Nitrogen Fertilization of Radishes on Histosols: Response and ¹⁵N Recovery

C.A. Sanchez, H.Y. Ozaki, K. Schuler, and M. Lockhart
University of Florida, Institute of Food and Agricultural Sciences,
Everglades Research and Education Center P.O. Box 8003, Belle
Glade, FL 33430

Additional index words. isotopic N, organic soils, *Raphanus sativus*

Abstract. Experiments were conducted from 1985 to 1989 to evaluate the response of radishes (*Raphanus sativus* L.) to N fertilization on Histosols. Three of these experiments used ¹⁵N-labeled fertilizer to evaluate the recovery of N by radishes. There was no response to N fertilization in seven of the eight experiments, even though some of them were conducted under conditions of high rainfall. The one experiment in which radish yields increased with N was conducted in a poorly drained, waterlogged field that was atypical of normal radish production fields. Recoveries of fertilizer N in the marketable radish roots averaged 19%. The results of N and ¹⁵N analysis showed that although fertilizer N was available for uptake, so was an ample amount of soil mineralized N. These results indicate that under typical growing conditions, radishes produced on Florida Histosols do not respond to N fertilization.

More than 20,000 ha of radishes are produced on organic soils (Histosols) in the United States and Canada. Nitrogen mineralized from Histosols ranges from 200 to 1500 kg·ha⁻¹ annually, depending on soil depth, management practices, and environmental conditions (Guthrie and Duxbury, 1978; Isirimah and Keeney, 1973; Reddy, 1982; Terry, 1980). However, not all mineralized N is available to crops because of denitrification and leaching losses (Duxbury and Peverly, 1978; Terry and Tate, 1980; Terry et al., 1981).

Nitrogen fertilizer is recommended for radishes produced on Histosols in several states (Rehm et al., 1986; Sanchez, 1990; Warncke et al., 1985). However, we have little basis for the current N recommendations for radishes in Florida and were unable to identify relevant research reports from areas outside of Florida.

Studies were conducted from 1985 to 1989 to evaluate the response of radishes grown on Histosols to N fertilization and to determine recovery of fertilizer N (Table 1). Experiments 85a, 85b, 86, and 87c were

conducted on Pahokee muck (euic, hyperthermic Lithic Medisaprist); experiments 87a and 87b were conducted on a Terra Ceia muck (euic, hyperthermic Typic Medisaprist), and experiments 88 and 89 were conducted on Okeelanta muck (euic, hyperthermic Heroic Medisaprist).

Plots were 6.0 m long × 6.7 m wide and were arranged in randomized complete block designs with four to six replications. Phosphorus and K were applied to each experiment as recommended by preplant soil tests (Sanchez, 1990). Micronutrients were applied to all plots to supply Zn, B, and Mn at 9.0, 1.1, and 9.0 kg·ha⁻¹, respectively. The Zn and Mn were applied as sulfates, and B was applied as Solubor. The K, P, and micronutrients were applied preplant and disked into the soil before seeding. ¹⁵N-labeled fertilizer was used in Expts. 87c, 88,

and 89 to determine the uptake and recovery of N applied. 'Red Devil' radish was seeded with a between-row spacing of 23 cm and a within-row spacing of 2.5 cm to give an approximate population of 165 plants/m². Sub-surface irrigation was provided from field ditches to maintain a water table depth at ≈40 cm, although this was not possible in Expt. 85b.

Experiments 85a and 85b. Nitrogen was applied as ammonium nitrate at rates of 0, 56, 112, and 186 kg N/ha. The N was broadcast and disked into the soil before planting.

Experiments 86, 87a, and 87b. Nitrogen fertilizer was applied as urea-ammonium-nitrate solution (UAN, 32% N) at rates of 0 and 56 kg N/ha. The N fertilizer was sprayed on the surface and tilled into the soil at planting.

Experiment 87c. Nitrogen rates were 0, 25, 50, and 75 kg N/ha applied both as ammonium nitrate and ammonium sulfate. ¹⁵N-depleted (0.01 atom% ¹⁵N) fertilizers were substituted for unlabeled fertilizer on 1-m² subplots within the main yield plots. This subplot size was determined to be adequate for determining N recovery by radishes using methods described previously (Sanchez et al., 1987). All N fertilizer was applied as a top-dress and cultivated into the soil 1 week after planting.

Experiments 88 and 89. Nitrogen rates were 0, 25, and 50 kg·ha⁻¹ applied as ammonium nitrate, ammonium sulfate, and potassium nitrate. Although ¹⁵N-depleted fertilizers permit accurate calculation of N fertilizer recovery by plants, they do not give sufficient sensitivity to calculate the fertilizer N remaining in soils, particularly in soils having large pools of indigenous N. Hence, ¹⁵N-enriched fertilizer was used in these experiments so that we could calculate the fertilizer N remaining in the soil. ¹⁵N-enriched (5 atom%) fertilizer was substituted for unlabeled fertilizer on 1-m² subplots within the

Table 1. Planting date, harvest date, and weather data for eight radish experiments conducted from 1985 to 1988.

Expt.	Planting date	Harvest date	Mean temp (°C)	Solar [‡] radiation (W·m ⁻²)	Rainfall (mm)	Pan evaporation (mm)	Marketable yield [‡] (t·ha ⁻¹)
85a	26 Mar.	22 Apr.	19.2	172	130	164	6.0
85b	12 Apr.	6 May	22.2	172	158	149	5.6
86	27 Feb.	31 Mar.	15.6	167	129	265	6.0
87a	16 Dec.	19 Jan.	15.3	107	115	85	7.7
87b	1 Feb.	4 Mar.	16.7	119	60	106	9.5
87c	20 Feb.	30 Mar.	19.2	149	169	152	4.9
88	15 Jan.	25 Feb.	16.1	135	113	202	7.1
89	20 Feb.	17 Mar.	15.0	138	58	107	10.5

[‡]Mean daily average.

[‡]Mean across all N treatments.

Received for publication 11 July 1990. Univ. of Florida Expt. Sta. Journal Series no. R-00839. We thank A. Duda and Sons, Hundley Farms, Roth Farms, and Chapman and Sons Farms for providing the experimental sites used in these studies and part of the crop care. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Table 2. Amount of labeled fertilizer accounted for at harvest of radishes in Expts. 88 and 89.

Expt.	N rate (kg·ha ⁻¹)	Fertilizer N (kg·ha ⁻¹) ²		
		Plants ¹	Soil ²	Total
88	25	10.1	4.6	14.7
	50	14.2	9.9	24.1
89	25	10.1	14.8	24.9
	50	19.1	23.8	42.9

¹Mean across N sources.

²Includes both marketable (roots) and unmarketable (leaves and roots) plant parts.

*Amount of fertilizer remaining in the top 30 cm of soil.

Fig. 1. Total N and fertilizer-derived N (FN) recovered in the marketable radish roots as affected by N rate and source [ammonium nitrate (AN), ammonium sulfate (AS), and potassium nitrate (PN)] in Expts. 87c, 88, and 89. Fertilizer-derived N was significantly ($P < 0.01$) increased by N rate in all experiments. Total N was significantly ($P < 0.05$) increased by N rate, first increment, only in Expt. 89. Total N and fertilizer N were significantly ($P < 0.05$) higher with AN than with AS and PN in Expt. 89. No other effects were statistically significant at $P = 0.05$.

main yield plots. All N fertilizers were applied as a topdress and cultivated into the soil 1 week after planting.

Radish yields were measured by removing the middle four 3-m sections of row from each plot. The radishes were graded using standard marketing criteria (U.S. Dept. of Agriculture, 1968). Marketable yields were determined after excluding undersized and oversized radishes and those with growth cracks or discoloration. At maturity, whole-plant samples were collected from the center of the ¹⁵N-enriched subplots in experiments 87c, 88, and 89. All plant material was dried at 60°C and ground for analysis. After harvest, soil samples were taken from the yield plots and from the center of the ¹⁵N-enriched subplots at depths of 0 to 15 cm and 15 to 30 cm. The soil samples were then frozen

until analysis. The permanganate-reduced Fe modification of the Kjeldahl procedure was used to determine the N content of plant and soil samples (Bremner and Mulvaney, 1982). Isotope ratio analyses were performed by reacting the resulting distillate with sodium hypobromite and injecting the resulting N₂ into a mass spectrometer. Calculations of fertilizer N recovery were performed as described by Hauck (1982). In Expts. 86, 87a, 87b, 87c, 88, and 89, leaf tissue was digested with H₂SO₄ and H₂O₂ and analyzed for P calorimetrically; K by flame emission spectroscopy; Ca, Mg, Fe, Zn, Mn, and Cu by atomic absorption spectroscopy; and B by inductively coupled plasma spectroscopy.

Statistical analyses were performed using the SAS-GLM procedure (SAS, 1982). In Expts. 86, 87a, and 87b, only the main effect of N was tested. In experiments 85a and 85b, the response to N rates was tested by trend analysis. In Expts. 87c, 88, and 89, where more than one N source was evaluated, N rate, N source, and interactions were tested for significance.

Marketable radish root yields ranged from 4.7 to 11.1 t·ha⁻¹ in Expts. 85a through 89 (Table 1), a range that nearly coincides with the 4 to 11 t·ha⁻¹ commonly obtained by growers in Florida. Under adverse growing conditions, such as those encountered in Expts. 85b and 87c, growth cracking, root discoloration, and other marketing defects limited yields to less than half the theoretical maximum for this planting density. However, when conditions were nearly ideal, as in Expt. 89, marketable radish root yields were close to the likely maximum yield of 11.5 t·ha⁻¹. Results of tissue analysis conducted in Expts. 87a, 87b, 87c, 88, and 89 showed that concentrations of P, K, Ca, Mg, Fe, Zn, Mn, and B in radish leaves were all within sufficiency ranges and not limiting to growth and yield (data not shown).

Nitrogen fertilization produced a significant ($P < 0.05$) linear increase in radish root yields in Expt. 85b. Radish root yields were 3.8, 5.7, 5.8, and 6.9 t·ha⁻¹ at 0, 56, 112, and 168 kg N/ha, respectively. There was no response to N fertilization (rate or source) in the seven other experiments. Several of these experiments were conducted under conditions of high rainfall (Table 1) and, presumably, under conditions conducive to large N losses. However, the water table on all sites, except 85b, was managed as recommended for optimal radish production (Snyder et al., 1978). Experiment 85b was conducted on a poorly drained, waterlogged field with limited water control. Denitrification of soil-mineralized N probably created conditions where N was restricting crop growth on this site. Nevertheless, because of diseases and other problems associated with poor water control, radish production would not be recommended and would almost never occur on such a site. Hence, we must conclude that under typical growing conditions, radishes produced on Florida Histosols do not respond to N fertilization.

The total amount of N (soil- and fertilizer-derived N) recovered in the marketable rad-

ish roots averaged 30, 52, and 57 kg·ha⁻¹ in Expts. 87c, 88, and 89, respectively, closely following the trend in marketable root yields (Fig. 1). The total amount of fertilizer-derived N in the marketable crop these same years averaged 2, 8, and 8 kg·ha⁻¹, indicating most of the N accumulated was derived from soil mineralization. In Expts. 87c and 88, the amount of accumulated fertilizer N increased with N rate, but the amount of accumulated total N remained unchanged, indicating that fertilizer N merely substituted for soil-derived N. In Expt. 89, N fertilization increased N uptake, particularly the ammonium nitrate, but because radish yields were not significantly increased, it must be concluded that this increased N uptake was luxury consumption.

The amount of fertilizer N in the marketable roots expressed as a percentage of the amount applied ranged from 6% to 35%, with an average of 19% (Fig. 1). Furthermore, the total amount of fertilizer N accounted for in the whole plant and remaining in the soil to a depth of 30 cm at harvest averaged 50% during a relatively moist season (Expt. 88) and averaged 95% during a relatively dry season (Expt. 89) (Table 2). Although N losses from the rooting zone varied with environmental conditions, appreciable amounts of ¹⁵N-labeled fertilizer remained available for crop uptake even during the moist season.

Overall, results show that although fertilizer N was available for crop uptake, so were ample amounts of mineralized soil N. Based on this information, N fertilizer recommendations for radishes produced on Histosols in Florida will be discontinued. Perhaps, N fertilizer recommendations for radishes produced on Histosols in other areas should be reevaluated.

Literature Cited

- Bremner, J.M. and C.S. Mulvaney. 1982. Nitrogen-total, p. 595-624. In: A.L. Page (ed.). Methods of soil analysis. Part 2. Agronomy. vol. 9. Amer. Soc. Agron., Madison, Wis.
- Duxbury, J.M. and J.H. Peverly. 1978. Nitrogen and phosphorus losses from cultivated organic soils. J. Env. Quality 7:566-570.
- Guthrie, T.F. and J.M. Duxbury. 1978. Nitrogen mineralization and denitrification in organic soils. Soil Sci. Soc. Amer. J. 42:908-912.
- Hauck, R.D. 1982. Nitrogen isotope ratio analysis, p. 735-776. In: A.L. Page (ed.). Methods of soil analysis. Part 2. Agronomy. vol. 9. Amer. Soc. Agron., Madison, Wis.
- Isirimah, N.O. and D.R. Keeney. 1973. Nitrogen transformations in aerobic and waterlogged Histosols. Soil Sci. 115:123-129.
- Rehm, G.W., C.J. Rosen, J.F. Moncrief, W.E. Fenster, and J. Grava. 1986. Guide to computer programmed soil test recommendations for field crops in Minnesota. Ext. Bul. AG-BU-0519.
- Reddy, K.R. 1982. Mineralization of nitrogen in organic soils. Soil Sci. Soc. Amer. J. 46:561-566.
- Sanchez, C.A. 1990. Soil testing and fertilizer recommendations for crop production on organic soils in Florida. Univ. Florida Tech. Bul. 876.
- Sanchez, C.A., A.M. Blackmer, R. Horton, and D.R. Timmons. 1987. Assessment of errors associated with plot size and lateral movement of

- nitrogen-15 when studying fertilizer recovery under field conditions. *Soil Sci.* 144:344-351.
- SAS Institute, Inc. 1982. SAS user's guide: Statistics. SAS Institute, Inc., Cary, N.C.
- Snyder, G.H., H.W. Burdine, J.R. Crockett, G.J. Gascho, D.S. Harrison, G. Kidder, J.W. Milshoe, D.L. Myhre, F.M. Pate, and S.F. Shih. 1978. Water table management for organic soil conservation and crop production in the Florida Everglades. Univ. Florida Tech. Bul. 801.
- Terry, R.E. 1980. Nitrogen mineralization in Florida Histosols. *Soil Sci. Soc. Amer. J.* 44:747-750.
- Terry, R.E. and R.L. Tate, III. 1980. Denitrification as a pathway for nitrate removal from organic soils. *Soil Sci.* 129:162-166.
- Terry, R.E., R.L. Tate, III, and J.M. Duxbury. 1981. Nitrous oxide emissions from drained, cultivated organic soils of Florida. *Air Pollut. Control Assoc. J.* 31:1173-1176.
- U.S. Department of Agriculture. 1968. United States standards for grades of radishes. Agr. Mktg. Ser., Washington, D.C.
- Warncke, D.D., D.R. Christenson, and M.L. Vitosh. 1985. Fertilizer recommendation: Vegetable and field crops in Michigan. Michigan State Univ. Ext. Bul. E-550.