IRRIGATION AND NITROGEN FERTILITY OF PEPPERMINT IN CENTRAL OREGON, II. NITRATE LEACHING*

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Abstract

The irrigation by nitrogen fertilizer study provided an opportunity to study nitrate leaching under different inputs of both. Passive capillary samplers below the root zone indicated that there was no leaching of water or nitrate during the summer and fall of 1992, but leaching occurred during the winter precipitation period in 1993. Soil profile nitrate concentrations were measured to determine the loss of nitrate for each treatment.

Introduction

Nitrate is a potential contaminant of groundwater at levels above 10 mg/1 nitrogen (N). Non-point source nitrate originates in animal manures and commercial fertilizers, especially for high-valued crops where nitrogen is abundantly applied and the root zone is shallow. The fundamental question is how much nitrogen is required to produce optimum yields of peppermint, and how much nitrate is lost below the root zone.

With growing concern over environmental pollution, including agricultural contributions of N in the form of nitrate to groundwater, it is imperative to know the N rates for optimum economic yield, as well as N rates for minimal groundwater contamination. The present N-fertilization practice for central Oregon is to apply a total of 250-300 lb/ac of N to a peppermint crop divided into several applications. Although peppermint yields best under high N fertilization, the fact that multiple applications are practiced suggests that much of the N is lost. Only 150 lb/ac of N is accounted for by the above-ground plant (Hee, 1974). The remaining 100-150 lb/ac may be lost below the root zone due to excessive irrigation. The process of nitrification transforms fertilizer N to nitrate, a very soluble N form which is then susceptible to being carried below the root zone by excess applied water.

Tested together, irrigation and nitrogen factors will provide data on the amount of N lost below the root zone. The loss of N due to leaching beyond the root zone is a water management as well as a fertilizer management problem. These two studies are being conducted together in order to study the interactions of irrigation and N.

Objectives

The objective was to investigate management practices for their effect on nitrate leaching

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beyond the root zone.

Materials and Methods

Leaching of Nitrate

Passive capillary samplers (PCAPS) were designed and built by Dr. John Selker, OSU Dept. of Bioresource Engineering, based on the design of Boll et al. (1992). Twelve PCAPS were installed in the peppermint plots on April 23, 1992. The samplers (12.8 inches by 34.1 inches at the top by 20 inches deep) were buried with the top placed at the interface between the soil and the hard pan, which was 24 to 29 inches deep. The PCAPS were placed in the I3, I4, and I5 levels of nitrogen plots N0, N2, N5, and N6 as shown in Figure 1. (For information on the irrigation and nitrogen treatments, see pages 54 and 55 of the previous report, "I.Yield and Oil Quality".)

As shown in Figure 2, the PCAPS, or wick lysimeters, were designed to collect the water that passes through the root zone into the vadose zone, the unsaturated soil that exists between the root zone and the ground water table. Wicks on the top face of a PCAPS extend to three collection jars located 18 inches below the top. This design provides for water collection with a small negative tension, or without requiring soil saturation, usually an unnatural condition in the arid zones. Water was collected from four small tubes connected to the three jars and to the overflow, and the tubes were extended to a manifold at the edge of the field 50 ft away. A vacuum pump was used to collect the leachate that was later analyzed for ingorganic N.

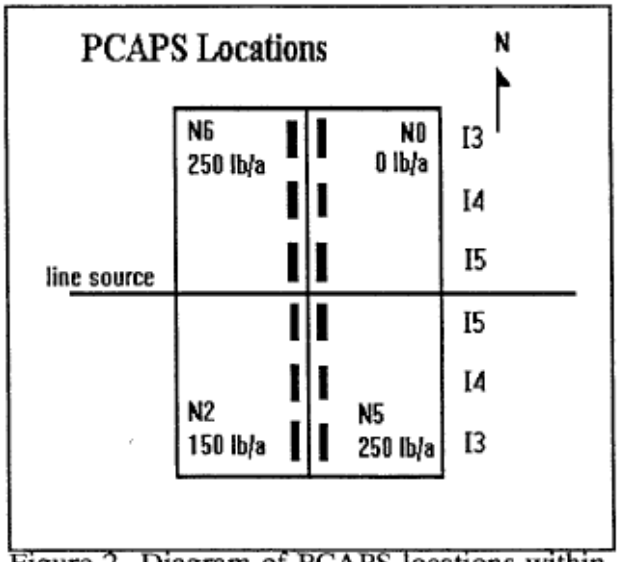


Figure 2. Diagram of PCAPS locations within the line-source sprinkler experiment established April, 1992 at Madras, OR.

Figure 2. Passive capillary sampler installed in April 1992 at Madras, OR.

Soil sampling for nitrate and ammonia determination was conducted in the first and second replication. Soil cores were taken to a depth of 5 ft with a hand core sampler for the top 2 ft, and a hydraulic core sampler for the remaining 3 ft. The soil was extracted with 2 N KC1 then analyzed for inorganic N (Wescan Model 360, Alltech Assoc. Inc., Deerfield, IL).

Results

Leaching of Nitrate--PCAPS

Throughout 1992, the PCAPS samplers did not intercept any water during the growing season. The neutron probe and Watermark data showed water contents were not at saturation near the PCAPS, which corroborated our conclusion of no leaching.

In March 1993, leachate was obtained from the PCAPS. High winter precipitation likely contributed to the leaching. A weather station within 1,000 ft of the site measured 7.11 inches of precipitation from October 1992 to March 19, 1993, the date of our first PCAPS sample. No readings were taken during that winter period due to snow accumulation. Because the samples sat in the PCAPS the entire winter, we do not know the time that leaching occurred. Also, many of the PCAPS collection bottles were full, which may have underestimated the leachate depth. It is also important to keep in mind that the peppermint was replanted over the PCAPS in May 1992, and that during the season, the plants were not at full cover.

The nitrogen concentration (nitrate plus ammonia), leachate depth, and total nitrogen loss of the PCAPS solutions are shown on the following pages in Figures 3, 4, and 5, respectively. These graphs are designed to show the PCAPS data with irrigation level constant in the vertical direction, and N level constant in the horizontal direction. Increasing levels of irrigation and N are downward and to the right.

The nitrogen concentration of the leachate (Figure 3) ranged from a low of 20 mg/1 to a high over 300 mg/1, an order of magnitude difference. The USEPA drinking water standard is 10 mg/l. In general, N6 (250 lb/ac) had the highest concentration and N2 (150 lb/ac) the lowest. The NO treatment was fertilized at a 250 lb/ac rate during establishment in 1991 and the medium rate may be a result thereof. The highest irrigation level, 15, consistently had the highest concentration.

Concentration must be considered with the total leachate. In Figure 4 the March leachate is colored in black. Although all plots (supposedly) received the same precipitation, the March leachate was highly variable. During the summer of 1993 the PCAPS showed some leaching in the IS irrigation treatment, but relatively little in the 14 and 13 irrigation levels. As mentioned previously, the 1993 irrigation was managed to be in excess for the IS treatment. These results showed that little, if any, nitrate was lost during the growing season under well managed irrigation. Thus the leaching of nitrate occurs primarily during the winter months, December to March, when central Oregon receives over half its precipitation.

Figure 3. Nitrogen concentration (nitrate plus ammonium) of PCAPS leachate, Madras, OR, 1993.

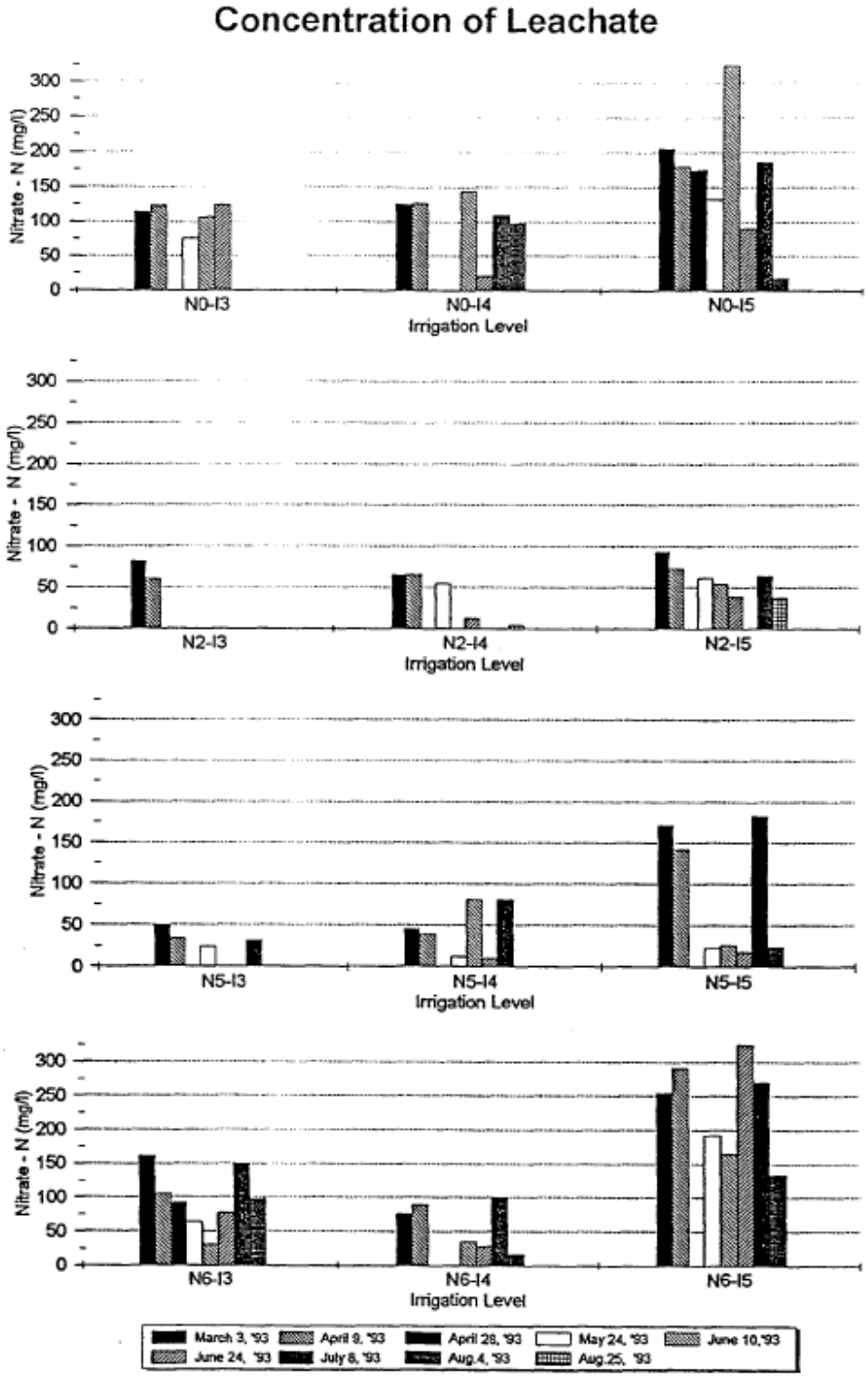


Figure 4. Quantity of PCAPS leachate, Madras, OR, 1993.

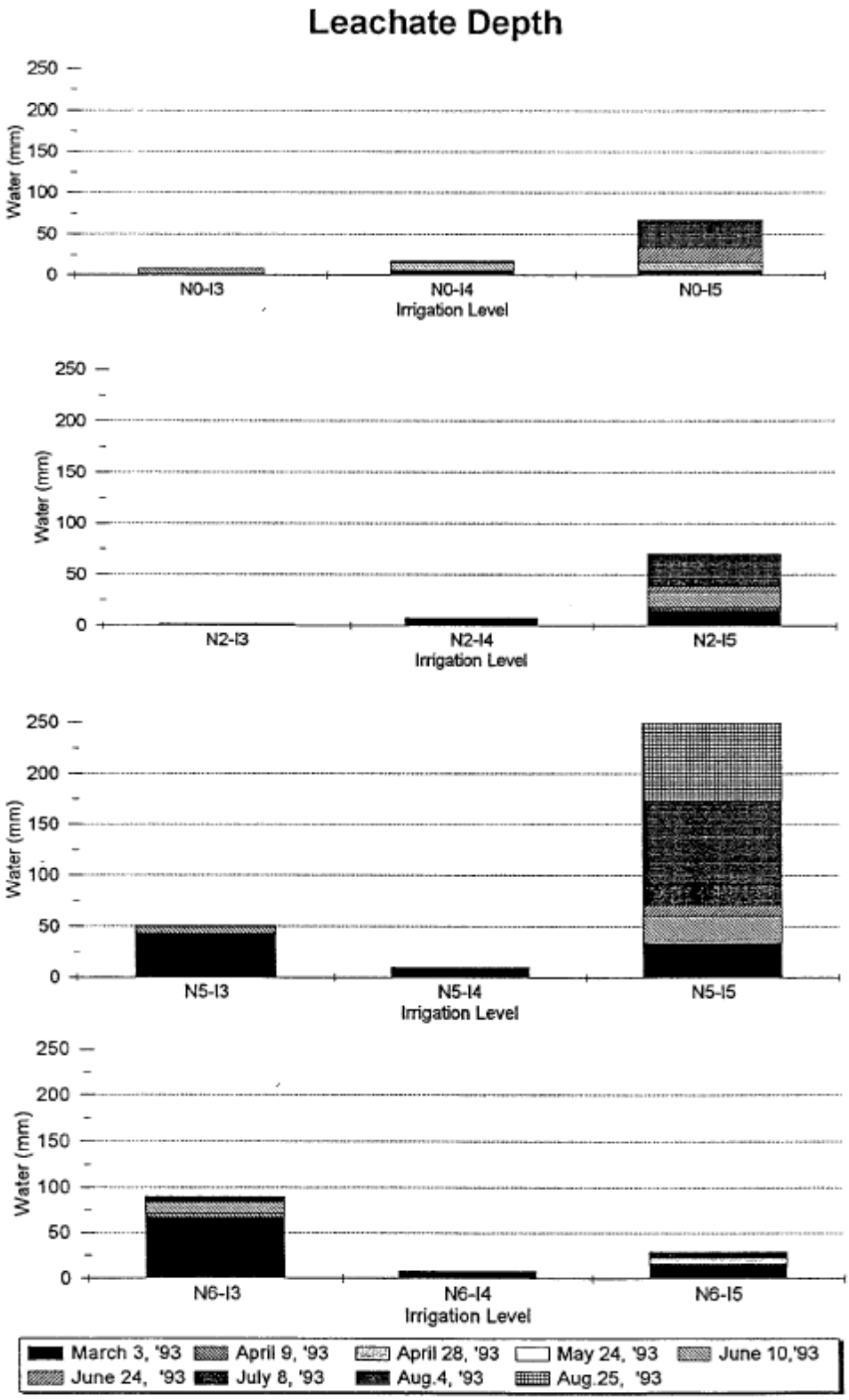
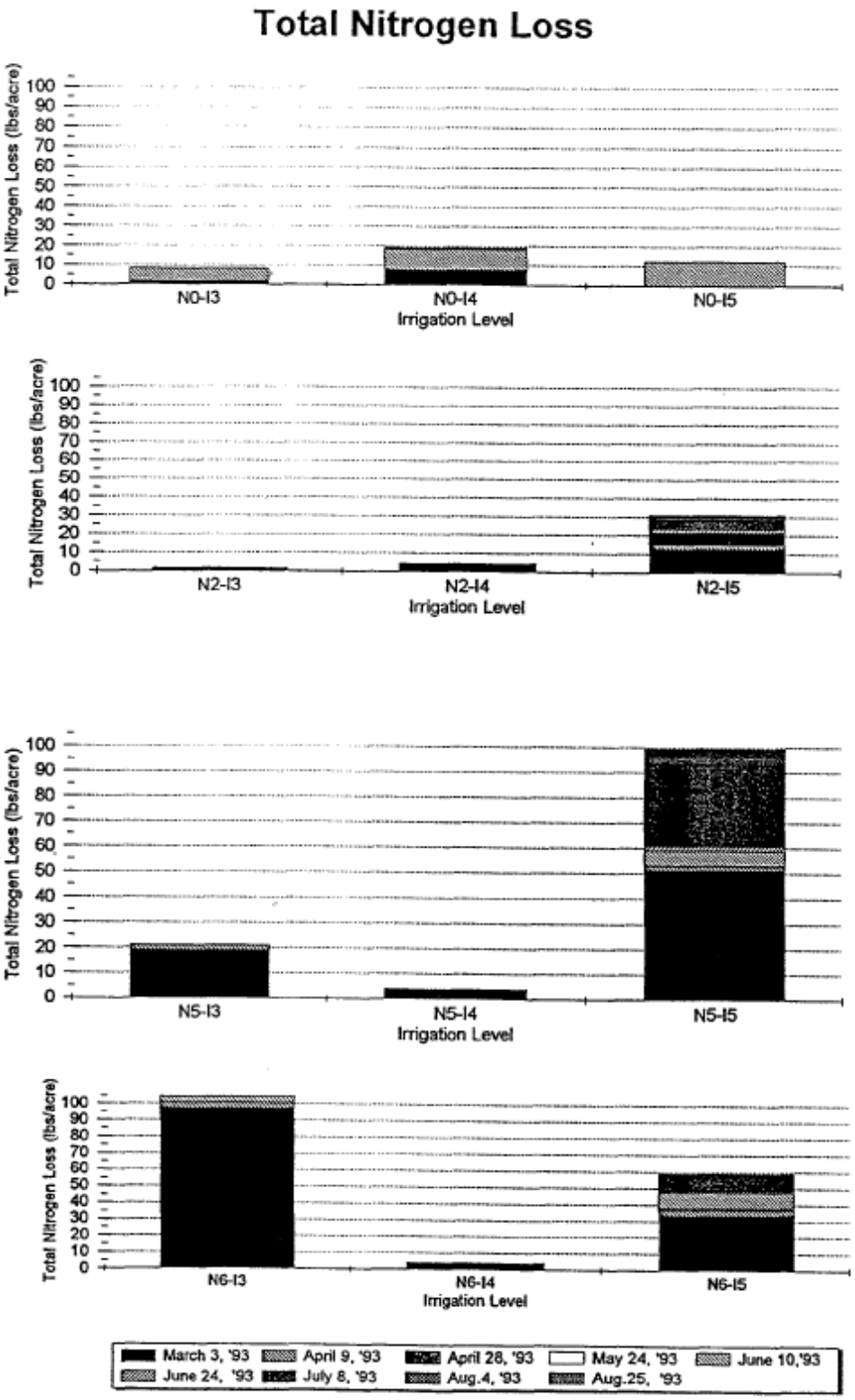


Figure 5. Total nitrogen loss from soil monitored by PCAPS samplers, Madras, OR, 1993.



Total nitrogen loss is shown in Figure 5. Expected trends prevailed with more N loss under high fertilizer and higher irrigation level. However, for the high fertility treatments, the I4 irrigation level was much lower than the I3 and I4 levels. The N6-I3 PCAPS sampler was much higher than the rest with the equivalent of an 100 lb/ac N loss.

Nitrate Leaching--Soil Samples

Soil samples taken in winter of 1991, prior to initiation of the project, and in the fall of 1991 indicated that nitrogen had increased at the 5-ft depth below the root zone (Mitchell, 1991) The data showed that the initial 10-mg/l soil N level had increased to 20 to 40 mg/l. The nitrate peak at the 5-ft depth indicated to us, at that time, that nitrate leaching had occurred to a depth of 5 ft, although sampling contamination may have been at fault.

More recently, soil samples taken in March 1993 in the plots near the PCAPS show soil inorganic nitrogen at levels near 25 mg/l (Figures 6 and 7). In order to compare with the PCAPS samples, one must divide the level by the soil water content, or approximately 0.30 g water/ g soil. The result is approximately 85 mg/l N in solution, which compares well with the PCAPS concentrations (Figure 3).

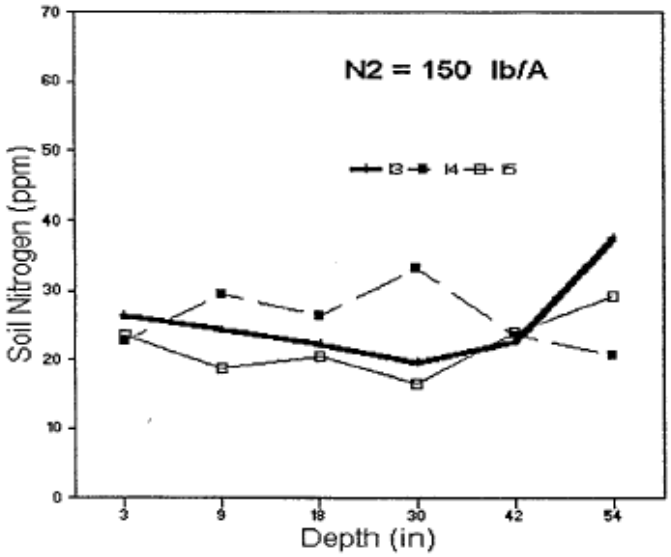


Figure 6. Soil inorganic nitrogen for the N2 treatment sampled March 1993, Madras, OR.

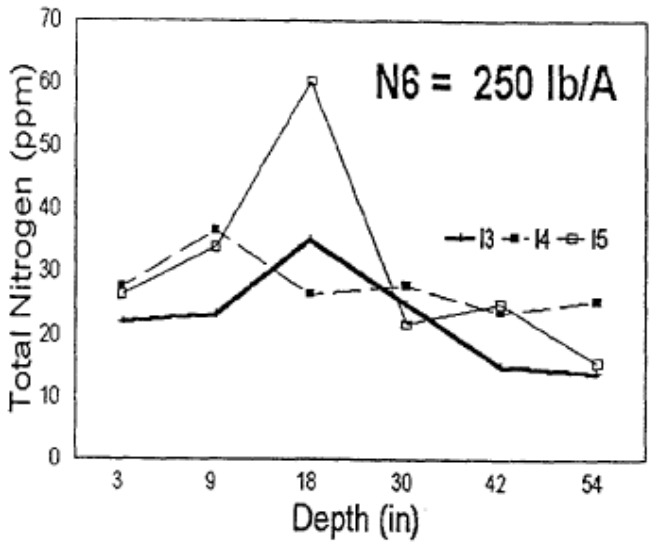


Figure 7. Soil inorganic nitrogen for the N6 treatment sampled March 1993, Madras, OR.

The other noticeable information in the soil data is effect of the irrigation level on nitrate content. For treatment N6 (Figure 7), the highest irrigation level I5 showed a sharp N peak at 18 inches, which is the B horizon. Other than that, there appears to be no consistent irrigation effect on nitrate concentration. One explanation may be that differential irrigation was applied only in spring and summer, while like amounts were applied in the fall and, of course, during winter precipitation.

Summary

Passive capillary samplers (PCAPS) were installed at the bottom of the root zone, and indicated that water and nitrate leach during the winter and under high irrigation. Nitrate concentrations in the soil water below the root zone were found to be greater than the drinking water standard.

Although there is much soil data still to be analyzed, the PCAPS data indicated that winter leaching can occur on all treatments, but that summer leaching was miminal for this soil/crop system unless excess irrigation was applied. For 1993, the total nitrogen lost was highly variable between 5 and 100 lb/ac/yr.

References

Boll, J., J.S. Selker, and T.S. Steenhuis. 1992. Fiberglass wicks for sampling water and solutes in the vadose zone. Soil Sci. Soc. Am. J. 56:701-707.

Hee, S.M. 1974. The effect of nitrogen fertilization on peppermint oil quality and content. M.S. Thesis, Oregon State Univ.

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