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Effects of Nitrogen, Potassium, and Irrigation on Yield and Quality of Lemon[1,2]

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Abstract. Yields and quality were compared on young bearing 'Bearss' lemon (*Citrus limon* L.) trees grown with 3 rates of N and K and 2 levels of soil moisture over a 4-year period. Increased rates of N application increased fruit production, incidence of fruit with scab, and green fruit; and decreased acid content of juice. Potassium applications increased the acid content of juice. Irrigation increased fruit size and decreased the number of green fruit after curing. A leaf N content of 2.2 to 2.6% is suggested for optimum fruit production for 'Bearss' lemon under Florida conditions.

The mineral nutrition of citrus has been extensively reviewed by Chapman (3) and Smith (12). Most of the investigations were concerned with oranges and grapefruit. Few studies have been conducted on the nutritional and water requirements of lemon. Jones et al. (8) reported that N applications increased yield of 'Lisbon' lemons and suggested that a leaf N between 2.2 and 2.5% be maintained for optimal yield depending on the vegetative vigor of the strain. Chapman et al. (4) working with container grown young 'Lisbon' lemons found best yields with medium rate of N (50-70 ppm) and suggested leaf N of 2.25 to 2.40% being ample. Embleton et al. (5, 6) found that massive applications of K to deficient trees resulted in increased yield, fruit size, juice, soluble solids, and acid contents. Massive application of P produced no change in fruit quality but increased yield. Koo (9) suggested an N:K ratio of 1:1.25 for maximum yield of acid in lemon. Furr and Taylor (7) reported fruit size reduction on lemon trees growing on a light textured soil which showed moisture stress between irrigations when compared to trees supplied with adequate soil moisture.

Little information is available on cultural requirements of lemon in Florida. Most lemon growers follow production practices used for oranges. Information is needed on the fertilizer and irrigation requirements of lemon. An experiment was initiated in 1968 to study the effects of N, K, and irrigation on yield and quality of lemons. This paper reports data obtained from 1969-72.

Materials and Methods

The experiment was conducted on 'Bearss', a selection of the Sicilian strain within the 'Lisbon' group. The trees, on sour orange rootstock, *C. aurantium* L., were planted near West Palm Beach, Florida in 1965 at a spacing of 4.57 m x 7.62 m and a density of 385 trees per ha. The soil is an imperfectly drained acid sandy soil of low native fertility. It is classified as an association of the Myakka and Immokalee series, which are members of sandy, siliceous, hyperthermic families of Aeric and Arenic Haplaquods, respectively (1). To facilitate drainage, trees are planted in rectangular blocks of approximately 3.3 ha, and bordered by deep canals every 450 m in one direction and lateral ditches every 115 m in the other direction. In the block, the trees are planted in elevated rows about 30 cm above the furrow.

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The experiment consisted of 18 treatments: 2 levels of soil moisture and 3 rates each of N and K. Soil moisture levels (irrigation) were the main plots and N and K rates were the subplots in a split plot design. Treatments were replicated 4 times in 6-tree plots making a total of 72 plots. Each main plot was buffered with 6 rows of trees on all sides. Permanent overhead sprinklers were used for irrigation with separate valves controlling each main plot. There were no guard trees between subplots because the trees were planted on elevated rows; few or no roots were found in the water furrows.

Fertilizer treatments were applied 3 times a year and irrigation was applied as indicated by soil moisture tensiometers. Soil moisture tensions of 60 (I_1) and 10 (I_2) centibars at the 30 to 46 cm depth were used as criteria for the 2 irrigation treatments (Table 1). Trace elements (Mn, Zn, Cu, and B) at recommended rates were applied as foliar applications (10).

Table 1. Fertilizer and irrigation treatments applied to 'Bearss' lemons.

Year	Rainfall	Irrigation I_1	Irrigation I_2	NK rates	Fertilizer N	Fertilizer K	Fertilizer P	Fertilizer Mg
	cm	cm	cm		g/tree/yr			
1969	203	7.4	24.9	Low	365	303	159	220
1970	140	3.7	14.2	Medium	650	539	159	220
1971	130	7.4	24.9	High	935	776	159	220
1972	191	3.7	24.9					

Leaf samples were collected once a year, usually in July, from hardened current flush leaves and leaves immediately behind the current flush in equal proportions. This was done because lemon trees in humid regions such as Florida are in a continuous state of growth. Fruit samples were collected for internal quality studies at harvest, usually in November. Additional fruit samples were collected in August for the fresh fruit study in 1970-72. The fresh fruit samples were cured at 20°C for 5 weeks and then graded for external quality.

Data are summarized to show the main effects of N, K, and irrigation treatments and only measurements showing significant differences are reported.

Results and Discussion

Leaf composition. Nitrogen content of leaves varied directly with rate of N application (Table 2). No consistent effects of K and irrigation treatments were observed. Potassium content of the leaves was influenced by both N and K treatments. The suppressing effects of N applications on leaf K were of the same magnitude as the positive effects of K applications. Lowering leaf K content due to increased N application agrees with results for citrus reported by other workers (2, 12). Irrigation had no effects on K or other macronutrient elements. Nitrogen treatments also resulted in lower P but higher Mg concentration while K treatments inversely affected both Ca and Mg concentration. The data are not presented as they agree with published data (2, 11).

Fruit production. Fruit production increased with increased rates of N application (Table 2). Highest fruit production resulted from the high rate (935 g/tree/year) of N, although the difference between the high and medium (650 g) rates were not significant. The main difference was between the low (365 g) and the other 2 rates. Using the medium rate (650 g) as a base, it appears that the N rate for optimum fruit production of lemons in Florida is similar to that for 'Persian' lime (13) and is about 40 to 50% higher than rates recommended for orange and grapefruit (10).

Irrigation and K treatments did not affect fruit production. Due to the limitations of the experimental design, however, large differences are required for significance in main plot irrigation treatments. The numerical difference in fruit production between the 2 irrigation treatments, though not significant, was substantial from 1970 to 1972. The excessive rainfall of 1969 (203 cm) probably nullified effects of irrigation that year.

Fruit quality. The acid content of the juice was affected by all treatments (Table 3). Increasing K applications increased the acid content in all 4 years. Nitrogen, on the other hand, reduced the acid content of the juice. The reduction in the acid content of juice with increasing N applications seems to be related to suppressing effects of N on the leaf K content. Irrigation treatments affected the acid content in 2 of the 4 years, higher soil moisture produced fruit of lower acid content. None of the treatments affected the juice or soluble solid contents.

Irrigation treatments affected external quality more than internal quality. Trees maintained at higher soil moisture (I_2) produced significantly larger fruits and fewer green fruits after curing than did trees at lower soil moisture (I_1). The wet (I_2) treatment also produced fruit with a higher incidence of scab in 2 of the 3 years. The percent of green fruit and scab-infested fruit varied directly with the rate of N application. The more succulent fruit rind and denser foliage of trees in the high N plots may have produced a microclimate that enhanced scab infection. It should be further investigated. The relationships between K treatments and fruit color or scab infestation were not consistent.

Leaf N and yield relations. Annual sampling of leaves from nonfruiting stem showed a correlation between leaf N and fruit yield (Fig. 1). A highly significant linear correlation (r = .844**), indicated that leaf N can be used to evaluate yield potential of the tree.

Leaf sampling of lemon trees in humid regions such as Florida is complicated by continuous vegetative growth of the trees throughout the year. Preliminary studies showed that

Table 2. Main effects of N, K, and irrigation treatments on N and K contents of leaves and fruit yield.

Measurement		Irrigation I_1	Irrigation I_2	N (g/tree/year) 365	N (g/tree/year) 650	N (g/tree/year) 935	K (g/tree/year) 303	K (g/tree/year) 539	K (g/tree/year) 776
Leaf N	69	2.06a	2.11b	1.81A	2.15B	2.37C	2.10	2.10	2.13
(% dry wt)	70	2.00	2.13	1.98A	2.14B	2.38C	2.18	2.13	2.19
	71	2.63B	2.40A	2.32A	2.52B	2.71C	2.55b	2.46a	2.55b
	72	2.15	2.06	1.91A	2.13B	2.28C	2.12	2.08	2.11
Leaf K	69	1.54	1.60	1.87C	1.54B	1.31A	1.35A	1.57B	1.80C
(% dry wt)	70	1.72	1.73	1.97C	1.67B	1.54A	1.49A	1.78B	1.92C
	71	1.73	1.59	1.95B	1.57A	1.45A	1.40A	1.69B	1.89C
	72	1.90	1.86	2.19C	1.80B	1.65A	1.59A	1.93B	2.12C
Yield	69	52.7	53.1	35.4A	60.4B	62.6B	49.5	52.7	56.3
(kg/tree)	70	45.6	55.8	41.8A	56.7B	58.6B	53.1	48.1	55.8
	71	99.4	112.6	104.0	106.2	107.1	105.8	103.1	109.0
	72	65.4	72.2	59.0A	72.6B	74.4B	71.3	67.2	67.6

[z]Means not followed by the same letters are different at 5% (small letters) or 1% (capital letters) level of significance. Absence of letters after means indicate differences are not significant.

Table 3. Main effects of N, K, and irrigation treatments on fruit qualities of 'Bearss' lemon.

Measurement		Irrigation		N (g/tree/year)			K (g/tree/year)		
		I_1	I_2	365	650	935	303	539	776
Acid	69	6.44	6.44	6.52B	6.46B	6.33A	6.31A	6.45B	6.55C
(% in juice)	70	6.50	6.55	6.64B	6.51A	6.43A	6.42A	6.58B	6.58B
	71	5.97b	5.88a	6.00B	5.95AB	5.83A	5.86a	5.94a	5.98ab
	72	6.59b	6.43a	6.55	6.47	6.51	6.42a	6.57b	6.54b
Size	70	5.26A	5.44B	5.36	–[z]	5.33	5.31	–[z]	5.38
(cm diam)	71	5.54a	5.92b	5.69	5.74	5.77	5.71	5.74	5.76
	72	5.64a	6.12b	5.94	5.87	5.84	5.89	5.87	5.89
Green fruit	70	25b	20a	19a	–[z]	27b	21a	–[z]	26b
(%)	71	19b	12a	14	16	17	14	16	17
	72	6B	1A	3A	3A	6B	2A	6B	3A
Scab fruit	70	32	30	27A	–[z]	40B	30	–[z]	37
(%)	71	25a	37b	16A	36B	41B	30a	26a	38ab
	72	22a	34b	24a	27a	34b	28	29	28

[z]Samples were not collected from the medium rates in 1970.

[y]Means not followed by the same letters are different at 5% (small letters) or 1% (capital letters) level of significance. Absence of letters after means indicate differences are not significant.

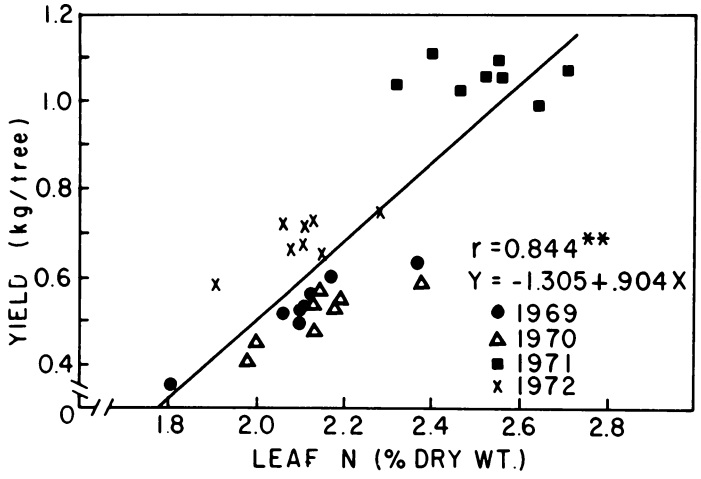

Fig. 1. Relation of leaf N to yield of 'Bearss' lemon.

lemon trees in Florida may produce 7 flushes of leaves a year instead of 3 flushes produced by most other citrus species. Mixed terminal hardened leaves and leaves preceding the current flush sampled in July-August seemed to yield most reliable results. Such a sample would consist of leaves from nonfruiting stems mostly 2 to 4 months old. A satisfactory range of 2.2 to 2.6% leaf N would be desirable using the method described. The range suggested for optimum fruit production of 'Bearss' lemon is similar to the values reported for 'Monroe Lisbon' in California (8).

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