Project Number: 96-AB1

FINAL REPORT

Leguminous Cover-Crop Residues in Orchard Soils: Decomposition and Fate of Nitrogen

Workgroup/Department: Almonds/Environmental Horticulture/Pomology

University of California
Division of Agriculture and Natural Resources

Project Year: 1996-1997

Project Leader:

Alison M. Berry
Department of Environmental Horticulture
University of California
Davis, CA 95616
916-752-7683 amberry@ucdavis.edu

Cooperating Personnel:

Robert L. Bugg
UC Sustainable Agriculture and Education Program
University of California

Steven Weinbaum
Department of Pomology
University of California
Davis, CA 95616

Robert McGuinn
Dept. of Env. Horticulture
University of California
Davis, CA 95616

Ray Eck
AlmondEck Ranch
18497 Williams Avenue
Hilmar, CA 95324

Keywords: Nitrogen, almonds, mineralization, nitrogen fixation, cover crops, vetch

Commodity: Almonds

PROJECT GOALS

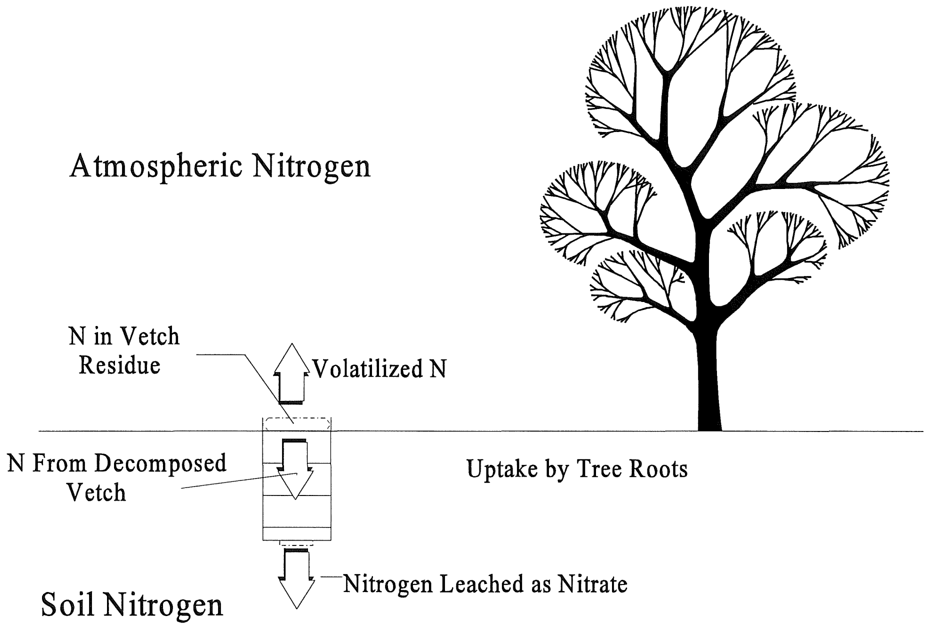
The overall goals of the 3-year project are: 1. to quantitatively trace the fate of legume cover-crop nitrogen in an almond orchard soil using ^{15}N-labeled vetch hay; and 2. to contribute information to improved orchard management practices.

I. PROBLEM AND ITS SIGNIFICANCE

Cover crops in orchards can provide several benefits, including improvements in soil structure and water-holding capacity. A potential additional benefit of leguminous cover crops is their capacity to "fix" nitrogen from the atmosphere, and convert it into a usable chemical form. Through decomposition of leaf litter and N release from the hay, nitrogen-fixing cover crops can provide a net input to the soil N budget. Over time, site productivity may be enhanced. In an almond orchard, this could mean that tree N demand can be partially met by application of legume cover crops such as vetch. "Lana" woollypod vetch has been estimated to fix 230 lbs N/acre (Stivers and Shennan 1991).

Nitrogen availability, volatilization and leaching. There is a clear need to determine how cover-crop N is mineralized and made available to almond trees under the non-tillage, sprinkler-irrigated regimes that prevail in California. In orchard systems, soil nitrogen availability during the growing season is dependent not only on N input, but also on environmental conditions that influence decomposition and N mineralization, especially temperature and soil moisture (see Fig. 1). Loss of nitrogen by **volatilization of ammonia** from cover crop clippings and/or **denitrification of nitrate** in the soil could lead to inefficiency. **Leaching losses of nitrate** through the soil column can also be a major source of N loss, and nitrate pollution of groundwater. Covercrop management of soils can provide a "buffer" of microbial activity and stored C/N to reduce such soil N losses. However, there is very little information on the soil nitrogen cycles that occur in covercrop managed orchards.

Seasonal pattern of N release from cover-crop hay. Total annual N use by almond trees is estimated to range from 80 to 130 lbs N/a (Weinbaum et al. 1992). Recent data indicate that patterns of nutrient uptake in almond trees areconditioned by patterns of organ nutrient demand N demand are likely to occur during leaf expansion (March to mid-April), fruit (pericarp)



(Weinbaum et al. 1984). Major periods of tree Fig. 1. Schematic diagram of N cycles in an orchard soil with vetch covercrop applied: N is released as the hay is decomposed, and mineral N moves into the soil column. Some N will be taken up by the tree, some N will be lost through leaching out, and some lost to the atmosphere through volatilization and denitrification.

----

growth(March-April) and nut fill (May through July), see Weinbaum & Muraoka, 1986). It is important to understand how the timing of cover-crop N release in the orchard can coincide with periods when almond nutrient uptake takes place.

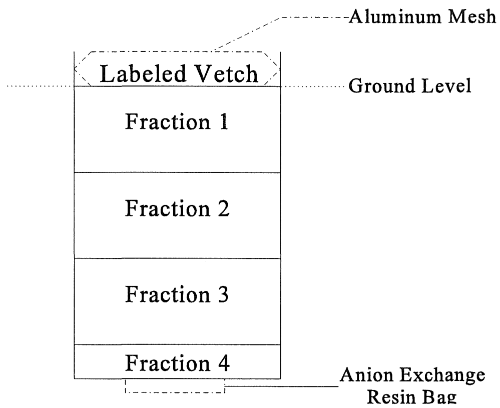
II. EXPERIMENTAL METHODS

During summer, 1995, we installed and evaluted field experiments to test the method of ^{15}N enrichment of vetch hay, and to track the appearance of the ^{15}N label in soil columns. A BIOS managed orchard near Hilmar, CA, using sprinkler irrigation, was chosen as the study site.

In summer, 1996, we conducted a large-scale field trial, from March 4 through June 13. Twenty-five sampling sites were identified within a randomly-chosen row, at midpoints between trees. Irrigation was monitored initially to determine that each site received approximately equal sprinkler coverage.

The vetch was grown in a greenhouse in steam-sterilized soil mix and fertilized with a Hoagland's nutrient solution enriched with 15N-ammonium nitrate (10 atom% ^{15}N). It was grown to flowering, harvested just before field installation, and applied as fresh hay.

Column Design



Two PVC pipes, 10" long by 6.25" inner diameter, were driven into the ground at each sampling site in the orchard (2 columns X 25 sites). Vetch hay was placed on the top of one soil column, and the second column was left as a control. The hay was placed on aluminum mesh (1/4") in contact with the soil surface, 67 g per column (wet wt). Anion exchange resin bags were installed at the base of each vetch column per site, to measure nitrate leaching. Ten additional columns were installed randomly in the row, and vetch hay without label was applied at the same rate, to serve as a non-labeled comparison. Two temperature probes with digital data recorders were placed at one randomly-chosen site-- at the soil surface beneath the vetch, or at the soil surface in the control column.

Columns were lifted at five sampling dates: T_0 (March 4), and every two weeks after until T_4 (June 13). Five columns per treatment per date were analyzed. Each column was sliced into four, 5-cm fractions. The remaining hay where present was harvested separately. Subsamples of each fraction were dried, weighed and ground prior to being analyzed for total N and ^{15}N content using mass spectrometry. Anion exchange resin bags were stored frozen, then extracted for nitrate and ^{15}N-nitrate analysis according to published methods (Brooks et al. 1989).

III. RESULTS

1. Initial Input of Nitrogen

In the beginning of the experiment, 67 g of vetch hay was applied at the top of each installed column. This application is equivalent to about 6,000 lbs/a of hay (dw), a typical application rate for cover crop management. Since the hay was composed entirely of vetch, a nitrogen-fixing legume, its nitrogen content was high, about 5.7%. This represents a total application of nitrogen equivalent to 383 lbs/a.

2. Biomass Loss from Vetch Hay

The vetch hay biomass decomposed rapidly following application-- by the first 2 weeks, 64% of total biomass had turned over, leaving 36% of original biomass as vetch residue. By the 6th week, 85% of the hay biomass had been lost, and by the 10th week, 94% had disappeared.

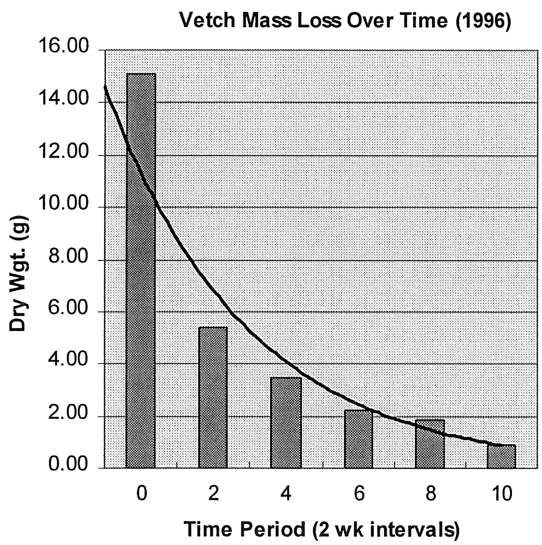


Figure 2: Mass loss as an exponential trendline.

3. Nitrogen Release from Vetch Residue

Nitrogen release from the vetch paralleled biomass loss in the first time period (Fig. 3), but appeared to proceed somewhat more rapidly thereafter. Within the first 2 weeks following application of the vetch hay, <u>65% of the total N was released</u> . By the fourth week, 85% of vetch N was released. By the end of the experiment, 10 weeks after application, 97% of the total vetch N had been lost from the hay.

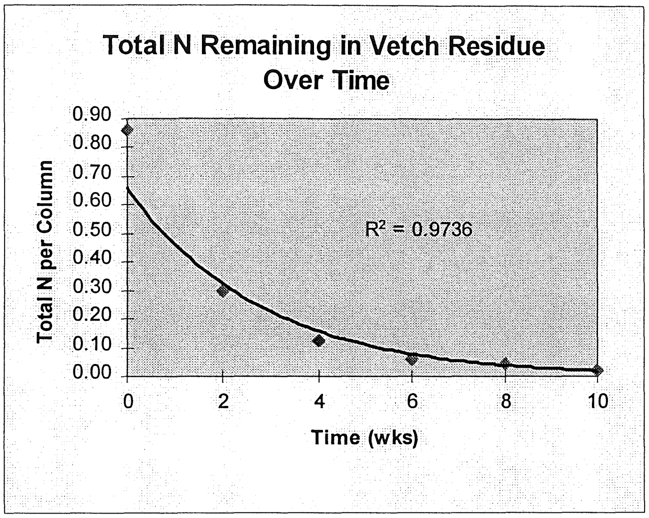
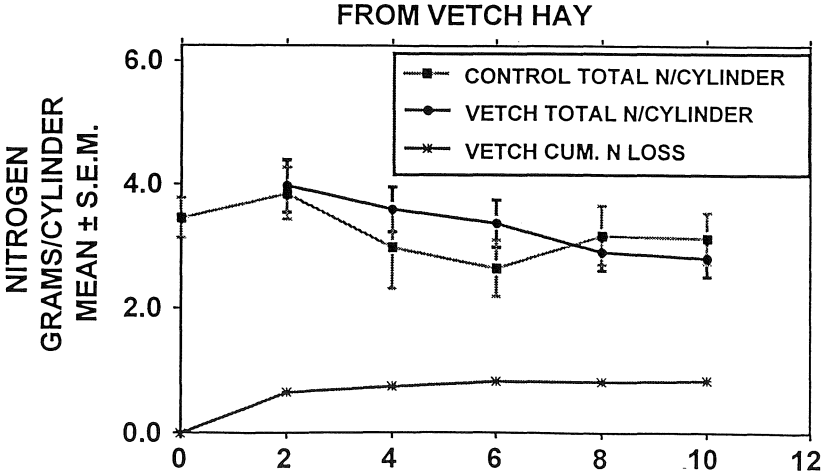


Figure 3: Nitrogen loss as an exponential trendline

4. Fate of Nitrogen Released

a. TOTAL N. We found increases in total N in vetch-treated columns vs. control, at weeks 2-6. However, none of the differences between + vetch and -vetch soil columns were statistically significant at any time point (Fig. 4). This is probably due to overall variability in background soil N. Because we cannot accurately measure the total N gains in the soil, we were not able to calculate N losses due to volatilization and leaching using a budget approach, as we had hoped we could do. We hope to do direct measurements of N losses from ammonia volatilization and nitrate leaching in 1997.



McGuinn et al., unpublished

Fig. 4

b. AVAILABLE N. Our measurements of N available to the plant (nitrate and ammonium) showed a 3-fold increase in available N for the whole soil column by weeks 2-4 (Fig. 5), which was significant statistically. In the top 5-cm soil fraction, the difference between vetch treatment and control was even greater, about a 330% increase in available N. This corresponds to about 20 kg/ha additional available N at both the 2 and 4 week sampling dates.

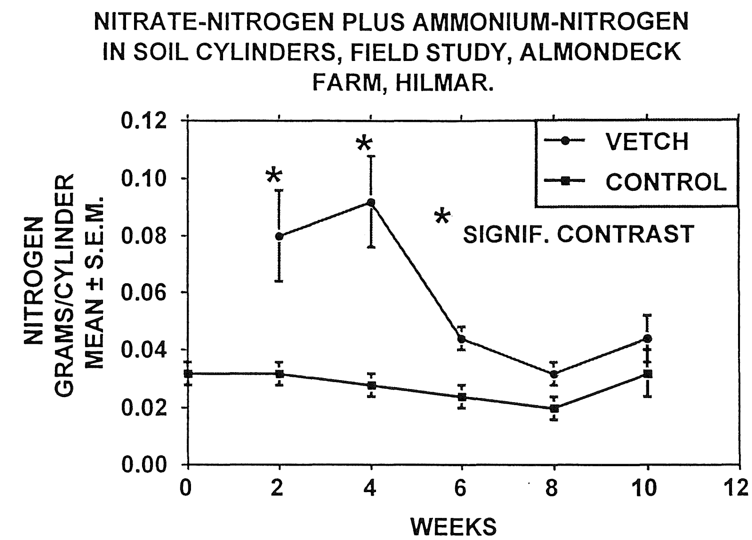


Fig.5

c. ^{15}N ISOTOPIC ENRICHMENT OF SOIL. A significant enrichment in ^{15}N-nitrogen both as total N and available N was measured in the soil column within the first 2 weeks after application of the ^{15}N-enriched vetch hay. The enrichment was most readily measured in the available N fraction, and was highest in the top soil fraction. For example, nitrate-N in the top 5 cm of the soil was highly enriched for ^{15}N (Table 1), indicating that about 75% of the nitrate was derived from the vetch. This provides proof that the vetch hay provided a 3-fold increase in available N by 2 weeks after application, in the top 5 cm. Lower fractions of the soil were also enriched to a lesser degree (data not shown).

Table 1. Comparison of relative isotopic enrichment in vetch-treated vs. untreated soils at 2 weeks after hay application, top 5 cm.

	$^{15}N/^{14}N$ Isotope Ratio in Nitrate	
	No vetch	**Plus vetch**
Soil layer		
1	**0.36**	**3.66**
2	**0.37**	**2.03**
3	**0.36**	**1.32**
4	**0.34**	**0.86**

d. VETCH HAY ^{15}N ISOTOPE RATIO. Interestingly, both in 1995 and 1996, we observed a decline in the $^{15}N/^{14}N$ ratio in the vetch hay residue, over the course of the experiment (Fig. 6), by about 18-30% of the original value. This result suggests either that there were 2 pools of N in the vetch tissue with different isotopic ratios, and that the pool with the higher fraction of 15N was lost preferentially; or that a microbial process during decomposition and mineralization

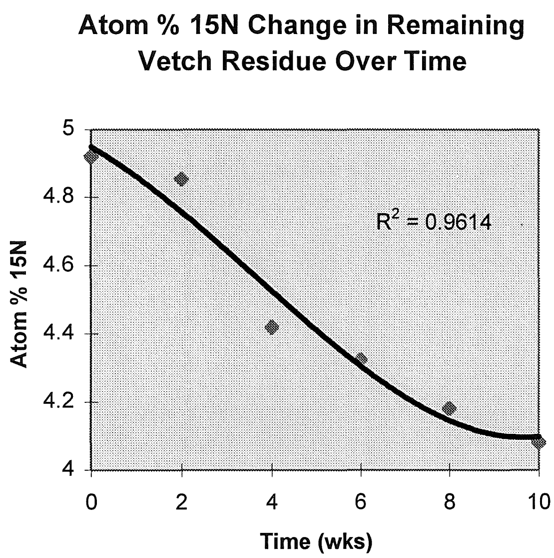


Fig. 6. Change in ^{15}N enrichment in vetch residue over the course of the experiment.

---

discriminated against the heavier isotope. Evans et al. (1996) found that plant asssimilation of nitrate via nitrate reductase produces an isotope effect that could explain our findings, since the vetch was originally fertilized with KNO_3. Alternatively, the only major microbial process known to result in lower $^{15}N/^{14}N$ pools is nitrogen fixation. This is a newly-reported observation that could have implications for understanding the N dynamics of covercrops.

5. Carbon Content of Soil

In addition to N enrichment of the soil, we measured total soil carbon. Preliminary calculations indicate that the carbon content of the soil and the C:N ratio were significantly lower in the vetch-treated columns (0-5 cm fraction). This suggests that vetch application stimulated soil microbial activity, increasing mineralization and availability of N.

6. Almond Tree N Uptake from Vetch

In 1996, we placed ^{15}N-labeled vetch around a single, 5-year almond tree, and harvested leaves at each time point, and analyzed the leaf N for ^{15}N enrichment. We did not measure any significant change in isotope ratio in the leaves of a single almond tree treated with ^{15}N-enriched vetch, over the growing season. There were problems with this experiment however, which may have obscured the result we were seeking. The vetch was applied somewhat late relative to seasonal N uptake cycles described by Weinbaum and coworkers, and the level of labeling was low for this particular batch of vetch (about 1% enrichment). We will repeat this experiment with a modified design in 1997.

IV CONCLUSIONS

1. 65-85% of the covercrop nitrogen was released during the first 2-4 weeks following hay application, during the month of April.

2. High levels of enrichment of available N in the soil were observed in the first 2-4 weeks following hay application. The isotopic ratios indicated that the additional available N was derived from the vetch. After 6 weeks, the enhancement effect of the covercrop on soil available N declines, suggesting that there is a "window" of maximum availability of N for almond tree nutrition.

3. Isotopic ratios in the vetch tissue surprisingly declined over the time course of the experiment. This observation warrants further investigation.

4. Covercrop mowing should be timed to permit the N release process to coincide with the period of maximum N uptake by the almond trees. We will continue to further define the dynamics of soil N uptake and turnover to permit more precise recommendations for covercrop N management practices.

References.

Brooks, P.D., J.M. Stark, B.B. McInteer, T. Preston. 1989. Soil Sci. Soc. Amer. J. 53:1707-1711.

Evans, R.D., A.J. Bloom, S.S. Sukrapanna, J.R. Ehleringer. 1996. Plant, Cell, Environment 19:1317-1323.

Hoefs, J. 1987. Stable Isotope Geochemistry, 3rd Edition. Springer-Verlag, Berlin.

Jayaweera, G R. 1991. Assessment of Ammonia Volatilization from Flooded Soil Systems. In: Brady, N.C. (Ed.). Advances in Agronomy, V. 45. Academic Press, Inc., San Diego. pp. 303-356.

Schwintzer, C.S., A.M. Berry and L.D. Disney. 1982. Can. J. Bot. 60: 746-757.

Stivers,L. and Shennan C. 1991. J. Production Agric. 4:330-335.
Tiedje, J.M., Simkins, S. and Groffman, P.M. 1989. Plant and Soil 115, 261-284.
Weinbaum,S. and T. Muraoka. 1986. J.Am.Soc.Hort.Sci. 11:224-228.
Weinbaum,S., R. Johnson, & T. DeJong. 1992. HortTech. 2:112-121.
Weinbaum,S., I. Klein, F. Broadbent, W. Micke & T. Muraoka. 1984. J.Am.Soc.Hort.Sci. 103:516-519.
Wyland, L.J., L.E. Jackson and K.F. Schulbach. 1995. J. Agric. Science 124, 17-25.