formulating and applying TRIA, a general set of conditions could be defined where consistent yield enhancement with TRIA could be achieved for many crops. Several variables were tested, but conditions where some predictable yield response could be obtained were not defined. Without the ability to consistently get a controlled response, it was impossible to thoroughly test any one environmental variable. For example, the effect of stage of crop development could not be conclusively determined if the effect of environmental conditions could not be separated from developmental factors. We have described a set of conditions that will give a higher probability of a positive TRIA effect on yield. Our results support the developing consensus that chemical manipulation of yield is closely linked to cultural protocols and environmental factors (2, 3, 7).

Literature Cited

1. Biernbaum, J.A. 1985. Environmental factors altering the response of plants to triacontanol. PhD Diss., Michigan State Univ., East Lansing.
2. Christy, A.L., D.R. Williamson, P.W. Brown, and R.S. Pirog. 1984. Approaches to yield enhancement—environmental factors. Proc. 11th Annu. Plant Growth Regulat. Soc., 29 July–1 Aug. 1984. Boston.
3. Higgins, J.M., J.T. Cothren, and T.D. Miller. 1984. A preliminary investigation of bioregulants for enhanced wheat production. Proc. 11th Annu. Plant Growth Regulat. Soc., 29 July–1 Aug 1984. Boston.
4. Jones, J., V.F. Wert, and S.K. Ries. 1981. Specificity of 1-triacontanol as a plant growth stimulator and inhibition of its effect by other long-chain compounds. Planta 144:277–292.
5. Laughlin, R.G., R.L. Munyon, S.K. Ries, and V.F. Wert. 1983. Growth enhancement of plants by femtomole doses of colloidally dispersed triacontanol. Science 219:1219–1221.
6. McKeown, A.W. 1982. Increasing the effectiveness of l-triacontanol applied to plants. PhD Diss., Michigan State Univ., East Lansing.
7. Nickel, L.G. 1983. Plant growth regulating chemicals. CRC Press, Boca Raton, Fla.
8. Regehr, D.L. 1982. Dinoseb and triacontanol as growth regulators in irrigated and nonirrigated field corn. Agron. J. 74:111–115.
9. Richman, T.L. 1979. Yield of crops treated with l-triacontranol. MS Thesis, Michigan State Univ., East Lansing.
10. Ries, S.K. 1985. Regulation of plant growth with triacontanol. CRC Crit. Rev. Plant Sci. 2(3):239–285.
11. Ries, S.K. and R. Houtz. 1983. Triacontanol as a plant growth regulator. HortScience 18(5):654–662.
12. Ries, S.K., T.L. Richman, and V.F. Wert. 1978. Growth and yield of crops treated with triacontanol. J. Amer. Soc. Hort. Sci. 103:361–364.
13. Ries, S.K., V.F. Wert, and J.A. Biernbaum. 1984. Inhibition of triacontanol activity by constituents present in agricultural sprayers. J. Amer. Soc. Hort. Sci. 109(2):145–150.
14. Ries, S.K., V.F. Wert, J.A. Biernbaum, T. Gibson, and W.J. Bradley. 1983. Factors altering the response of plants to triacontanol. J. Amer. Soc. Hort. Sci. 108(6):917–922.
15. Welebir, A.J. 1981. Highly effective plant growth stimulating formulations of l-triacontanol containing Ca^{+2} and indole-3-acetic acid. Abstracts of 181st ACS Mtg. AGFD 042, 29 Mar.–3 Apr. 1981. Atlanta, Ga.

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Nitrate Monitoring for Pumpkin Production on Dryland and Irrigated Soils

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Additional index words. *Cucurbita moschata*, critical nitrate level, minimum sufficiency level, plant nutrition

Abstract. **Field experiments were conducted in 1985 and 1986 to determine in-season indexes for petiole NO_3-N in dryland-grown and irrigated pumpkins (*Cucurbita moschata* Poir.). The level of NO_3-N in petioles of recently mature leaves was a good indicator of the seasonal N status for pumpkins on irrigated sand, and to a lesser degree for pumpkins on dryland loam. Petiole NO_3-N concentrations decreased with time and with decreasing N rate at both sites, with the rate and extent of decrease considerably greater on the irrigated sand. The optimum time of sampling was at about initial fruit set or early fruiting. Critical (10% yield reduction) and minimum sufficiency (lowest concentration before yield reduction) levels for petiole NO_3-N at early fruiting were estimated at 6300 and 8000 $\mu g \cdot g^{-1}$, respectively, in dryland and 4000 and 6700 $\mu g \cdot g^{-1}$, respectively, for irrigated plantings. Deficiency symptoms were associated with NO_3-N concentrations < 1500 $\mu g \cdot g^{-1}$. Soil NO_3-N levels proved unsatisfactory as a NO_3-N index in dryland soil, but meaningful relationships ($R^2 = 0.31$) were obtained between fruit yield and soil NO_3-N on irrigated sand. Fertilizer N requirements for 90% and 100% of marketable yield were estimated at 44 and 158 kg N/ha for dryland and 125 and 225 kg N/ha for irrigated pumpkins, respectively. However, N fertilizer rates of 202 and 269 kg N/ha delayed harvest 9 days on irrigated sand and 15 days on dryland loam, compared to lower N rates.**

The relationship between yield and tissue nutrient content and the concept of critical nutrient level as a basis to evaluate the nutritional status of crops is well-established. Ulrich and Hills (16) divided a plant nutrient calibration curve into three segments—deficient, transition, and adequate. Critical nutrient concentration was defined within the transition zone and was associated with a 10% growth reduction (90% of maximum yield). Roberts and Dow (13) regarded the plant nutrient concentration below 95% of maximum yield as the critical nutrient level, and the range of values between the critical level and the optimum concentration (100% of maximum yield) as the critical nutrient range.

Critical concentrations for NO_3-N have been determined for a number of vegetable crops (4, 5, 8). Nitrate in the plant serves

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Table 1. Description of selected soil chemical properties and climatic conditions at experimental sites.

Soil and climatic condition	Dryland Drummer loam 1985	Dryland Drummer loam 1986	Irrigated Maumee sand 1986
Soil analysis (0–200 mm)			
pH (1:1)	6.1	5.9	5.9
Organic matter (%)	4.9	5.6	1.4
N ($kg \cdot ha^{-1}$)	21	25	10
Rainfall (mm)[z]			
May	49	48	5
June	140	108	137
July	111	96	75
August	147	13	38
September	14	0	64
Total	461	265	319

[z]Data are for the period 3 days prior to seeding until 3 days prior to harvest.

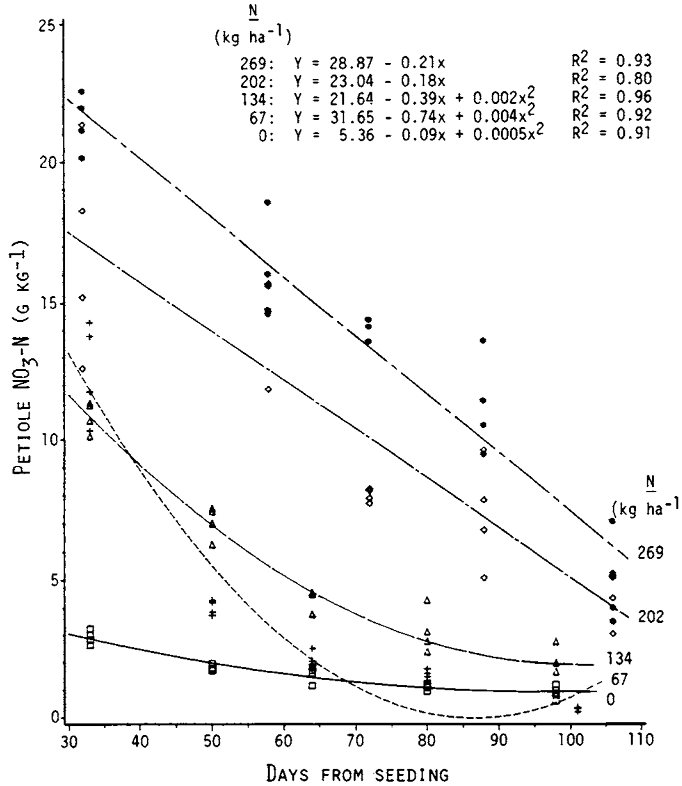

Fig. 1. Relationship between petiole NO_3-N concentration and days from seeding during pumpkin growth on irrigated Maumee sand for five rates of N fertilization.

as a reservoir of unassimilated N, and, until it falls below a critical level, growth and yield are not affected. While total N in the plant results from accumulated N uptake, NO_3-N indicates the N status at a given sampling time.

To be effective in evaluating the nutritional status of plants, critical NO_3-N levels in plant tissues need to be established for various growth stages under various cultural conditions. This type of information would be especially appropriate for pumpkin production in Illinois, where the commercial acreage is almost evenly distributed between irrigated culture on sandy soils, used primarily for the early crop, and dryland culture on heavy soils, used for the main-season and late crop. Recent studies (15) have shown that petiole NO_3-N concentrations in pumpkins are very responsive to N fertilizer and provide a reliable indiction of plant N status under field conditions.

In the research reported here, the relationship between petiole NO_3-N concentration and marketable fruit yield was evaluated at five physiological growth stages for dryland and irrigated pumpkins. The objective of this work was to establish in-season indexes for petiole NO_3-N for pumpkins on dryland and irrigated soils. In the process, the influence of N application rate on fruit yield and quality was determined. Also in this study, an attempt was made to correlate in-season soil NO_3-N with pumpkin yield.

Materials and Methods

Field studies were conducted at the Univ. of Illinois Vegetable Crops Research farm at Urbana on a dryland Drummer silty clay loam (fine silty, mixed mesic Typic Haplaquoll) in 1985 and 1986, and at the Kankakee River Valley Sand Field in Wichert, Ill., on an irrigated Maumee loamy fine sand (sandy mixed, mesic Typic Haplaquoll) in 1986. Soil samples (0 to 20 cm) were taken at each site prior to each experiment. Information on selected soil chemical properties and monthly rainfall data for each experiment is presented in Table 1.

Treatments consisted of five rates (0, 67, 134, 202, and 269 $kg \cdot ha^{-1}$) of N applied as NH_4NO_3, broadcast and incorporated

Table 2. Response of pumpkin fruit yield, fruit number, and cull fruit weight to N rate on dryland (1985 and 1986) and irrigated soil (1986).

N rate ($kg \cdot ha^{-1}$)	Marketable fruit yield ($t \cdot ha^{-1}$) Dryland	Marketable fruit yield ($t \cdot ha^{-1}$) Irrigated	No. marketable fruit/ha Dryland	No. marketable fruit/ha Irrigated	Cull fruit yield ($t \cdot ha^{-1}$) Dryland	Cull fruit yield ($t \cdot ha^{-1}$) Irrigated
0	51.5[z]	36.7[y]	8,211	5,352	6.3	8.1
67	60.0	57.6	9,197	7,937	5.8	8.0
134	61.8	69.2	10,573	10,039	4.0	8.3
202	60.5	75.7	10,185	9,768	6.7	9.6
269	57.3	76.1	9,036	10,371	7.4	10.8
Significance[x]	Q*	L**Q*	L**Q**	L**Q**	NS	NS
Year						
1985	61.2	---	9,861	---	5.4	---
1986	55.2	63.1	9,020	8,693	6.7	9.0
Significance	*	---	NS	---	NS	---

[z]$Y = 50.29 + 0.152x - 0.00048x^2$, $R^2 = 0.29$.
[y]$Y = 37.00 + 0.360x - 0.0008x^2$, $R^2 = 0.83$.
[x]Quadratic (Q), linear (L), nonsignificant (NS), 5% level (*), 1% level (**).

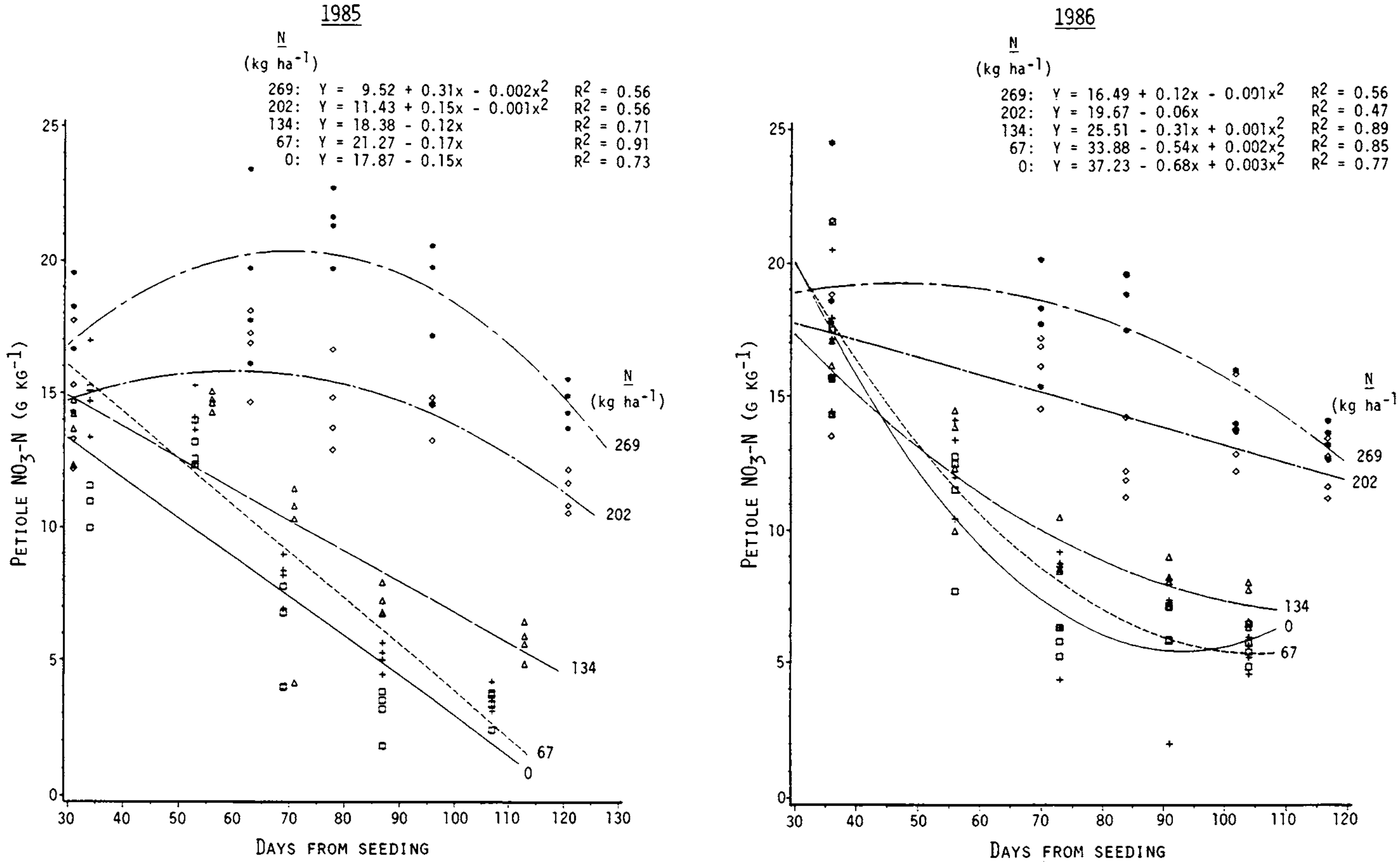

Fig. 2. Relationship between petiole NO_3-N concentration and days from seeding during pumpkin growth on dryland Drummer loam in 1985 and for five rates of N fertilization.

just prior to seeding. Individual plots comprised 115 m^2 (9 × 12.8 m). All treatments on the irrigated sand received 49 kg P/ha as triple-superphosphate and 139 kg K/ha from muriate of potash. No additional fertilizer was applied to the dryland Drummer soil. Overhead sprinkler irrigation was applied to the Maumee sand to provide a total (including rainfall) of 388 mm of water per week. This amounted to a total of nine irrigations: four in August, three in July, and one each in June and September. At each location, N treatments were arranged in a completely randomized design with four replications.

'Libby Select' pumpkin was seeded in hills at 0.46-m intervals in double rows 1.8 m apart and 12 m long in the center of each plot. When seedlings developed two true leaves, hills were thinned to one plant. Composite samples of first fully expanded recently mature leaves closest to the growing tip were taken at growth stages corresponding to vine initiation, initial fruit set, and early, mid-, and late-fruiting (15, 30, and 45 days after fruit set, respectively). Initial fruit set in each plot was designated as the date when six fruit were pollinated, fertilized, and remained on the vine for 3 days. The leaf samples were collected about midday and immediately placed on ice; later, petioles were separated from leaf laminae. When ≈ 75% of fruits in each plot reached maturity, as indicated by fruit size and color change from green to tan, plots were harvested and marketable and non-marketable fruit were counted and weighed.

Petiole samples were dried at 70°C to constant weight and ground in a cyclone mill to pass a 60-mesh sieve. Tissue NO_3-N was determined by shaking 400 mg of tissue in 50 ml of distilled water for 20 min, filtering, and measuring the NO_3-N concentration by ion chromatography (6). Composite soil samples (0 to 20 cm) were obtained from each treatment at the early fruiting stage in each experiment. The samples were dried at 40°, passed through a 2-mm sieve, and soil NO_3-N determined potentiometrically (10), after extraction with 0.01 M $CuSO_4$. Soil organic matter (OM), total N, and pH analyses were made only on the samples taken prior to each experiment. Total soil N was determined by a semimicro-Kjeldahl method (11) and OM by the Walkley–Black method (1). Soil pH was determined on 1 soil : 1 water suspension (v/v).

Data were subjected to analysis of variance for a completely randomized design. Fruit yields expressed as relative yields (percent of maximum) were based on the highest marketable fruit yield for that site. The relationship between relative fruit yield (dependent variable) and petiole NO_3-N was described through an iterative process to achieve a best least-squares fit (14). In this method, the response portion of the curve was fitted with a linear or quadratic equation, and the non-response portion with a horizontal line. The point where the response segment intersected the non-response portion was considered to be the minimum sufficiency level (lowest concentration before yield reduction) for petiole NO_3-N. The procedure of Cate and Nelson (3) for separating data into response groups was used to describe the relationship between soil NO_3-N and relative yield. Regression analyses were conducted to test for significant linear and quadratic effects of N rate on marketable and cull fruit yield and fruit number, and for describing the relationship between petiole NO_3-N concentration and pumpkin stage of development.

Table 3. Relationship between percent maximum marketable fruit yield (Y) and petiole NO_3-N concentration (x) for selected growth stages in dryland and irrigated pumpkins.

Sampling stage[z]	Regression equation (segmented model)[y]	R^2	Petiole NO_3-N Critical level ($\mu g \cdot g^{-1}$)	Min. sufficiency level ($\mu g \cdot g^{-1}$)
	Irrigated sand–1986			
VI	$Y = 17.43 + 11.40x - 0.390x^2$	0.59	9500	14,600
	$Y = 100.7$, if $X_p \geq 14.6$			
FS	$Y = 15.63 + 17.99x - 0.988x^2$	0.76	6000	9,100
	$Y = 97.5$, if $X_p \geq 9.1$			
EF	$Y = 40.57 + 17.24x - 1.292\, x^2$	0.80	4000	6,700
	$Y = 98.1$, if $X_p \geq 6.7$			
MF	$Y = 26.35 + 42.38x - 6.242x^2$	0.87	2100	3,400
	$Y = 98.3$, if $X_p \geq 3.4$			
LF	$Y = 12.22 + 62.73x - 11.377x^2$	0.88	1800	2,750
	$Y = 98.7$, if $X_p \geq 2.75$			
	Dryland loam–1985 and 1986 (combined data)			
EF	$Y = 49.07 + 6.04x$	0.35	6300	8,000
	$Y = 97.4$, if $X_p \geq 8.0$			
MF	$Y = 51.33 + 8.38x$	0.28	4100	5,240
	$Y = 95.2$, if $X_p \geq 5.24$			
	Dryland loam–1985			
MF	$Y = 44.49 + 9.90x$	0.47	4250	5,240
	$Y = 96.4$, if $X_p \geq 5.24$			
LF	$Y = 60.15 + 9.05x$	0.28	2870	3,900
	$Y = 95.4$, if $X_p \geq 3.90$			
	Dryland loam – 1986			
FS	$Y = 38.26 + 5.15x$	0.54	9650	11,550
	$Y = 97.5$, if $X_p \geq 11.5$			
EF	$Y = 55.77 + 4.87x$	0.34	6450	8,440
	$Y = 96.9$, if $X_p \geq 8.44$			
MF	$Y = 62.89 + 4.55x$	0.25	5160	7,720
	$Y = 96.0$, if $X_p \geq 7.27$			

[z]Vine initiation (VI), initial fruit set (FS), early fruiting (EF), mid-fruiting (MF), late-fruiting (LF).

[y]X_p represents petiole NO_3-N concentration ($mg \cdot g^{-1}$) at which yield plateau is reached, and corresponds to the minimum sufficiency level (lowest concentration before yield reduction).

Results and Discussion

Fruit yield and quality. Fruit yield responded to N rate dissimilarly on dryland and irrigated culture (Table 2). On the irrigated sand, yields of marketable fruit increased with N rate up to 202 kg N/ha and then leveled off; on the dryland loam, marketable fruit weight increased primarily for the initial N increment of 67 $kg \cdot ha^{-1}$ and appeared to decrease slightly at 269 kg N/ha. Although marketable yields of dryland pumpkins were higher in 1985 than 1986, the relative response in marketable fruit weight to N rate was the same each year. Pumpkins on the dryland soil yielded marketable fruit up to 65.8 $t \cdot ha^{-1}$ in 1985 and 59.5 $t \cdot ha^{-1}$ in 1986. From the response functions generated from the data, marketable yields at 90% and 100% of maximum were estimated at respective N rates of 44 and 158 kg N/ha in dryland soil and 125 and 225 kg N/ha in irrigated sand.

Fruit quality in dryland and irrigated pumpkins was not affected by N rate, although there was a trend for more cull fruit weight at both locations with increasing N rate, ranging from ≈4 to 11 $t \cdot ha^{-1}$ and associated primarily with immature green secondary fruits. Field observations at both sites indicated that high N rates stimulated excess vine growth, which, on the dryland soil, resulted in a reduction in the number of marketable fruit at 202 and 269 kg N/ha. There was a delay of fruit set with 202 and 269 kg N/ha, averaging 8 days on irrigated soil and 12 days on dryland soil, compared to the other N treatments. This effect carried through the season, with harvest taking place 9 days later on irrigated sand and 15 days on dryland loam with 202 and 269 kg N/ha, compared to lower N rates.

Petiole NO_3-N. On irrigated and dryland soils, petiole NO_3-N concentrations tended to decrease with time and with decreasing N rate (Figs. 1 and 2). The rate and extent of this decrease was considerably greater on the irrigated sand than on the dryland loam. For irrigated pumpkins, particularly, there was a period of rapid depletion of petiole NO_3-N early in the season when levels in the 0, 67, and 134 kg N/ha treatments decreased to $<7500\ \mu g \cdot g^{-1}$ by initial fruit set. The low level of petiole NO_3-N in the control (0 kg N/ha) throughout the season was indicative of the N fertility status of the irrigated sand. Deficiency symptoms in irrigated pumpkins appeared in 0 and 67 kg N/ha treatments shortly after fruit set and were associated with petiole NO_3-N concentrations $<1500\ \mu g \cdot g^{-1}$.

On the dryland soil, the response in petiole NO_3-N concen-

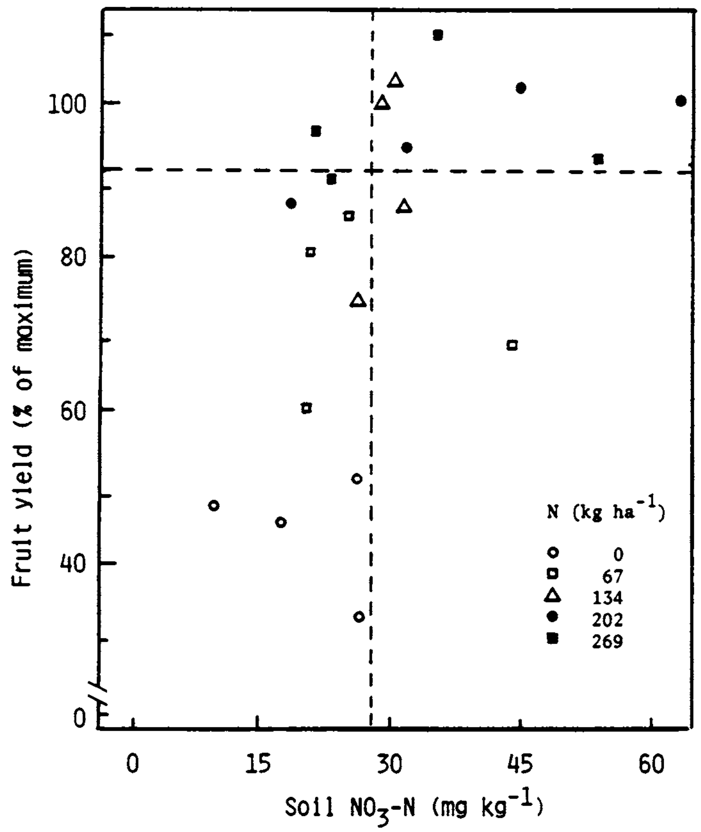

Fig. 3. Relationship between soil NO_3-N (0- to 200-mm depth), at early fruiting, and relative fruit yield in irrigated pumpkins as depicted by a Cate-Nelson (3) plot (sufficient: upper right quadrant, deficient: lower left quadrant).

tration to N rate varied between years (Fig. 2). This occurred primarily at the lower N rates (0, 67, and 134 kg N/ha), when petiole NO_3-N levels in these treatments decreased linearly with time in 1985, but leveled off at the mid- and late-fruiting stages in 1986. Since both sampling dates corresponded to the time in August and September when rainfall in 1986 was extremely low (Table 1), NO_3-N accumulation in these treatments may have been drought-related. Previous studies have found water stress to be associated with increased NO_3-N concentrations in plants (7), even causing toxicity problems in grazing animals (18).

Petiole NO_3-N indexes. Significant relationships between marketable fruit yield and petiole NO_3-N concentration were obtained at all sampling dates for irrigated pumpkins (Table 3). The correlation between petiole NO_3-N and marketable fruit yield generally improved with plant age. Using the functions for best fit, the segmented line models indicated a curvilinear response in marketable fruit weight up to a minimum sufficiency level of petiole NO_3-N (lowest concentration before yield reduction), after which relative yields leveled off as petiole NO_3-N continued to increase. Critical levels (10% yield reduction) of petiole NO_3-N for irrigated pumpkins ranged from 9500 $\mu g \cdot g^{-1}$ at vine initiation to 1800 $\mu g \cdot g^{-1}$ just prior to harvest. The range between critical and minimum sufficiency values decreased as the season progressed.

On the dryland soil, critical and minimum sufficiency levels for petiole NO_3-N could not be predicted consistently (Table 3). Pumpkins showed no deficiency symptoms, even in treatments when no N was applied. Significant correlations between marketable fruit yield and petiole NO_3-N for the combined 2-year data were obtained at the early and mid-fruiting stages. For 1-year data, meaningful relationships between petiole NO_3-N and marketable yield were obtained at mid- and late-fruiting in 1985, and at fruit set, early, and mid-fruiting in 1986. In each case, the observed variability (R^2) in yield attributed to variations in petiole NO_3-N was considerably reduced. The critical and minimum sufficiency values estimated for petiole NO_3-N in dryland soil were higher than on irrigated sand. Although pumpkins on the dryland site appeared to have been influenced by excess available N at 202 and 269 kg N/ha, as suggested by the excess vine growth and concomitant reduction in fruit number, critical values for petiole NO_3-N associated with excess N could not be precisely determined.

Soil NO_3-N indexes. Soil NO_3-N data on the irrigated sand at the early fruiting stage were partitioned into sufficient and deficient classes (Fig. 3) (3). Thirty-one percent of the observed variability (R^2) in relative yield was explained by extractable soil NO_3-N. Relative yields of marketable fruit of 92% were estimated to require extractable soil NO_3-N of 28 $mg \cdot kg^{-1}$. This agrees reasonably well with values reported for sweet potato (9) and tobacco (12), although few published data correlate in-season soil NO_3-N levels with yield. Lack of correlation was evident on dryland loam, where soil NO_3-N results proved too variable to reliably indicate soil N status in either year (data not shown).

Our results indicate that growth stage is very important for correct interpretation of petiole NO_3-N indexes in pumpkin. Despite using petioles of leaves of the same physiological age, critical and minimum sufficiency values estimated for petiole NO_3-N in irrigated and dryland pumpkins varied considerably among growth stages. The optimum time of sampling was at about initial fruit set or early fruiting, which was late enough for meaningful correlation between fruit yield and petiole NO_3-N and early enough to sidedress with N, if necessary. The data suggest that near-maximum fruit yields of pumpkins can be expected if the NO_3-N concentration in petioles of recently mature leaves at early fruiting is $\approx$8000 $\mu g \cdot g^{-1}$. This value appears to be a reasonable approximation for both dryland and irrigated pumpkins, although the actual level may vary depending on growing conditions.

The concentration of NO_3-N in petioles at which N deficiency symptoms appear in pumpkin foliage was $<$1500 $\mu g \cdot g^{-1}$. The critical concentration of petiole NO_3-N at the early fruiting stage was estimated at 4000 $\mu g \cdot g^{-1}$ in irrigated pumpkins and 6300 $\mu g \cdot g^{-1}$ on dryland soil. This compares favorably with previous reports for muskmelon and watermelon, which suggested that 5000 μg NO_3-N/g in petioles at early fruiting was insufficient (8).

The yield responses to N in this study are typical of those observed for commercial pumpkin production in Illinois. Although N requirements for maximum yield were estimated at 158 kg N/ha in dryland and 225 kg N/ha in irrigated pumpkins, very little yield response to N rate occurred above 67 kg N/ha on the dryland soil or above 134 kg N/ha on irrigated sand. The N requirements estimated for 90% maximum yield ranged from 44 kg N/ha in dryland soil to 125 kg N/ha under irrigation. These values are similar to N recommendations (67 to 100 kg N/ha) reported for optimum yields in other vine species (2, 17). Nitrogen rates of 202 and 269 kg N/ha delayed fruit set and harvest in dryland and irrigated pumpkins. Therefore, any yield advantage due to high N fertilization on irrigated soil was negated by the delay in harvest. This is of practical importance since earliness is the primary reasons for pumpkin production on sandy soil. The data suggest that, for early production on irrigated sandy soil, N rates of $\approx$134 kg N/ha would supply N requirements for near-maximum yield, not delay fruit set, and result in optimum ripe fruit load at harvest.

Literature Cited

1. Allison, L.E. 1965. Organic carbon. Methods of soil analysis. Part 2. Agronomy 9:1367–1378.
2. Bhella, H.S. and G.E. Wilcox. 1986. Yield and composition of muskmelon as influenced by preplant and trickle applied nitrogen. HortScience 21:86–88.
3. Cate, R.B. and L.A. Nelson. 1971. A simple statistical procedure for partitioning soil test correlation data into two classes. Soil Sci. Soc. Amer. Proc. 35:648–659.
4. El-Sheikh, A.M., M.A. Abd El-Hakam, and A. Ulrich. 1970. Critical nitrate levels for squash, cucumber and melon plants. Commun. Soil Sci. & Plant Anal. 1:63–74.
5. Gomez-Lepe, B.E. and A. Ulrich. 1974. Influence of nitrate on tomato growth. J. Amer. Soc. Hort. Sci. 99:45–49.
6. Grunau, J.A. and J.M. Swiader. 1986. Application of ion chromatography to anion analysis in vegetable leaf extracts. Commun. Soil Sci. Plant Anal. 17:321–335.
7. Iversen, K.V., R.H. Fox, and W.P. Piekielek. 1985. The relationship of nitrate concentrations in young corn stalks to soil nitrogen availability and grain yield. Agron. J. 77:927–932.
8. Lorenz, O.A. and K.B. Tyler. 1978. Plant tissue analysis for vegetable crops. Soil and plant-tissue testing in California. Univ. of Calif. Bul. 1879.
9. Mascianica, M.P., R.R. Bellinder, B. Graves, R.D. Morse, and H. Talleyrand. 1985. Forecasting of N fertilizer requirements for sweet potatoes. J. Amer. Soc. Hort. Sci. 110:358–361.
10. Mills, H.A. 1980. Nitrogen specific ion electrodes for soil, plant and water analysis. J. Assn. Official Anal. Chem. 63:797–801.
11. Nelson, D.W. and L.E. Sommers. 1980. Total nitrogen analysis of soil and plant tissue. J. Assn. Official Anal. Chem. 63:770–778.
12. Peterson, L.A. and O.J. Attoe. 1965. Importance of soil nitrates in determination of need and recovery of fertilizer nitrogen. Agron. J. 57:572–574.
13. Roberts, S. and A.I. Dow. 1982. Critical nutrient ranges for petiole phosphorus levels of sprinkler-irrigated russet Burbank potatoes. Agron. J. 74:583–585.
14. SAS Institute. 1982. SAS user's guide: statistics. SAS Institute, Cary, N.C.
15. Swiader, J.M. 1983. Seasonal nitrogen evaluations in pumpkin, p. 27–30. In: J.M. Swiader (ed.). 1983 Illinois Vegetable Research Report. Univ. of Illinois, Urbana-Champaign. Hort. Ser. 47.
16. Ulrich, A. and F.J. Hills. 1973. Plant analysis as an aid in fertilizing sugar crops: Part I. Sugar beets, p. 271–288. In: L.M. Walsh and J.D. Beaton (eds.). Soil testing and plant analysis. Soil Sci. Soc. Amer., Madison, Wis.
17. Wilcox, G.E. 1973. Muskmelon response to rates and sources of N. Agron. J. 65:694–697.
18. Wright, M.J. and K.L. Davison. 1964. Nitrate accumulation in crops and nitrate poisoning in animals. Adv. Agron. 16:197–247.

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Stand Deficiencies and Replanting Effects on Tomato Fruit Yields and Size

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Abstract. **The effects of replanting stand-deficient plots on marketable tomato (*Lycopersicon esculentum* Mill.) fruit size and yields were investigated at Bradenton, Fla. during the 1986 spring and fall seasons. Treatments consisted of a control (10-plant plot) and plots with 9, 8, and 7 (10%, 20%, and 30%) missing plants. Other plots with the same stand deficiency were replanted to attain a complete stand 2 or 3 weeks and 1, 2, or 3 weeks after initial transplanting in the spring and fall experiments, respectively. Plots with 30% stand reduction produced a lower weight and number of marketable fruit per hectare than control plots in both seasons. In spring, replanting stand-deficient plots did not increase marketable fruit yields relative to plots not replanted, regardless of the time of replanting or percentage of stand reduction. In fall, under an unfavorable environment due to a late infestation of bacterial spot, replanting plots with 30% stand reduction increased marketable fruit yields over similar plots that were not replanted, when the replanting occurred 1 or 2 weeks after initial transplanting, but not when replanting was delayed 3 weeks. Small, medium, or extra-large marketable fruit weight per hectare were similar in both seasons for plots with 30% stand reduction, whether replanted or not. Mean fruit size (g/fruit) did not differ significantly among treatments in either experiment. These results suggest that replanting improved marketable tomato yields only when the level of stand deficiency reached 30% and only in a stressed environment.**

Tomato plant losses during or shortly after stand establishment can be associated with poor-quality transplants, plant injury by various pests, unfavorable environmental conditions, or inadequate management of cultural practices. However, transplant losses generally are variable within and between commercial tomato fields. Most growers will replant stand-deficient fields within 2 weeks after initial transplanting. The decision to replant is based on the extent of plant losses and the economic climate of the season. Growers usually determine the reduction of stand establishment by subjective visual observations of their fields.

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