NEW TOOLS FOR PLANT-RESPONSE NITROGEN TESTING OF PEPPERMINT*

Alan R. Mitchell and Neysa A. Farris
Central Oregon Agricultural Research Center
Madras, OR

Abstract

Peppermint, a crop that requires high rates of water and nitrogen fertilizer, was the focus of a nitrate-nitrogen (NO_3-N) sensing study. A second-year stand of Murray Mitchum peppermint was evaluated using three methods: stem NO_3-N analysis, a CARDY ion meter that measures sap NO_3-N, and a SPAR chlorophyll meter. This study was designed to judge the accuracy of the two real-time sensors against the stem NO_3 content determined in the laboratory. The three methods were evaluated using data collected on soil NO_3-N, dry matter yield, and fertilizer rates. The stem dry matter NO_3-N was found to be correlated with the appropriate fertilizer rate. The CARDY meter was not correlated with the other methods or to the fertilizer rates, but the meter showed an inverse correlation with the dry matter yield. The SPAR meter showed correlation with the CARDY meter, but the results did not reflect the fertilizer rates. Water and salt stress occured in June, and although the plants showed good recovery, repercussion from the stress may have influenced our results. These results indicated that all plant-based measurements can be influenced by factors other than NO_3-N stress.

Introduction

With today's concern with ground water contamination, managing nitrate (NO_3) to prevent NO_3 leaching is important. Peppermint is a crop that has been shown to respond well to inputs of water and nitrogen (N) fertilizers (Clark and Menary, 1980), the high value of peppermint oil has provided an economic incentive for growers to make sure these inputs are not in deficit. High irrigation and fertilizer rates, along with a shallow root zone and permeable soils, make peppermint a target crop for NO_3 leaching. Timed NO_3 applications could improve N use efficiency. In this study, two real-time sensors will be compared to the traditional dry matter method of measuring stem NO_3, which involves a long turn-around time with an analysis laboratory.

Huettig (1969) and Brown (1982) have shown a relationship between final yield and NO_3-N concentrations in peppermint, and that stem NO_3-N concentrations were significantly increased with higher N rates. Using this information, Brown (1982) has calculated the critical stem NO_3-N level for maximum yield. The critical level falls during the season as the plant takes up NO_3.

This research was supported by the Oregon Mint Commission and the Oregon Department of Agriculture.

Real-time analysis of N status of the crop would provide a tool for split N applications when they are needed most, not just in peppermint but also in other high-input, high-management crops (i.e. potato). Work with the CARDY NO_3 ion meter for measuring petiole sap NO_3 in potato has been successful (Wescott, 1992). Also, two years of field testing in Montana and Minnesota have confirmed that direct measures of potato petiole sap NO_3 are highly correlated (r=0.962**) with petiole dry matter NO_3.

The SPAD chlorophyll meter is a non-destructive sensor that measures leaf reflectance properties to determine leaf chlorophyll content (Yadava, 1986). Since leaf chlorophyll content is closely related to NO_3 in the plant, the chlorophyll meter readings have been related to leaf NO_3.

The objectives of the study were to calibrate new tools for plant response nitrogen testing of peppermint, i.e., the SPAD and CARDY meters.

Materials and Methods

This study was conducted at Oregon State University-Central Oregon Agricultural Research Center (OSU-COARC), Madras, Oregon, during the summer of 1992, on a second-year stand of Murray Mitchum Peppermint. The plots were set up using the line-source sprinkler system (Hanks, et al., 1976) to apply five different irrigation levels, of which only two were evaluated in this study: 14 was managed to replace 100 percent of the water deficit in the field, and 15 was 120 percent of 14. Six different rates of urea fertilizer were studied, ranging from 50 to 350 lb/a in a split application (Table 1). Polymer coated urea (250 lb/a) was also tested. Spring fertilization occurred on June 3-5, 1992. Later applications of the aqueous fertilizer, Solution 32, were applied to N4 and N6 treatments on July 10 and 17 at the rate of 50 lb/a. The plots were irrigated twice a week with amounts determined by weekly neutron probe readings.

Table 1. Fertilizer trial rates

Fertilizer plot	Spring	Summer**	Total
		lb N/a	
N1	50	0	50
N2	150	0	150
N3	250	0	250
N4	250	100	350
N5 PCU*	225	0	225
N6	150	100	250

* polymer-coated urea
** split application of 50 lbs each

Twelve samples were taken, one from each of the two irrigation levels at the six fertilizer rates, to evaluate the three different NO_3 analysis techniques. The samples were composites of four stems taken in each of the eight replicated plots. Each stem consists of the top 6 inches of the plant minus the leaves and petioles. Before the leaves were stripped from the stem, the Minolta SPAD-502 chlorophyll meter was used. This meter was used on a leaf at the second or third node from the top to read the "greenness" of the leaves. The SPAD measures the "greenness" of the leaves by using the red and infrared energy bands to calculate an index, which is closely related to leaf chlorophyll content.

After the leaves were stripped, the stems were cut to 6-inch lengths from the top node down, and the ends clipped off to be put into a garlic press. The press was used to release sap onto the Horiba CARDY ion meter, distributed by Spectrum Technologies, Inc., Plainfield, IL 60544. The CARDY meter reads the ppm NO_3-N in the sap. The reading was later converted to a dry matter number for comparison, by using a ratio of the wet weight to dry weight of the stems.

The remaining portions of the stems were packaged and sent to a plant analysis laboratory (Agri-Check, Inc., Umatilla, OR 97882) for dry matter analysis for NO_3-N.

Peppermint was harvested on July 29 and 30 with a forage harvester taking a 40-inches-wide and 25-feet-long swath. Samples were taken to determine dry matter and oil yields.

Results and Discussion

The NO_3-N data from the stem-dry matter followed the pattern of development of Brown (1982), where NO_3-N concentrations decreased according to the fertilizer treatment, and as the season developed (Figure 1). It appeared that a salt or water-stress condition occurred in the early summer, which lowered the NO_3-N levels in the stems. On June 19 (day 171), there was no differentiation between fertilizer rates. By June 25 (day 177), some of the rates were differentiated according to their NO_3-N concentrations. Fertilizer plots N2 and N3 showed NO_3-N levels expected following spring fertilization in accordance with Brown (1982). At irrigation level 15, the Ni treatment showed low stem N due to lower applied N, while N4 exhibited lower stem N as an indication of a salt effect due to excess fertilizer. These results were not true at the lower irrigation level 14. N1 did not show any lowering of NO_3 concentration but was 875 ppm higher than N1 in irrigation IS. However, the salt damage in N4 showed more damage at 14 (data not shown). The stem NO_3-N concentrations at harvest were higher for the split-application treatments (N4 and N6) and the slow release urea (N5) than on early summer application. The measurements stayed above Brown's (1982) threshold of 8,000 ppm NO_3 except late in the season.

The results of all three methods indicated some type of stress condition early in June. The stem dry matter and soil NO3 concentrations indicated excess salt and low nitrogen. The SPAD meter showed possible water stress, followed by new growth and maturity. At irrigation level IS, recovery from these conditions was more complete than from 14, but the repercussion from the stresses influenced our results during the entire study. WATERMARK measurements of soil moisture indicated possible water stress from June 4 to June 25 (data not shown).

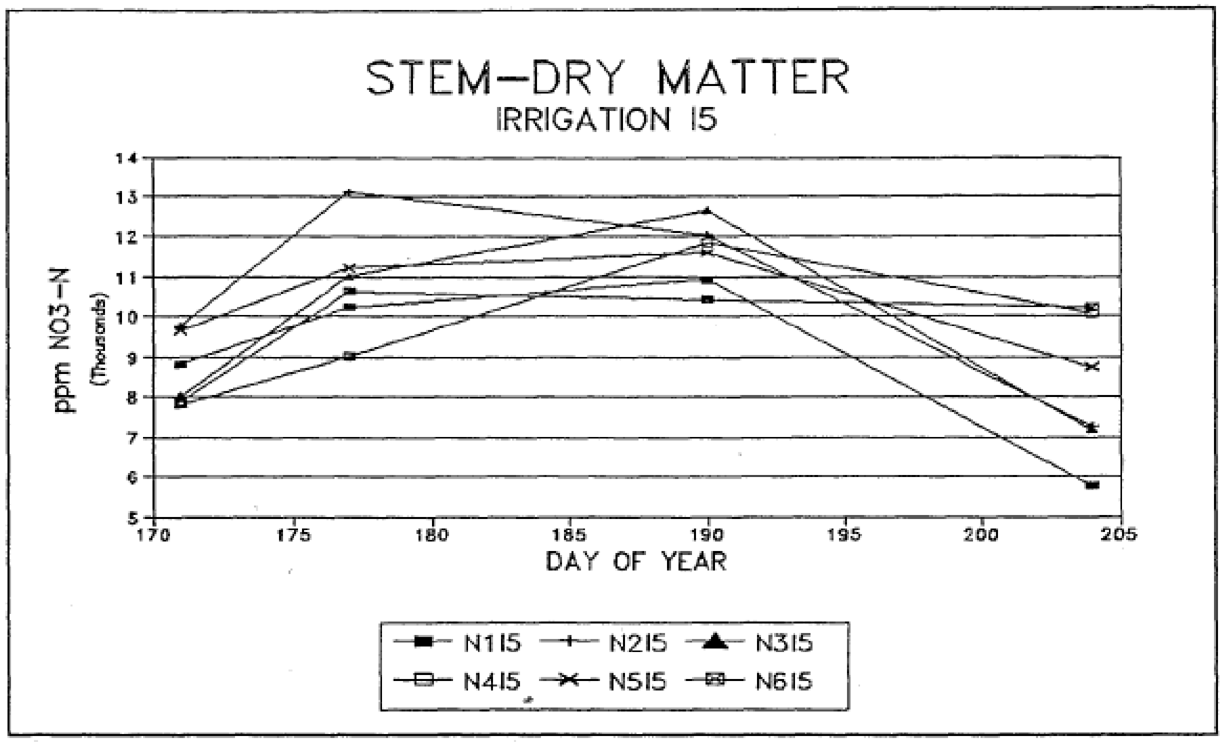

Figure 1. NO3-N Concentration in the stem-dry matter, Madras, OR, 1992.

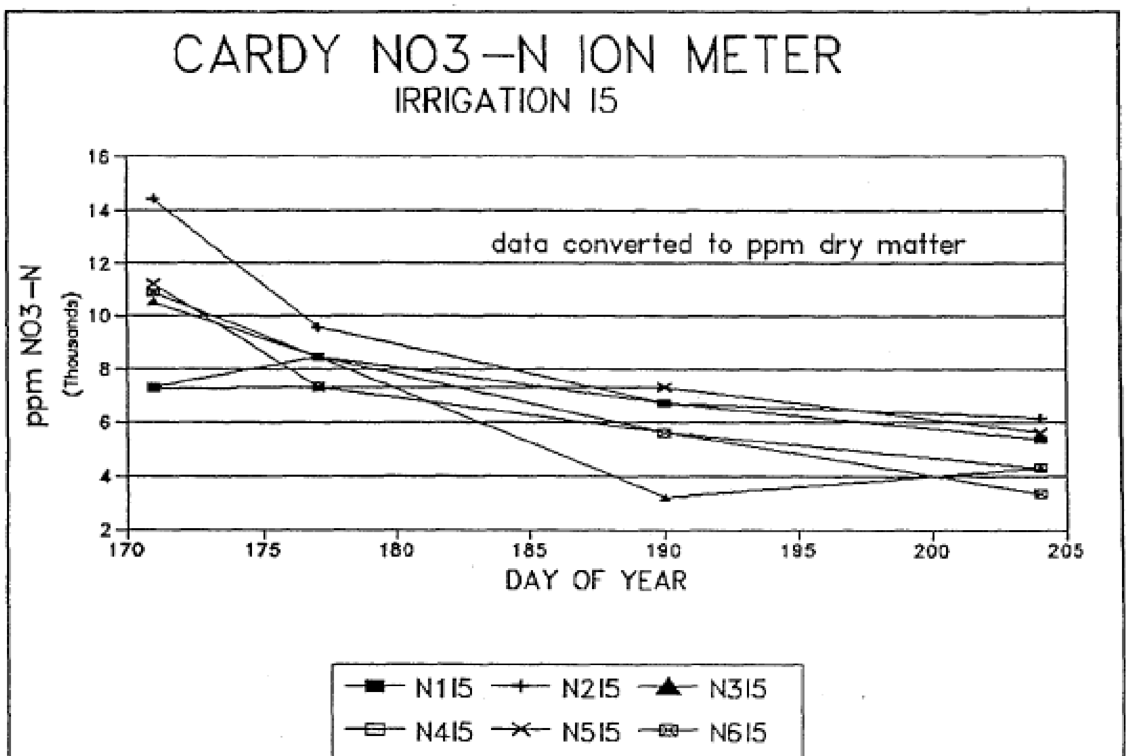

Figure 2. NO3-N concentration in the peppermint stem sap (dry-matter conversion), Madras, OR, 1992.

The CARDY meter did not show any correlation with the other methods or to fertilizer rate (Figure 2). Correlation with the stem-dry matter becomes smaller as the season progresses. Interestingly, the final CARDY meter measurements and the dry matter yield were ***inversely*** correlated, high final NO_3-N concentrations produced low dry matter yield.

Table 2. Correlation coeffcients of N sensing methods, Madras, OR, 1992.

	CARDY (DM)	SPAD	YIELD (DM)	SOIL
STEM	0.029	0.076	0.545	0.261
CARDY (DM)		0.478**	-0.657*	0.176
SPAD			-0.363	0.416*
YIELD (DM)				-0.079

**, * Significant at the 0.01 and 0.05 probability levels, respectively.

The SPAD meter, like the CARDY meter, showed mixed results (Figure 3). There was more correlation (0.478) between the SPAD and the CARDY meters (Table 2) than any other comparison. The results from both methods seem to show a period of water stress on June 25 (day 177), but then the SPAD readings indicated possible improvement to a level of maturity by July 22 (day 204). The poor results may be due to how the plant partitions N. Nitrogen translocates upward, taking N from the mature leaves when it is not available in the soil to supply the leaves with the highest growth rate. Recalling that the SPAD measurements were taken on the leaves at the third node, it is possible that the SPAD measurements may not have been representative of the entire plant.

The NO_3-N analysis of the soil gave results that reflected the fertilizer rates (Figure 4). At Irrigation level IS, Ni had 49 ppm NO_3-N on June 19 (day 171), and by July 22 (day 204) the NO_3-N level had rapidly dropped to 10.5 ppm, this did not seem to make any difference on the dry matter yield results N1-I5 and N1-14 yielded 333 and 527 lb/a, respectively, better than the lowest yields. N3 and N4 showed very different concentrations in the beginning, 81 and 53 ppm respectively, despite the same spring fertilizer rates. This could be due to the remaining NO_3-N in the soil from 1991 when they had different rates: N3 =200 lb/a and N4=150 lb/a plus 5 percent DCD. By the end of the experiment N3 dropped off sharply to end at 28 ppm NO_3-N and N4 gradually decreased until an additional 100 lbs of fertilizer were applied in July when the NO_3-N concentration increased 8 ppm. N5, slow-released urea, showed a release of N after June 25 (day 177). At 14, the NO_3-N concentration stayed fairly steady, 15 followed the same pattern but much more dramatically, increasing sharply to a peak on July 8 (day 190), and then dropping off.

The correlation between stem-dry matter and the soil was not significant (r=0.261), but the correlations between yield and stem NO_3-N for individual sampling dates increased as the sampling approached harvest. For example, N2I5 had both a low soil and stem-dry matter NO_3-N concentration, 16.5 and 7,250 ppm respectively, and the lowest treatment yield at 2,579 lb hay/a. N4I5 had a soil concentration of 45 ppm and a stem-dry matter of 10,075 ppm, and yielded 3,054 lb hay/a. A possible stress threshold was found to be between 20 and 30 ppm NO_3-N in the soil.

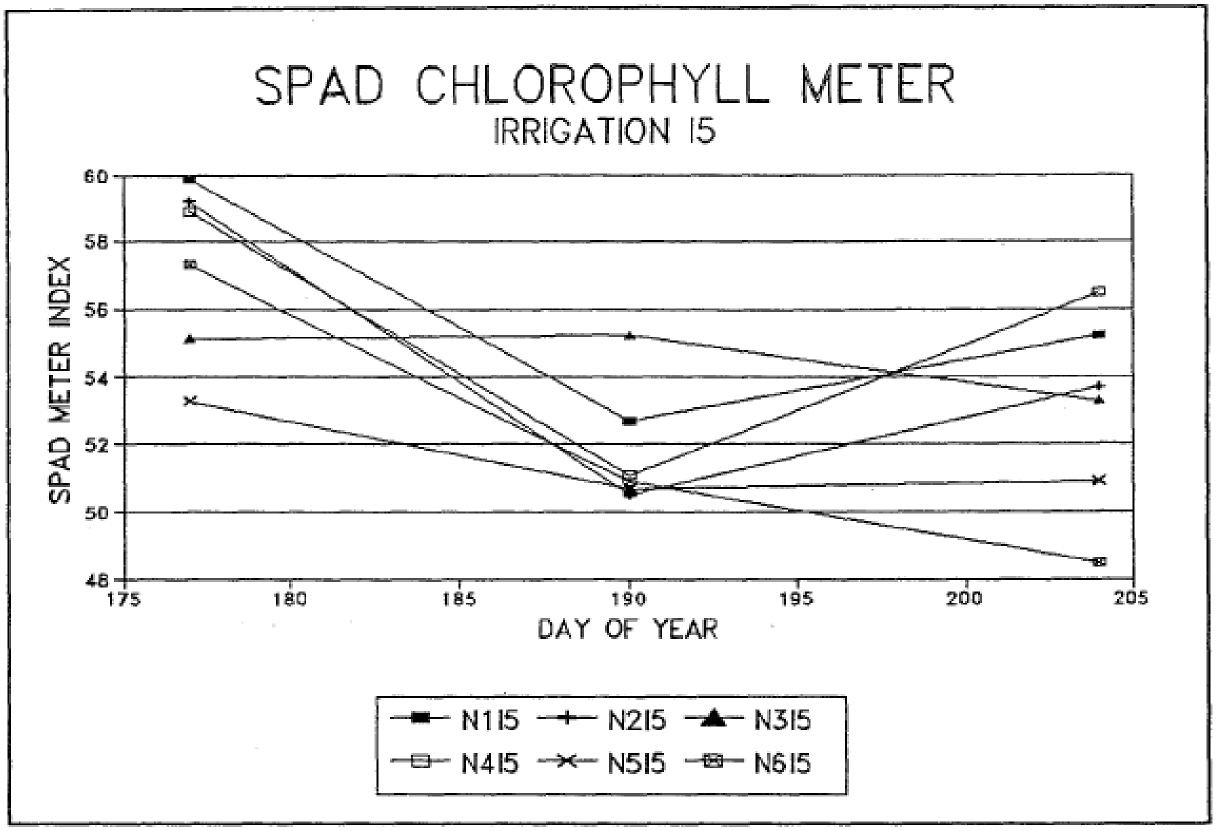

Figure 3. SPAD meter results throughout the season, Madras, OR, 1992.

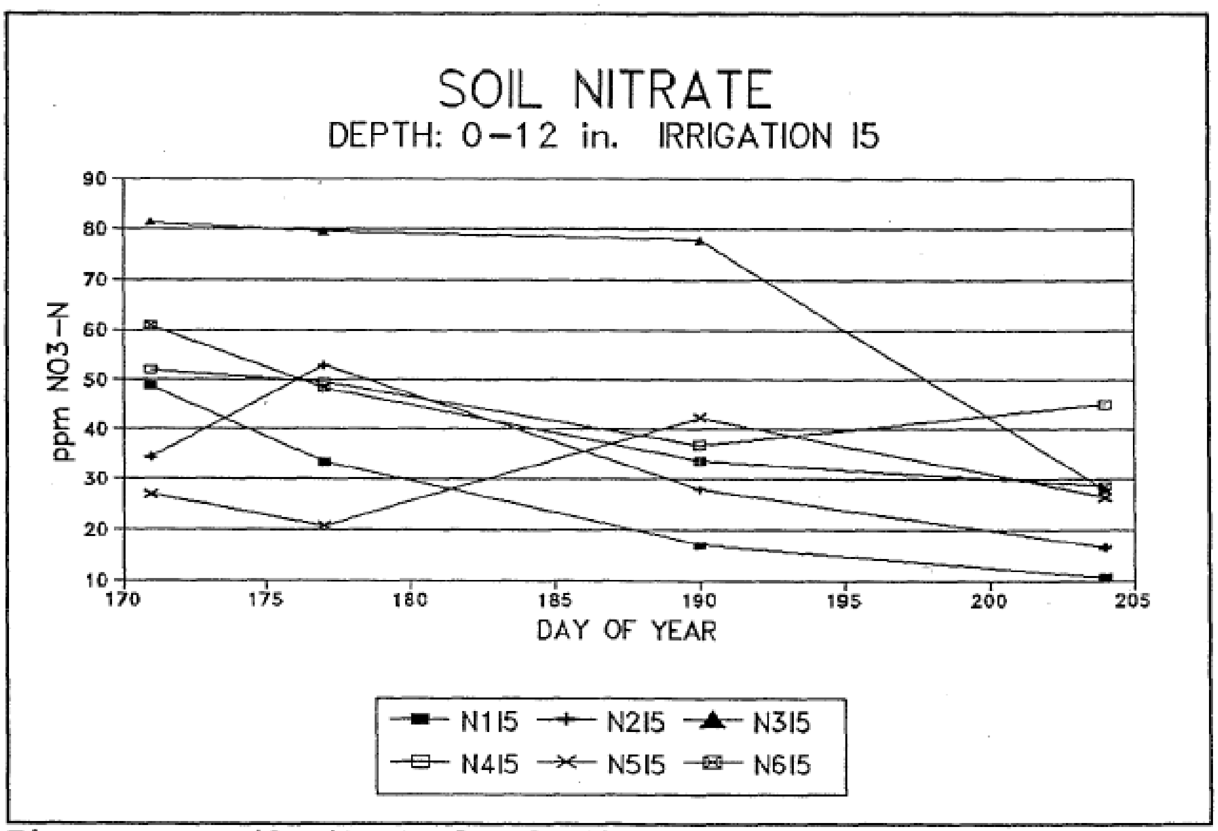

Figure 4. Soil nitrate levels throughout the season, Madras, OR, 1992.

CONCLUSION

Of the methods analyzed in this report the traditional stem analysis appeared to be the most accurate. The CARDY and SPAD meters showed correlation with each other but not with stem NO_3-N. This may be the result of water or salt stress in June, but it points out that all plant-based measurements can be influenced by factors other than NO_3-N stress. The stress factors were not excessive (no plants died), which indicates the limitation of the plant stress monitoring. The stem NO_3 measurements were above the 8,000 ppm level until late in the season. A possible soil NO_3-N threshold is the 20-30 ppm level.

Similar studies being conducted by Dr. Malvern Wescott, Montana State University, Western Agricultural Research Station, show correlation between the three methods. These studies were conducted on Black Mitchum peppermint. Next year, with funding from the Oregon Department of Agriculture Ground Water Research and Development Grants, studies in Madras will be conducted on both Murray and Black Mitchum peppermint with water stress kept at a minimum.

REFERENCES

Brown, B. 1982. Nitrogen tissue test procedures for peppermint. In Proceedings, Thirty-third Annual Northwest Fertilizer Conference of the Pacific Northwest, Boise, ID. July 13-14, 1982.

Clark, R.J. and R.C. Menary. 1980. The effect of irrigation and nitrogen on the yield and composition of peppermint oil. Aust. J. Agric. Res. 31:489-498.

Hanks, R.J., J. Keller, V.P. Rasmussen, and G.D. Wilson. 1976. Line source sprinkler for continuous variable irrigation-crop production studies. Soil Sci. Soc. Am. J. 40:426-429.

Huettig, M.A. 1969. The effect of fertilizer treatments on oil content and nutrient concentration of peppermint. M.S. Thesis, Oregon State University.

Westcott, M.P., V.R. Stewart, and R.E. Lund. 1991. Critical petiole nitrate levels in potato. Agron. J. 83:844-850.

Yadava, U.L. 1986. A rapid and nondestructive method to determine chlorophyll in intact leaves. Hort. Sci. 21:1449-1450.