigation *practices.*

1. No operational problems of overhead sprinklers have been observed such as clogging and leaf burn. Rinsing the trees for 4 to 6 hr after fertigation is important. The total dissolved solids (TDS) of the fertilizer solutions used ranged from 250,000 to 350,000 ppm TDS depending on formulations and materials. The solution emerging from the sprinklers varied from 10,000 to 20,000 ppm TDS which was more than 10 times the tolerance for citrus leaves (3). No leaf burn or leaf drop was observed when the irrigation system was operated 4 to 6 hr after fertigation was completed.

2. Good ground coverage is the most important consideration in low volume fertigation. Leaf N content, a good indicator of nutritional status, varied directly with the extent of ground covered. Results to date suggest that at least 60 to 70% of the root zone should be covered in low volume irrigation systems. It is possible that in humid regions of abundant rainfall, in contrast to arid regions, high concentrations of roots are not confined to areas under the drippers or jets making the extent of ground coverage more important. A larger area may have to be irrigated in order to reach 60 to 70% of the root zone.

3. While it is generally believed the fertilizer uptake efficiency can be increased by frequent light applications (4, 7), supporting evidence in citrus is lacking. Present data to date indicate timing or frequency of fertigation is not critical. No difference was found between fertigation 3 (L-3) or 10 (L-10) times a year. It is possible that citrus with extensive root systems on deep sandy soils is quite efficient in absorbing plant nutrients, thereby making fertigation rate and timing less critical than for trees with limited root systems on shallow soils.

4. Clogging of drippers or jets is a major concern with fertigation through low volume irrigation systems. Excessive clogging was not found at the experimental location as long as only solution fertilizer was used. Very little difference in the incidence of clogging was found between pre and post

Table 4. Effects of fertigation on fruit quality and fruit production.

		Low volume irrigation (Grove A)							Sprinkler irrigation					
		Fertilization[z, x]			Irrigation[y, x]				Grove B		Grove C		Grove D	
Measurements	Year	Dry	L-3	L-10	E-2	E-4	J-1	J-2	Liquid	Dry	Liquid	Dry	Liquid	Dry
Juice (%)	1st	54.8b	56.3a	56.6a	56.0	56.0	56.2	55.4	65.1	59.0	45.7	41.8	49.7	53.9
	2nd	52.8	51.8	51.8	51.8	51.6	52.8	52.3	56.8	54.8	54.0	56.0	58.4	58.7
Brix (%)	1st	13.9	14.0	13.7	14.0	13.8	13.9	13.9	10.2	9.6	7.5	7.5	8.9	9.1
	2nd	13.1	13.2	13.3	12.9	13.0	13.4	13.2	10.8	10.4	7.9	8.6	10.0	9.7
Acid (%)	1st	.92a	.88b	.85c	.90a	.90a	.89a	.85b	.87	.87	1.03	.99	.68	.75
	2nd	.92a	.88b	.87b	.89ab	.89ab	.91a	.87b	.92	.96	1.07	1.16	.68	.67
Brix-Acid Ratio	1st	15.1b	15.9a	16.1a	15.5b	15.5b	15.6b	16.2a	12.5	11.9	7.3	7.6	13.1	12.0
	2nd	14.2b	15.2a	15.3a	14.5	15.0	14.7	15.3	11.7	10.5	7.4	7.5	14.7	14.5
Solids (lb/box)	1st	6.9b	7.1a	7.0ab	7.0	7.0	7.0	7.0	6.0	5.1	3.1	2.8	4.0	4.4
	2nd	6.2	6.2	6.2	6.0b	6.2ab	6.4a	6.2ab	5.5	5.1	3.9	4.3	5.3	5.1
Fruit wt. (%)	1st	189a	171b	176b	181	176	179	179	153	200	336	340	169	168
	2nd	210	206	207	211	198	211	210	169	172	350	335	196	198
Production (box/tree)	1st	6.4a	5.6b	5.7b	5.6	5.6	6.1	6.4	—	—	—	—	8.8	9.1
	2nd	2.8a	1.6b	1.6b	2.0	1.9	2.1	2.0	—	—	—	—	9.3	9.5

[z]L-3 & L-10 liquid fertilizer applied through irrigation system 3 & 10 times a year.
[y]E-2 & E-4, 2 & 4 emitters per tree; J-1 & J-2, 1 & 2 green jets per tree.
[x]Means not followed by the same letters are different at 5% level of significance. Absence of letters after means indicate differences are not significant. Data for sprinkler irrigation were not analyzed.

fertigations. Clogging ratio, under normal conditions using well water, was 5:1 (8.0%:1.5%) between drippers and jets at the experimental grove.

5. Certain precautions with the compatability of different fertilizer compounds should be observed during fertigation operations. Magnesium is one of the more difficult elements to dissolve in solution. Magnesium nitrate, while a satisfactory source of Mg, cannot be used in presence of P and NH_3 or it will react to form insoluble magnesium ammonium phosphate and will clog irrigation equipment.

The pH of the water for fertigation should be considered when P is used as water with high alkalinity will react with P to form insoluble tribasic calcium phosphate which will clog irrigation equipment (8). Therefore, the pH of solutions discharging from sprinklers or emitters should be monitored where P is involved.

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PATHOGENICITY OF FUSARIUM SOLANI TO CITRUS ROOTS AND ITS POSSIBLE ROLE IN BLIGHT ETIOLOGY[1,2]

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Abstract. **Studies of root systems on blight trees have shown that** Fusarium solani **is associated with a fibrous root rot on such trees. Citrus rootstock seedlings inoculated with pathogenic trains of** F. solani **cultured from wood of diseased roots developed the same kind of root-rot symptoms. Aboveground symptoms first appeared as a leaf roll and wilt; leaf color became a dull green as they dehydrated; and final leaf symptoms were a severe wilt, followed by desiccation and some leaf drop. Early leaf symptoms occurred after the fungus had invaded the root cortex but before it had fully colonized the water-conducting wood. After the wood became infected, vessel plugging developed in the roots and stem. No rootstock seedlings were resistant to infection, but some displayed a tolerance to wilt. Fungus strain variability ranged from nonpathogenic to highly pathogenic types. Pathogenic variability of the fungus may be related to its capacity to produce biologically active metabolites. In the field, vessels in trunks and in infected fibrous roots on blight trees were also plugged.**

Fusaria are soil fungi that cause various vascular wilts and root and stem rots of cultivated plants (3, 10). Studies have shown that Fusaria can be pathogenic on citrus alone, in combination with a primary parasite, and when environmental conditions are created to favor the fungus versus the host (1, 6, 22, 23, 29, 32). Although *Fusarium solani* (Mart.) Appel and Wr. emed. Snyd. and Hans. is a common inhabitant around citrus roots in Florida (19), it and others have acquired the reputation among most researchers of being no more than saprophytes on citrus roots in Florida. This reputation is due partly to early studies on the cause of spreading decline and blight. Sherbakoff, studying spreading decline (26), and Rhoads (25) and Childs (7), studying blight, were unsuccessful in showing that the Fusaria they used were pathogenic on citrus. In later studies on blight, Cohen (8) dismissed fungi because soil microbial populations of blight and healthy trees did not differ. More recently, Hanks and Feldman (13) concluded that fungi do not appear to be directly involved as the causal agent of young tree decline (blight). Furthermore, soil fungi (including Fusaria) have been essentially ruled out as causes of blight because researchers have reported no apparent difference in the condition of roots on blight and healthy trees (8, 24, 27, 28), especially on trees with early symptoms (8, 11, 24). Knorr (16) summarized the importance of *Fusarium* spp. on citrus by stating that though they may be present in many parts of citrus trees, they are not considered primary pathogens.

These attitudes about blight and its relationship to soils and soil fungi are changing. More recent studies have shown that *F. solani* is the primary *Fusarium* colonizing citrus fibrous roots, that it is associated with root-rot symptoms on blight trees, and that it can be pathogenic on citrus roots (20). Its potential role in blight is complemented by studies and observations which indicate that blight is related to soils and soil edaphic factors (9, 18, 25). Also, amino acid patterns in roots (12) and results of root-pruning healthy trees (2) suggest the root as the origin of stress on the tree.

This report describes some of the pathogenic characteristics of *F. solani* on citrus seedlings, the reaction of seedlings and budded plants to infection, and the toxigenic effects of naphthazarins (produced by *F. solani*) to germinating seed.

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[2]Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.