Response of Micro-Sprinkler Irrigated 'Lisbon' lemons to N Rate and Source on a Superstition Sand[1]

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Abstract

Much of the citrus produced in southwestern Arizona is grown on sandy soils. Because these soils have a low ion exchange capacity, are highly permeable to water, and are prone to nitrate leaching, achieving efficient N management presents a continuing challenge. Studies were conducted during 1999, 2000, and 2001 to evaluate the response of micro-sprinkler irrigated lemons to N rate (0, 1.8, and 3.6 kg N tree^{-1} *yr*$^{-1}$*) and N source (UN32, CAN-17, CN9, and mixed program) on Superstition Sand. Lemon yield increased by N rate during the first and second harvests in 1999, 2000, and 2001. In 1999, yields increased linearly to 3.6 kg N tree*$^{-1}$ *yr*$^{-1}$ *but in 2000 and 2001 yields were maximized at 1.8 kg N tree*$^{-1}$ *yr*$^{-1}$*. In 1999 where larger increments of N were applied over a smaller time period relative to the other seasons, UN32 seemed to decrease yields at the highest N rate. There were no significant effects to N source in 2000 and 2001.*

Introduction

Much of the citrus produced in southwestern Arizona is grown on sandy soils. Because these soils have a low ion exchange capacity, are highly permeable to water, and are prone to nitrate leaching, achieving efficient N management presents a continuing challenge.

Finch and McGeorge (1945) reported that young Marsh grapefruit trees growing on Superstition Sand of the Yuma Mesa yielded more fruit when fertilized with nitrogen, but not with phosphorus or potassium. In another study, which evaluated the response of lemons to N, P, and manure, lemon yields were greatest when N was applied with P or manure (Rodney and Sharples, 1962). It should be noted that these experiments, as most in Arizona, were conducted on flood-irrigated citrus.

Previous research conducted by the University of Arizona, Yuma Agricultural Research Center has shown that several pressurized irrigation systems such as trickle, spray, or bubblers improved irrigation efficiency substantially over the traditional flood irrigation. The growth rate of young 'Campbell Valencia' trees irrigated by pressurized systems was greater than trees irrigated by the traditional flood systems (Rodney et al. 1977; Roth et al. 1978). Furthermore other

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studies showed that mature 'Valencia' oranges can be converted from flood irrigation to any of these pressurized systems without compromising fruit yield and quality (Roth et al., 1995). These systems also resulted in improved N fertilizer use efficiency through better timing and placement of N fertilizer. Leaf tissue data showed appreciably higher N concentrations in trees irrigated by pressurized systems compared to flood irrigation confirming the difficulties of managing N under traditional flood irrigation.

Based on past research in Arizona, 3.4 to 4.5 kg N/tree/year are recommended for mature, flood-irrigated orange trees when leaf tissue concentrations are below 2.2% (Doerge et al. 1987). However, fertilizer recommendations developed for flood-irrigated trees may not be applicable to trees irrigated by pressurized systems because of enhanced options for fertilizer timing, placement and reduced N leaching resulting from improved irrigation efficiency. The objective of this experiment were to evaluate the response of ‘Lisbon’ lemons under micro-sprinkler irrigation to N rate and N source.

Materials and Methods

This experiment was established on a 1.8 ha field of 'Lisbon' lemons located on the Yuma Mesa Agricultural Research Farm. The trees were 'Limoneria 8a Lisbon' on 'Volkamariana' rootstock and were planted September, 1993. The entire area was irrigated with a micro-sprinkler irrigation system designed for plot work with irrigation and fertilization. This system contains an array of water meters, injection apparatus, and pipes, which allows for the application of nine N and/or water treatments in a randomized block design with four replications. The treatments we selected for this study were as follows:

1. Control (no N fertilizer)
2. 1.8 kg N tree^{-1} yr^{-1} as Urea Ammonium Nitrate (UN-32)
3. 1.8 kg N tree^{-1} yr^{-1} as Calcium Ammonium Nitrate (CAN-17)
4. 1.8 kg N tree^{-1} yr^{-1} as mixed program (CN9/CAN17/UN32/CN9)
5. 1.8 kg N tree^{-1} yr^{-1} as Calcium Nitrate (CN-9)
6. 3.6 kg N tree^{-1} yr^{-1} as Urea Ammonium Nitrate (UN-32)
7. 3.6 kg N tree^{-1} yr^{-1} as Calcium Ammonium Nitrate (CAN-17)
8. 3.6 kg N tree^{-1} yr^{-1} as mixed program (CN9/CAN17/UN32/CN9)
9. 3.6 kg N tree^{-1} yr^{-1}as Calcium Nitrate (CN-9)

N fertilizers were applied once weekly during an irrigation event using a venturi injection system. For 1999, fertilization began April 21 and ended October 27. Because this first experiment was initiated late in the spring, weekly N rates were higher in the beginning. For the 1.8 kg N tree^{-1} yr^{-1} treatments, weekly N rates per tree were 0.18 kg through May 5, 0.09 kg through May 26, and 0.045 kg through October 27. For the 3.6 kg N tree^{-1} yr^{-1} treatments, weekly N rates per tree were 0.36 kg through May 5, 0.18 through May 26, and 0.09 through October 27. For 2000, fertilization began January 26. For the 1.8 kg^{-} N tree^{-1} yr^{-1} and 3.6 kg N tree^{-1} yr^{-1} treatments, weekly N rates per tree were 0.045 kg and 0.09 kg, respectively, from January 26 through October 25. For 2001, fertilization was started March 15. Weekly N rates per tree for the 1.8 kg N tree^{-1} yr^{-1} were 0.068 kg from March 15 through May 31 and 0.045 from June 7 through October 25. Weekly N rates for the 3.6 kg N tree^{-1} yr^{-1} were 0.136 kg from March 15 through May 31 and 0.09 kg from June 7 through October 25. The treatments with mixed sources (treatments 4 and 8) received CN9 through early May, CAN 17 through the end of May, UN32 through late August, and CN9 through October 27.

Tree growth was determined before initiation of the experiment and will be determined each year during the experiments duration. Leaves were collected from each plot on August 19, 1999 and October 11, 2000, and October 30, 2001 to determine N concentration. Total N in leaves was determined using a micro-Kjeldahl procedure. In 1999, lemons were harvested (ring picked) on Sept. 21 and (stripped) on Nov. 17. In 2000, lemons were harvested on Sept. 21 and stripped on November 21. In 2001, lemons were harvested on October 2 and stripped on November 26. Ten fruit were randomly selected from each plot of the second harvest for juice quality measurements. Quality measurements included peel thickness, percent juice solid, percent acid, and total volume of juice. The percent total dissolved solids were determined with a refractometer and percent citric acid by titration with a 0.4 NaOH. All data were analyzed using an appropriate statistical model.

Results

Lemon yield increased by N rate during the first and second harvests in 1999, 2000, and 2001 (Tables 1 through 3). In 1999, yields increased linearly to 3.6 kg N tree^{-1} yr^{-1} rate. In 2000 and 2001 yields were generally maximized at 1.8 kg N tree^{-1} yr^{-1}.

Although the effect of N source was not statistically significant for the first harvest, it was significant for the second harvest in 1999. Furthermore, the effect of N source was significant for the combined harvest where the program using only UN32 resulted in lower yields compared to other N sources and N source combinations. The N rate by source interaction for yield, the second and combined harvests were also significant where the differences between sources were more pronounced at the high N rate (data not shown). There were no significant differences to N source in 2000 and 2001.

Percent juice by weight and acidity also generally were increased by N rate in 1999, which are desirable traits for lemons (Table 4). In 2000, total soluble solids increased with N rate (Table 5). In 2001, fruit weight, percent juice by weight, and total soluble solids also increased by N rate (Table 6). Unfortunately in 2000 and 2001, peel thickness also increased slightly in response to N rate. There were no significant differences in juice quality to N source in any year. Additionally, there were no significant N rate by N source interactions.

The presence of N deficiencies at the 0 kg N tree^{-1} yr^{-1} rate was verified by visual deficiency symptoms and leaf nutrient concentrations (Tables 7, 8, and 9). In each season the 0 kg N tree^{-1} yr^{-1} rate resulted in tissue N concentrations below the University of Arizona threshold of 2.2. The deficiency worsened each year and by 2001, no yield was produced for this treatment.

The tissue N concentrations are also useful in interpreting the response to N source in 1999. Note that the main effect means for UN32 were above the critical level. This data suggests that although yields were significantly lower for the UN32 treatments in 1999, the cause was not due to N deficiencies. We might speculate that there could have been toxicities to ammonium and/or urea. This would be consistent with the observation that differences between UN32 and other N sources or source combinations were greater at the highest N rate. Interestingly, the adverse effects of UN32 were not observed in 2000 or 2001, where smaller increments of N were applied over a longer period. Overall, under normal N fertilization practices, N sources should not be expected to be of prevailing importance from the standpoint of fruit production and quality. The selection of source should be based solely on economic considerations.

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Table 1. Main effect yields of lemons during first and second harvest and the total yield for the season as affected by N rate and source in 1999.

N rate kg tree^{-1} year^{-1}	Yield (First Harvest) kg tree^{-1} year^{-1}	Yield (Second Harvest) kg tree^{-1} year^{-1}	Total Yield kg tree^{-1} year^{-1}
0	14.0	45.6	60.8
1.8	18.7	53.4	73.8
3.6	21.2	77.1	100.1
Stat.	L*	L**	L**
UN32	17.4	51.7	70.6
CAN17	21.6	68.0	91.6
CN9/CAN17/UN32/CN9	22.0	66.6	90.6
CN9	18.8	74.6	95.1
LSD	NS	9.7	12.7

*, **Significant linear (L) or quadratic (Q) trend at the 5% and 1% levels, respectively.
LSD=Least Significant Difference. NS=P>0.05.

Table 2. Main effect yields of lemons during first and second harvest and the total yield for the season as affected by N rate and source in 2000.

N rate kg tree^{-1} year^{-1}	**Yield (First Harvest) kg tree^{-1} year^{-1}**	**Yield (Second Harvest) kg tree^{-1} year^{-1}**	**Total Yield kg tree^{-1} year^{-1}**
0	0	1.7	1.7
1.8	29.1	72.7	101.8
3.6	20.7	89.3	110.0
Stat.	Q**	L**Q**	L**Q**
UN32	26.8	74.3	101.1
CAN17	24.3	81.0	105.3
CN9/CAN17/UN32/CN9	24.7	81.6	106.3
CN9	23.9	87.2	111.1
LSD	NS	NS	NS

*, ** Significant linear (L) or quadratic (Q) trend at the 5% and 1% levels, respectively.
LSD=Least Significant Difference. NS=P>0.05.

Table 3. Main effect yields of lemons during first harvest for the season as affected by N rate and source in 2001.

N rate kg tree^{-1} year^{-1}	**Yield (First Harvest) kg tree^{-1} year^{-1}**	**Yield (Second Harvest) kg tree^{-1} year**	**Total Yield kg tree^{-1} year**
0	0	0	0
1.8	17.9	101.6	119.5
3.6	9.30	62.5	71.8
Stat.	Q**	Q**	Q**
UN32	14.9	73.6	88.5
CAN17	15.2	76.7	91.9
CN9/CAN17/UN32/CN9	12.6	73.4	86.0
CN9	11.8	104.4	116.2
LSD	NS	NS	NS

** Significant quadratic (Q) trend at the 1% level.
LSD=Least Significant Difference. NS=P>0.05.

Table 4. Main effect juice quality parameters of lemons during second harvest as affected by N rate and source in 1999.

N rate kg tree^{-1} year^{-1}	Fruit weight (g)	Juice (%)	Total Soluble solids (%)	Acid (%)	Solid/Acid ratio	Peel thickness (mm)
0	100.2	29.6	7.3	4.5	1.6	7.3
1.8	112.2	38.3	7.7	5.0	1.6	7.2
3.6	109.4	37.3	8.7	5.3	1.5	7
Stat.	NS	Q*	L**	L**	NS	NS
UN32	106.9	36.5	7.7	4.9	1.6	7.1
CAN17	106.5	36.9	7.8	5.1	1.5	7.0
CN9/CAN17/UN32/CN9	116.7	40.3	7.9	5.2	1.5	7.2
CN9	113.1	37.4	8.0	5.3	1.5	7.1
LSD	NS	NS	NS	NS	NS	NS

*, **Significant linear (L) or quadratic (Q) trend at the 5% and 1% levels, respectively.
LSD=Least Significant Difference. NS=P>0.05.

Table 5. Main effect juice quality parameters of lemons during second harvest as affected by N rate and source in 2000.

N rate kg tree^{-1} year^{-1}	**Fruit weight (g)**	**Juice (%)**	**Total Soluble solids (%)**	**Acid (%)**	**Solid/Acid ratio**	**Peel thickness (mm)**
0	106.2	37.4	7.7	5.6	1.4	3.2
1.8	113.8	36.3	8.0	5.8	1.4	3.8
3.6	112.0	37.9	8.5	5.9	1.4	3.7
Stat.	NS	NS	L**	NS	L*	Q*
UN32	115.4	36.0	8.0	5.8	1.4	3.9
CAN17	114.6	37.1	8.3	5.8	1.4	3.8
CN9/CAN17/UN32/CN9	112.8	37.8	8.4	5.9	1.4	3.8
CN9	108.9	37.5	8.4	6.0	1.4	3.6
LSD	NS	NS	NS	NS	NS	NS

*, ** Significant linear (L) or quadratic (Q) trend at the 5% and 1% levels, respectively.
LSD=Least Significant Difference. NS=P>0.05.

Table 6. Main effect juice quality parameters of lemons during second harvest as affected by N rate and source in 2001.

N rate kg tree^{-1} year^{-1}	**Fruit weight (g)**	**Juice (%)**	**Total Soluble solids (%)**	**Acid (%)**	**Solid/Acid ratio**	**Peel thickness (mm)**
0	72.4	37.3	7.2	5.2	1.4	3.5
1.8	119.8	42.5	7.7	5.3	1.4	4.0
3.6	121.9	41.6	7.8	5.3	1.5	4.1
Stat.	L**Q**	Q**	L**Q**	NS	NS	L**Q*
UN32	119.5	40.9	7.6	5.4	1.4	4.1
CAN17	120.0	41.9	7.8	5.2	1.5	4.1
CN9/CAN17/UN32/CN9	121.2	41.9	7.8	5.3	1.5	4.1
CN9	122.8	43.6	7.8	5.4	1.4	3.9
LSD	NS	NS	NS	NS	NS	NS

*, ** Significant linear (L) or quadratic (Q) trend at the 5% and 1% levels, respectively.

LSD = Least Significant Difference. NS=P>0.05.

Table 7. Leaf N concentration of lemon trees as affected by N rate and source in 1999.

N rate kg tree^{-1} year^{-1}	**Leaf N concentration (%)**
0	1.38
1.8	2.11
3.6	2.36
Stat.	L**Q*
UN32	2.33
CAN17	2.33
CN9/CAN17/UN32/CN9	2.16
CN9	2.11
LSD	NS

*, **Significant linear (L) or quadratic (Q) trend at the 5% and 1% levels, respectively.
LSD=Least Significant Difference. NS=P>0.05.

Table 8. Leaf N concentration of lemon trees as affected by N rate and source in 2000.

N rate kg tree^{-1} year^{-1}	**Leaf N concentration (%)**
0	1.3
1.8	2.0
3.6	2.1
Stat.	Q*
UN32	2.2
CAN17	1.8
CN9/CAN17/UN32/CN9	2.2
CN9	2.0
LSD	NS

*, ** Significant linear (L) or quadratic (Q) trend at the 5% and 1% levels, respectively.
LSD=Least Significant Difference. NS=P>0.05.

Table 9. Leaf N concentration of lemon trees as affected by N rate and source in 2001.

N rate **kg tree^{-1} year^{-1}**	**Leaf N concentration (%)**
0	1.2
1.8	2.0
3.6	2.2
Stat.	L**Q**
UN32	2.1
CAN17	2.0
CN9/CAN17/UN32/CN9	2.0
CN9	2.1
LSD	NS

*, ** Significant linear (L) or quadratic (Q) trend at the 5% and 1% levels, respectively.
LSD = Least Significant Difference. NS=P>0.05.