ALTERNATE AND ALTERNATING FURROW IRRIGATION OF PEPPERMINT TO MINIMIZE NITRATE LEACHING'

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Abstract

Furrow irrigation practices to alleviate nitrogen leaching and conserve water may have advantages over sprinkler irrigation for some crop and soil situations. Two *alternate-furrow* practices were compared on peppermint *(Mentha piperita,* L.) against a furrow-irrigated control, namely: an *alternate furrow* scheme where odd furrows are never irrigated, and an *alternating furrow* scheme where the every-other furrow scheme is shifted by one furrow every irrigation so that all furrows are irrigated over the course of two irrigations. Dry matter yield was significantly higher for the *alternating furrow* treatment. Oil yield was not significantly different among treatments. The interactions between treatment and field location were significant for dry matter yield. Nitrate leaching is not yet determined. Nine stations were set up for monitoring soil water content and nitrate movement, and corresponded to the three treatments times three locations in the furrow run, i.e. north, middle, and south. Soil was sampled for nitrate, and ammonia before, during, and after flood irrigations.

Introduction

High nitrate levels in groundwater have been attributed to irrigated agriculture. Surface irrigation systems (e.g. furrow, basin, border-strip) are especially suspect as nitrate con tributors if practiced on highly permeable soils. Flood irrigation may lead to high leaching rates at the top of the furrows, and still cause a water deficit at the lower ends of the runs. Flood irrigation systems generally have low efficiency in terms of crop-water requirement as a percent of water delivered. This inefficiency is partly the result of high water runoff rates from the end of the field, which are caused by large water application over the distance of irrigation run. Many of the proposed irrigation system upgrades to alleviate nitrate leaching (e.g. sprinkler, or drip irrigation) require large capital expenditures when converting from furrow irrigation. In addition, the energy costs of pumping for new irrigation systems may require new sources of electrical power.

There exists a need to improve management techniques for furrow irrigation in order to conserve water, and reduce groundwater contamination from nitrate. *Alternate furrow* irrigation has been reported as a method to reduce nitrate leaching on corn grown in

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Southern Idaho (Lehrsch et al., 1992). This report evaluates water and nitrate in the furrow irrigation system under *alternate-* and *alternating-furrow* irrigation strategies for their potential to reduce nitrate leaching.

Alternate-furrow irrigation consists of irrigating every other furrow of a field while leaving the off furrow dry. Several investigators studied *alternate-furrow* irrigation in the 1960s and early 1970s with much the same results: water was saved as compared to *every furrow* irrigation and yield was usually, but not always, unaffected. The research was over a wide variety of crops: Fishbach and Mulliner (1972) on corn, Grimes et al. (1968) on cotton, New (1971) on grain sorghum, Box (1973) on potatoes, and Musick and Dusek (1974) on potatoes, sugarbeets, and grain sorghum. Musick and Dusek (1974) cautioned that the practice could have a deleterious effect on water infiltration and yield of sugarbeets and grain sorghum in the lower one-fourth to one-half of the field, although potatoes showed no yield decrease. They recommended not using the practice for slowly permeable soils or wide furrow spacings. Crabtree et al. (1985) also found yield decreases for soybean under the alternate-furrow system, but found the water savings (50 percent less irrigation) to be an acceptable trade-off.

The *alternating-furrow* irrigation scheme consists of irrigating every odd furrow (1, 3, 5, etc.) during an irrigation event, then, during the following irrigation, irrigating even furrows (2, 4, 6, etc.). The overall benefits are first, that the amount of applied water is reduced, and second, the water flow in the furrow should have a larger lateral flow component. Because nitrate is very mobile in water, this would tend to increase the horizontal component of nitrate and water flow, and keep nitrate in the root zone, rather than have it leach downward. Water stress may be reduced in spite of an uneven water distribution because water transfer can occur within the root system, as shown by Baker and van Bavel (1988).

The objective of this study was to test *alternate-furrow, alternating-furrow,* and *every-furrow* irrigation practices for yield, water savings, and nitrate leaching. Peppermint *(Mentha piperita,* L.), which is grown under high irrigation and N fertilizer conditions (Clark and Menary, 1980), is subject to leaf damage by sprinkler irrigation that may cause 20 percent loss of marketable oil yield (Croteau, 1977), which makes furrow irrigation desirable.

Materials and Methods

Field Description

The experiment was conducted in a field of 3.21 acres, with 2.0 acres of peppermint surrounded by a rye border crop. The soil was Madras loam (fine-loamy, mixed mesic, Xerolic Duragrid). The field had a slope of 2.0 percent with a 560 ft irrigation run.

In March of 1992, the field was prepared for planting and fertilized with 64 lbs of 16-20-0-14 per acre. The peppermint rhizomes were then planted on March 16 and 18. On June 22, the field was again fertilized with an additional 184 lb N/a as urea. The furrows were dug using a rotary corrugator, which covers the bed with a mulch and buries the urea. The furrows were 4.5 inches deep and 24 inches apart.

Granular matrix sensors (GMS) were installed the following day. A total of 144 GMS were installed at nine different locations in the field (see "Granular Matrix Sensors" in this issue). The first furrow irrigation occurred on July 16. At this time the stand was approximately 8 inches tall and not at full canopy. Subsequent furrow irrigations occurred on July 17, 24, 31, and August 7, 12, 14, 18, and 21.

The mint was harvested on August 26-27. The peppermint was swathed in 12-ft windrows. At each tier (north, middle, south), three 10-ft windrow samples were taken for fresh matter yield. These samples were weighed and subsamples of 9-11 lbs were taken for oil yield analysis. Subsamples were processed at a research distillery at Oregon State University on November 13.

Plot Design

The experiment was a random block design with four replications. Each treatment consisted of six furrows. Treatments A, B, and C correspond to the *alternate-furrow, alternating-furrow,* and the *every-furrow* control. The field was irrigated using a gated pipe system flowing out of a pressure reduction tank. The gated pipe was 5 feet from the edge of the field in a border of rye and was set on cinder blocks, 3-4 inches above the ground. The gates were set and monitored to deliver 12 liters a minute per row. The gates were set using a stop watch and a 5 liter pitcher.

Sampling of N

Nitrogen movement was monitored in two ways-in a sampling grid throughout the bed, and at the end of the season, beneath the bed and furrow. The grid sampling was done at the nine different GMS locations within the first replication. Grid soil samples were taken at three times during the season-first on June 29, before the first furrow irrigation, but after several sprinkler irrigations. The second sample was taken on July 21, after three more sprinkler irrigations and one furrow irrigation (July 16). The third sampling was on September 1, after harvest. The grid soil samples were taken several feet south of the GMS locations in the first replication only. Sixteen total samples were taken in four layers, each 5 inches deep to a depth of 20 inches and 6 inches wide for the 24-inch width of the bed.

The total field was soil sampled in the last week of September and the first week of October with a hydraulic soil sampler mounted on a tractor (The Giddings Machine Company, Fort Collins, CO 80522). Three cores were taken and made in to a composite for the sample. Samples were taken in the same three tiers as before, but this time all replications were sampled. Samples were taken on the beds and in the furrows. In treatment A *(alternate-furrow),* the furrow samples were taken for both the irrigated and dry furrows.

The samples were air dried and ground if needed. Twenty grams of soil was mixed with 75 ml of KC1 extractant for an hour and filtered. The filtrate was then analyzed for ammonia with an ammonia analyzer, (Wescan Model 360. Alltech Associates, Inc, Deerfield, IL 60015). A reduction cartridge was used to reduce nitrate and nitrite ions to ammonium, allowing measurement of the total inorganic nitrogen concentration. Nitrate was determined by subtracting ammonia from total inorganic N, assuming nitrite concentration to be negligible for the high pH (> 7 pH) soil.

RESULTS

Yield

The dry matter yield showed significant differences for treatment (p=.07), location in field (p = .04), and the treatment-by-location interaction (p=.04). The alternating furrow irrigation (treatment B) had significantly greater dry matter yield, and it was greater for each location in the field (Fig. 1).

The peppermint oil yield statistics showed no significant treatment or location tests. The oil yield field average was 43.1 lb/a. It is not unusual to have such results for peppermint, where oil yield can be affected by other factors, such as maturity, which increases oil (Bullis et al., 1948), and insect damage, which decreases it. We noticed spider mite infestation at harvest, as well as differences in maturity (blooms) at harvest.

Nitrate Movement

The grid soil samples give us a moment in time picture of water movement under the furrow irrigation system. Figure 2 shows the nitrate concentrations of the control *(every-furrow)* before the first furrow irrigation, after first irrigation, and after harvest. After one irrigation, the water has moved the nitrate down and to the middle of the bed. Note that after harvest, the largest nitrate concentration is at the bottom of the profile.

Contrast this with the *alternate-furrow* data of Figure 3. After one irrigation, the nitrate is concentrated away from one furrow and toward the other. The highest N concentration after harvest is located at the top of the bed, not at the bottom of the profile.

Nitrate Leaching

Due to limited availablity of the data, this topic will be discussed in a future report.

Conclusions

Alternating-furrow irrigation yielded higher than the *alternate-furrow method* and *every-furrow* control treatment in dry matter. In oil yield there were no significant differences. This suggests that *alternating-furrow* irrigation may not be detrimental to yield and gross income. It is possible, but not yet proven, that nitrate leaching may be minimized under *alternate-furrow* irrigation. The work of Lehrsch et al. (1992) supports this conclusion. Water savings, although not studied here, may also result from the practice. *Alternating-furrow* irrigation of peppermint appears to be a viable practice for limiting leaching and saving water, without a yield decrease. The extrapolation of these results to other crop and soil situations should be done cautiously. For example, a field with furrow lengths longer than the 560 ft of this study may produce different results.

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Figure 1. Peppermint dry matter yield by treatment and location in the field, Madras, OR, 1992.

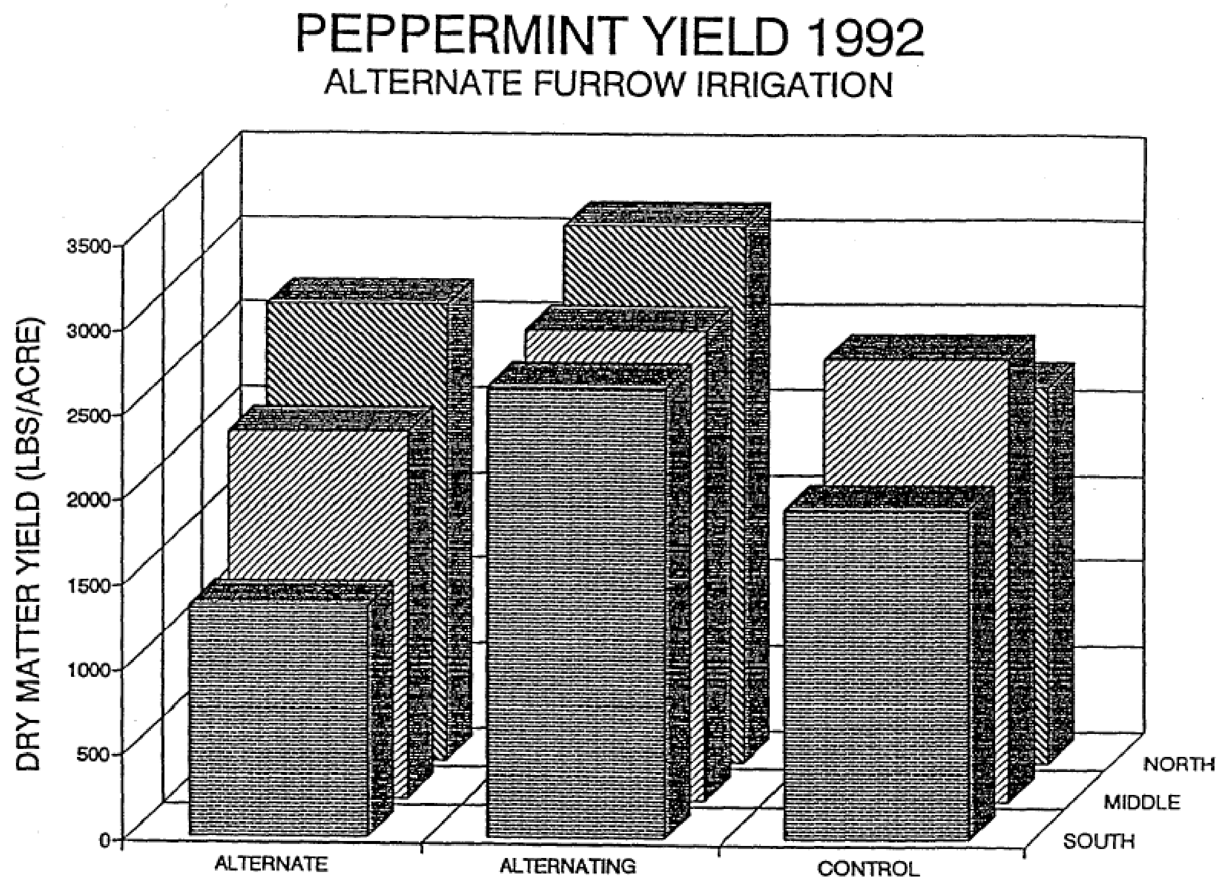

Figure 2. Nitrate concentration in furrow bed of *alternate-furrow* treatment at three times during growing season, Madras, OR, 1992.

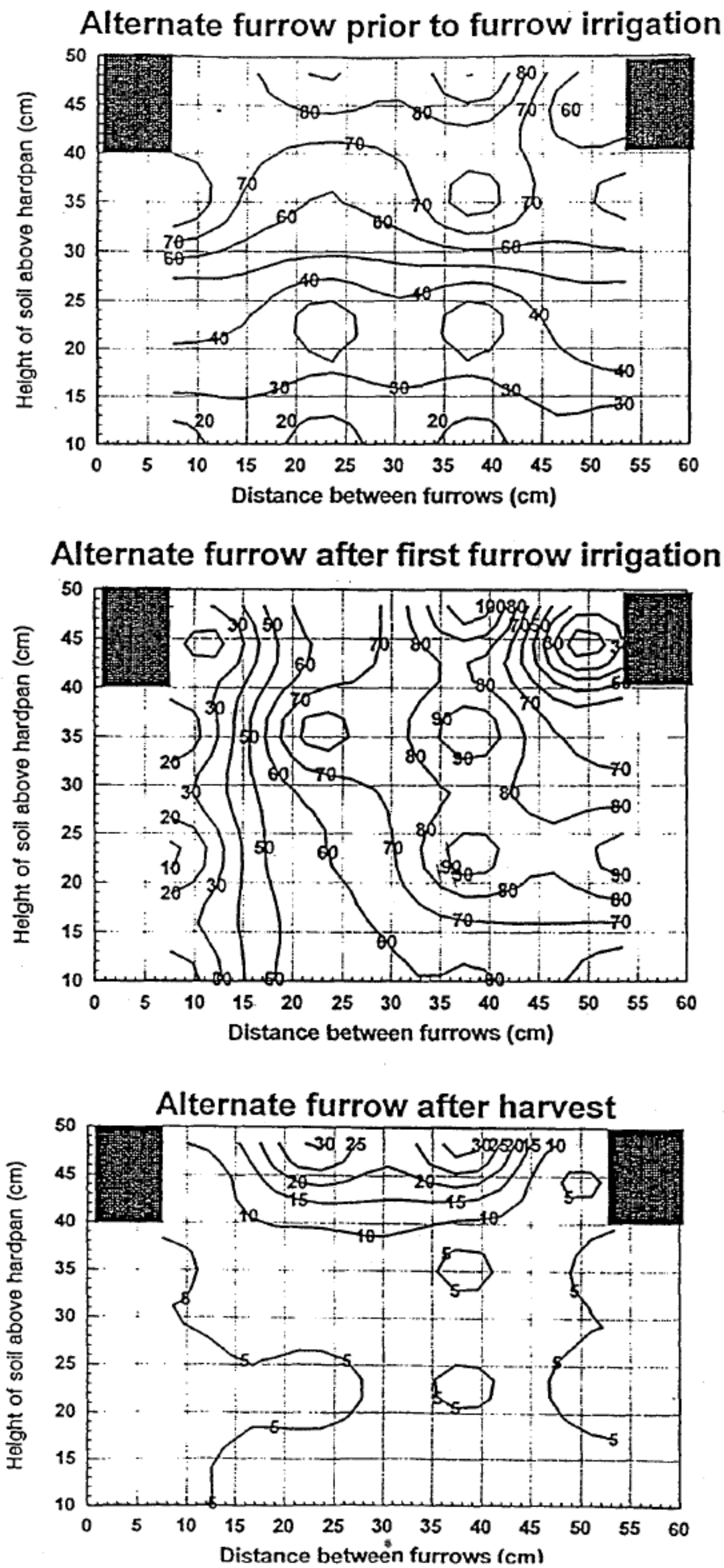

Figure 3. Nitrate concentration in furrow bed of *every-furrow* (control) treatment at three times during growing season, Madras, OR, 1992.