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NITROGEN FERTILITY REQUIREMENT FOR ICEBERG LETTUCE GROWN ON SANDLAND WITH PLASTIC MULCH AND DRIP IRRIGATION

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Abstract. **In order to insure a profitable industry and production of quality produce on the sandy soils of Florida, a series of experiments were conducted over four years to determine the response of iceberg lettuce (*Lactuca sativa* L.) grown with drip irrigation and plastic mulch to nitrogen (N). Beds were established with no preplant fertilizer, drip irrigation, and white-on-black co-extruded polyethylene film. Irrigation frequency was managed by tensiometers and was initiated as water tensions reached -10kPa. Nitrogen as NH_4NO_3 and KNO_3 was applied weekly via the drip tube at rates from 55 to 275 kg·ha^{-1} N. Lettuce yields were improved by total N rates of 160 to 195 kg·ha^{-1} N and thereafter decreased. Head firmness, head size, and (stem) butt diameter were generally largest with this same N fertility rate. Other quality factors such as core length and internal tip burn were minimized with the lowest N rate (55 kg·ha^{-1} N). Profitable production of high-quality iceberg lettuce on sandland with drip irrigation, plastic mulch, and 160 to 195 kg·ha^{-1} N in Florida is now possible.**

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Introduction

Approximately 3,500 ha of lettuce are grown in Florida annually, mostly on organic soils around Lake Okeechobee and Zellwood. Very little lettuce has been grown commercially on the mineral soils of the state. Likewise, there are very few reports of lettuce production or experimentation on sandy soils (Seale and Cantliffe, 1985, 1986; Cantliffe and Karchi, 1992; Seale et al., 1994; Robles, 1997).

Expansion of lettuce production to the abundant sandy soils in Florida seems logical for several reasons. Closer proximity to the U.S. East Coast markets offers Florida lettuce a competitive advantage in transportation costs compared to California lettuce. Mild climatic conditions throughout the entire peninsula of the state offer the possibility of obtaining added revenues from earlier production. The use of adapted cultivars, specific climatic regions, and special production techniques might enable lettuce production 8 to 10 months of the year in Florida. Lastly, decline of agricultural land due to oxidation of Histosols, the closing to agricultural production and flooding of the Histosols around Lake Apopka, and competition with other crops such as sugar cane, limit lettuce production on the muck soils.

Several problems with producing lettuce on sandland in Florida have been identified by Robles (1997). They included the need for more adaptive cultivars for sandland production, improvements in transplant technology, and the need for fertilizer recommendations, especially N, for lettuce grown with plastic mulch and drip irrigation.

In a fertilizer trial using open ditch seepage irrigation, Everett (1980) reported advantages of polyethylene mulch for increasing yields and lettuce head weight. However, fertilizer rates ranging from 470 to 1031 kg·ha^{-1} of 18-0-20 (N-P-K) above a standard rate of 560 kg·ha^{-1} of 5-4-7 had no effect on yield or head weight. Cantliffe and Karchi (1992) grew several cultivars of iceberg lettuce on white plastic mulch and drip irrigation with 1200 kg·ha^{-1} of 13-2-11 (N-P-K) fertilizer applied preplant and rotovated into the bed. Fertigation as weekly applications of 18 kg N, 12 kg P, and 6.7 kg K were also applied from planting until two weeks before harvest.

In order to better define the needs of iceberg lettuce grown on sandland with drip irrigation and plastic mulch in north Florida, N fertility studies were conducted over a four-year period to determine the effect of varying N rate on lettuce yield and head quality.

Materials and Methods

All trials were conducted at the Horticultural Research Unit at the University of Florida, Institute of Food and Agricultural Sciences (IFAS) in Gainesville, Florida during 1990, 1992, 1993, and 1994. The soil was a loamy, siliceous, hyperthermic Grossarenic Paleudults (Arredondo fine sand). The soil had a pH of 6.8 and was very high (Mehlich-I extractant) in P (110 ppm), low in K (28 ppm), very high in Mg and Ca (144 ppm and 1010 ppm, respectively) and had 3.1% organic matter. Methyl bromide-chloropicrin (98:2) was injected into the beds at 450 $kg \cdot ha^{-1}$ (broadcast rate) and the beds were covered with white polyethylene mulch (0.025 mm) in 1990, 1992, and 1993 and with white-on-black co-extruded (0.038 mm) polyethylene mulch in 1994. Lettuce was planted using 4-week-old transplants. The experimental design was a randomized complete block design with 6 replicates.

Fertigation (irrigation and fertilization) was applied by one or two drip lines (Typhoon by Netafim Irrigation Inc., Altamonte Springs, FL - 1.44 LPH @ 0.9×10^4 Pa, 45 cm spaced emitters) placed on each side of the center lettuce rows for 3- or 4-row beds, or down the center of a 2-row bed to ensure thorough wetting of soil. Overhead irrigation was applied immediately following transplanting. During the experiment, irrigation was applied daily for 45 minutes except on rainy days, totaling 2×10^6 $liter \cdot ha^{-1}$. Nitrogen was applied weekly beginning around the time of planting with seasonal totals of 0, 56, 112, 168, 224, and 280 $kg \cdot ha^{-1}$ N from NH_4NO_3 and KNO_3. In 1990 each N rate was split and two P rates, 0 and 65 $kg \cdot ha^{-1}$ P from phosphoric acid, were also examined. The P was added weekly with the N fertigation treatments. K from KNO_3 was applied at 65 $kg \cdot ha^{-1}$ K in 1990, 100 $kg \cdot ha^{-1}$ K in 1992, and 69 $kg \cdot ha^{-1}$ in 1993 and 1994. All K was from KCl in the 0 N treatment. Samples of 20 heads were harvested from each experiment. Individual heads were measured for weight, diameter, firmness, and stem length following longitudinal sectioning. All lettuce was harvested when the maximum number of heads in a plot were judged in the marketable category. Heads with weights of 0.5 kg or more were considered as marketable weight.

The lettuce in the 1990 experiment was transplanted on 14 Apr. and harvested 1 June. The beds were on 2.3 m centers and the plots were 3.8 m long. 'Empire' lettuce transplants were spaced 30 cm in the row and 35 cm between rows on 3-row beds to give a population of 46,100 plants per ha. In the 1992 experiment, 'Empire' lettuce was transplanted on 30 Mar. and harvested 22 May. The crop was grown on beds with 2 m centers, 4 rows per bed in plots 5 m long. Plants were spaced 30 cm in and between rows to give a population of 71,728 plants per ha. The lettuce in the 1993 experiment was transplanted 22 Mar. and harvested 24 May. A population of 53,800 plants per ha was grown on 2-row beds with 1.3 m centers, with 'Desert Queen' lettuce transplants spaced at 30 cm in and between rows in plots 4.3 m long. The lettuce in the 1994 experiment was transplanted 18 Feb. and harvested 22 Apr. Two rows of 'Desert Queen' lettuce were transplanted into beds on 1.2 m centers with plants spaced 30 cm in and between rows. The plots were 4.5 m long and the population was 53,800 plants per ha.

Table 1. The effect of N rate on sandland lettuce produced in 1990.

N rate ($kg \cdot ha^{-1}$)	Marketable yield ($MT \cdot ha^{-1}$)	Head weight (g)	Tipburn Rating[y]	Head diameter (cm)	Butt width (cm)	Core length (cm)
56	28.1	612	7.7	14.2	2.7	5.0
112	32.7	658	8.2	14.4	2.9	5.8
168	34.5	688	8.4	14.7	2.9	6.1
224	31.7	654	8.4	14.0	2.9	5.8
280	26.9	623	8.3	14.0	2.8	5.3
LSD[z]			0.33	0.66	0.096	0.68

[z]Significant at the 5% level or not significant (NS).
[y]9 = none, 1 = extensive.

Results

In 1990, an N rate of 160 $kg \cdot ha^{-1}$ produced the greatest marketable yield and largest head size (Table 1). Head quality data were generally maximized at this N rate, except for core length which was least at the 56 $kg \cdot ha^{-1}$ N rate. There were no significant N $\times$ P interactions. Lettuce with the 65 $kg \cdot ha^{-1}$ P rate treatments had greater yield, head weight, and core length, when compared to the 0 P rate (Table 2).

Similarly in 1992, yields and head weight of the same lettuce cultivar 'Empire' were greatest with 168 $kg \cdot ha^{-1}$ N (Table 3). No marketable heads were produced with the 0 N rate. N rate had no effect on internal tipburn, head diameter, butt width, and core length. Head firmness was similar with the 168 $kg \cdot ha^{-1}$ N rate to the other N rates.

The lettuce cultivar was changed to 'Desert Queen' in 1993 and 1994. Yield, head size, and head quality were generally maximized with 56 and 112 $kg \cdot ha^{-1}$ N in 1993 (Table 4). Very few heads reached marketable weight with the 0 N rate and thus, yield was severely reduced. In 1994, yields and head size were again greatest with the 168 and 224 $kg \cdot ha^{-1}$ N rates (Table 5). Except for internal tipburn ratings, head quality was similar to the other N treatments at these two N rates. Once again, no marketable heads were produced without N.

Regression model estimates indicated that yields could be maximized by 160 $kg \cdot ha^{-1}$ N in 1990, 190 in 1992, 165 in 1993 and 195 in 1994 (Table 6). Head size generally followed these estimates plus or minus 5 $kg \cdot ha^{-1}$ N.

Discussion

These experiments clearly demonstrated that iceberg lettuce grown with white polyethylene mulch and drip irrigation in north Florida could produce maximum yield, head size, and quality by the addition of 160 to 195 $kg \cdot ha^{-1}$ N. The N was delivered completely via weekly fertigations commencing around the time of planting. Recently, Tei et al. (1997) re-

Table 2. Effect of P rate on sandland lettuce production in 1990.

P ($kg \cdot ha^{-1}$)	Yield ($MT \cdot ha^{-1}$)	Head weight (g)	Core length (cm)
0	29.7	634	6.3
65	31.9	660	5.9
F value[z]	*	*	*

[z]*Significant at the 5% level.

Table 3. Effect of N rate on sandland lettuce production 1992.

N rate (kg·ha⁻¹)	Marketable yield (MT·ha⁻¹)	Head weight (g)	Firmness rating[y]	Internal tipburn rating[x]	Head diameter (cm)	Butt width (cm)	Core length (cm)
0	0	—	—	—	—	—	—
56	16.8	535	3.9	0.8	11.0	2.4	3.1
112	27.6	544	3.7	0.3	10.6	2.2	2.7
168	34.7	630	3.6	0.5	11.2	2.4	2.9
224	27.8	578	2.9	0.3	9.9	2.0	2.3
280	27.1	564	3.3	0.4	11.9	2.4	2.0
LSD[z]			0.8	NS	NS	NS	NS

[z]Significant at the 5% level or not significant (NS).
[y]5 = firm, 1 = soft.
[x]0 = none, 5 = extensive.

Table 4. Effect of N fertility on sandland lettuce produced 1993.

N rate (kg·ha⁻¹)	Marketable yield (MT·ha⁻¹)	Head weight (g)	Firmness rating[y]	Internal tipburn rating[x]	Head diameter (cm)	Butt width (cm)	Core length (cm)
0	0.3	160	2.9	0.4	8.6	1.9	2.9
56	29.0	625	4.4	2.0	11.1	2.7	4.6
112	29.4	626	4.2	2.7	11.5	2.9	5.3
168	23.5	575	4.1	3.1	11.3	2.8	4.9
224	20.1	548	3.8	2.3	11.1	2.9	4.6
280	23.5	538	4.3	1.8	10.8	2.9	4.3
LSD[z]			0.5	0.7	2.0	0.3	0.7

[z]Significant at the 5% level.
[y]5 = firm, 1 = soft.
[x]0 = none, 5 = extensive.

ported that two lettuce cultivars grown from transplants at Perugia Italy obtained maximum fresh dry weights with about 155 kg·ha⁻¹ N. The plants were grown with drip irrigation on silty-loam soil with 1.3% O.M. and the N fertilizer was broadcast at transplanting.

Calibrated soil test results generally placed P soil concentrations as very high. Even so, application of 65 kg·ha⁻¹ P fertilizer treatment in 1990 lead to a small but significant increase in yield and head size over no additional P. Sanchez et al. (1990) achieved a greater response from a band compared to a broadcast application of P in the low-available P Histosols of south Florida. In future work, it might be advantageous to examine P fertility effects in both low and high P soils and consider timing as well as placement (starter fertilizer) effects. In the present work, P was applied via phosphoric acid and as such, other factors such as soil pH could have been altered.

Besides N rate, the most striking influence on lettuce yields in these experiments was planting date wherein the highest yields were obtained from the 1994 trial which was planted in Feb. instead of late Mar. or early April. This followed the results reported for lettuce grown under similar conditions and planted over seasons from Sept. through Apr. (Robles, 1997).

The present work would not have been successful without the use of polyethylene mulch for weed control and effectiveness of the methyl bromide fumigation treatment for nematode, soil-borne plant pathogen control, and weed control. The color of the mulch has been an important factor for optimizing crop growth. Dark colored mulch, especially black, proved deleterious to crop growth (Seale and Cantliffe, 1985) and led to plant stem burning of the newly transplanted lettuce. White polyethylene mulch appeared somewhat more effective than white-on-black polyethylene, although full-season weed growth repression may be a problem on the former type of mulch. The use of drip irrigation is the only logical method of irrigation to deliver water and nutrients directly to the shallow-rooted lettuce crop without wetting the plants' leaves. The lettuce covered the punched hole in the mulch rapidly, thus making overhead irrigation impractical. Subirrigation or

Table 5. Effect of N fertility on sandland lettuce produced 1994.

N rate (kg·ha⁻¹)	Marketable yield (MT·ha⁻¹)	Head weight (g)	Firmness rating[y]	Internal tipburn rating[x]	Head diameter (cm)	Butt width (cm)	Core length (cm)
0	0	—	—	—	—	—	—
56	27.2	673	4.5	0.1	11.2	2.6	3.2
112	35.2	712	4.4	0.9	12.8	2.7	3.5
168	39.2	763	4.3	1.5	13.7	2.8	3.3
224	38.0	770	4.0	1.6	13.1	2.7	3.2
280	37.3	750	4.0	1.4	13.8	2.7	3.0
LSD[z]			0.3	0.5	0.8	NS	NS

[z]Significant at the 5% level or not significant (NS).
[y]5 = firm, 1 = soft.
[x]0 = none, 5 = extensive.

Table 6. Regression models and estimated maximum responses for yields and average head mass for crisphead lettuce responses to N fertilization in Florida 1990-1994.

		Regression model			Estimate of maximum
Season	Variable	Intercept	N	N^2	Response @ Max. N rate kg·ha^{-1}
1990	MT·ha^{-1}	20.1500	0.1700	-0.000534	33.7 MT·ha^{-1} @ 160
	kg/head	0.5300	0.0017	-0.000005	0.67 kg @ 170
1992	MT·ha^{-1}	0.3600	0.3420	-0.000900	32.9 MT·ha^{-1} @ 190
	kg/head	0.0806	0.0063	-0.000017	0.66 kg @ 185
1993	MT·ha^{-1}	6.6030	0.2687	-0.000810	28.9 MT·ha^{-1} @ 165
	kg/head	0.2491	0.0048	-0.000014	0.66 kg @ 170
1994	MT·ha^{-1}	3.0956	0.3948	-0.001004	41.9 MT·ha^{-1} @ 195
	kg/head	0.1052	0.0078	-0.000020	0.87 kg @ 195

flood irrigation led to unequal wetting patterns in Florida's sandy soils (Everett, 1980). Further, drip irrigation permits delivery of nutrients to the plants as needed. The use of drip irrigation also permits double-cropping, since chemicals can continue to be delivered to the second or third crop. Extremes in temperature are common during winter in Florida. Applying all of the fertilizer through the drip tubing provided adequate nutritional levels to the plants.

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PERFORMANCE OF DIRECT SEEDED AND TRANSPLANTED LETTUCE GROWN ON THE SANDY SOILS OF FLORIDA

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Additional index words. Lactuca sativa, plug transplant, leafy vegetable, stand establishment, lettuce yield.

Abstract. **Research on lettuce production on mineral soils in Florida is limited. The present research was designed to determine (1) the potential for lettuce production over a 10-month growing season on sandy soils in northern Florida, and (2) the effect of plant establishment method on overall yields and head quality. Significant seasonal responses and interactions were observed throughout this experiment. Based on this study, marketable yields of lettuce grown in north Florida could be obtained between 15 Sept. and 15 March. The fall planting dates led to greater marketable yields compared to the winter or spring plantings. April plantings resulted in poorest quality and lowest yields of lettuce. 'Desert Queen' produced significantly greater total fresh weight and total marketable yields than 'Maverick' over the entire growing season. Head diameters were within the recommended guidelines for marketable lettuce. Core lengths were longest in direct-seeded lettuce especially early and late in the growing season when field temperatures were high. Transplanted lettuce had earlier harvest, more uniform stands, and generally better head quality compared to direct-seeded lettuce. Polyethylene mulch for fumigation in combinations with drip irrigation for the delivery of water and fertilizer was essential to optimize lettuce production in north Florida.**

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Introduction and Literature Review

During the 1990 vegetable production season, the total harvested acreage of lettuce in the U.S. was 93,677 ha (231,300 acres) having a value of $840 million (Nat'l Agr. Stats. Serv., 1991). The most economically important lettuce types are iceberg or crisphead, romaine (cos), butterhead, bibb, Boston, and leaf lettuce. Three states contribute approximately all of the crisphead lettuce produced in the U.S. California contributes 80% of the market, Arizona supplies 16% and most of the winter crop, and Florida, 4% of the market.

Florida lettuce is grown primarily on the Histosols (muck soils) in the Everglades area of southern Florida. Zellwood and Lake Placid also contribute to the overall production of