LEGUMINOUS COVER-CROP RESIDUES IN ORCHARD SOILS: DECOMPOSITION AND FATE OF NITROGEN

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SUMMARY OF FINDINGS

1. Carbon and nitrogen turnover from vetch hay as a cover crop in almond orchards is usually very rapid. We found that a major fraction of total N -- 50-75%-- is released within 2 weeks of hay application, and up to 90% by 4 weeks, if the moisture regime is adequate. Based on this information, cover crop mowing can now be timed so that N is released during periods of almond tree demand .

2. However, the rate of N turnover and hay biomass decomposition is proportional to irrigation and moisture regime. Slower rates of N release occurred in our experiments when no irrigation was added (20% over 2 weeks). Therefore, at least one irrigation even in good rainfall years is recommended within 1-2 weeks after mowing the cover crop. Additional irrigation may be beneficial in low rainfall seasons.

3. Ammonia volatilization was measured. Volatilization represented a small fraction of nitrogen turnover of the cover crop --1-2% of N released during 2-3 weeks. Under typical orchard conditions in California, ammonia volatilization would not be expected to be a significant source of N loss during vetch cover-crop decomposition.

BACKGROUND

The general purpose of this project is to quantitatively trace the fate of legume cover-crop nitrogen in orchard soil. 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. Total annual N use by almond trees is estimated to range from 80 to 130 lbs N/a (Weinbaum et al. 1992). "Lana" woollypod vetch has been estimated to fix 230 lbs N/a (Stivers and Shennan 1991).

Nitrogen availability and volatilization. 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. Loss of nitrogen by volatilization of ammonia and/or denitrification of nitrate from cover crop clippings could lead to inefficiency. Our experiments now show for the first time what fraction of N released from vetch is lost by volatilization.

Seasonal pattern of N release from cover-crop hay. Recent data indicate that patterns of nutrient uptake in almond trees are conditioned by patterns of organ nutrient demand (Weinbaum et al. 1984). Major periods of tree N demand are likely to occur during leaf expansion (March to mid-April), fruit (pericarp) growth (March-April) and nut fill (May through July), see Weinbaum & Muraoka, 1986. It is important to understand the timing of cover-crop N release in the orchard, so that management practices will result in N release during periods when almond nutrient uptake takes place.

EXPERIMENTAL METHODS

In 1997 we carried out three experiments: 1. to measure ammonia volatilization from vetch hay in the orchard; 2. to assess the effect of irrigation pattern on cover-crop nitrogen release and ammonia volatilization; and 3. to examine how much cover-crop N was actually taken up into the almond trees. We will repeat the third experiment in 1998-99.

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

Soil columns were made of PVC pipes, 10" long by 6.25" inner diameter, and then driven into the ground at each sampling site in the orchard. For the greenhouse experiments, soil columns were then lifted and returned to the Dept. of Env. Horticulture, UCDavis. Vetch hay was placed on the top of one set of soil columns, and a second set of columns was left as a control. The hay was placed on aluminum mesh (1/4") in contact with the soil surface. The fresh wt of hay per column and initial %N varied from experiment to experiment. Air temperature, irrigation frequency and water volume applied during each experiment were all monitored.

Samples were harvested at intervals during each experimental period. Multiple samples per treatment per date were dried, weighed and analyzed. Ammonia volatilization was measured directly according to published methods (Jayaweera 1991).

RESULTS

In two experiments (Tables 1 and 2), the maximum amounts of N lost due to ammonia volatilization ranged from 0.1% to 0.6% of total N. Midday ammonia volatilization levels were extremely low at the first time points of both experiments, and increased somewhat over time (data not shown). There was no clear correlation between irrigation frequency and volatilization rate (Table 2).

Irrigation strongly influenced the rates of decomposition and N turnover (Table 2). A comparatively high rate of N release was observed with weekly irrigations.

Both total N turnover (kg/ha) and N turnover as a percentage of initial total N was higher in the field experiment (Table 1) compared with the greenhouse experiment (Table 2), for irrigation treatments of comparable volumes. In a 1996 experiment (Table 3), much higher rates of N turnover were observed in the field. The temperature regimes were comparable among all the experiments, except that the greenhouse had higher night temperatures. There was a much longer irrigation treatment in 1996 (34 cm., over 120 h), compared with 1997 (7 cm., over 24 h).

Table 1. Biomass loss, nitrogen turnover and ammonia volatilization of cover crop vetch in AlmondEck Orchard, March 24-April 4, 1997. Duration of experiment: 12 days. Irrigation was applied on Day 0 (7 cm over 24 h). Percent N released: 20%.

Treatment	Biomass turnover (% of initial)	N turnover (% of initial)	N turnover, kg/ha/da	N turnover, total (kg/ha)/N initial (kg/ha)	net NH_3-N volatilization, ±S.E.	fraction of N lost to volatilization
1 irrig. (day 0, 7 cm)	1.5%/da	2%/da	4.2 kg/ha/da	44/210	4g/ha/h ±1	0.5%

Table 2. Biomass loss, nitrogen turnover and ammonia volatilization of cover crop vetch in relation to irrigation timing, September 20- October 12, 1997. Duration of experiment: 21 days. Percent N released depended on irrigation regime (17%, 29%, 35%, and 46%, treatments 1-4, respectively).

Treatment	Biomass turnover (% of initial)	N turnover (% of initial)	N turnover, kg/ha/da	N turnover, total (kg/ha)/N initial (kg/ha)	net NH_3-N volatilization, ±S.E.	fraction of N lost to volatilization
No irrigation	0.8%/da	0.8%/da	1.0 kg/ha/da	21/125	0.6g/ha/h ±0.1	0.3%
1 irrig. (day 0, 7 cm)	1.4%/da	1.3%/da	1.6 kg/ha/da	36/125	2.0g/ha/h ±0.2	0.6%
1 irrig. (day 7, 7 cm)	1.5%/da	1.6%/da	2.0 kg/ha/da	44/125	2.5g/ha/h ±0.4	0.4%
4 irrig. (1/wk, 7 cm each)	2.6%/da	2.1%/da	2.6 kg/ha/da	57/125	4.6g/ha/h ± 0.5	0.1%

Table 3. Biomass loss and nitrogen turnover in cover-crop vetch in AlmondEck Orchard, April 4 - April 18, 1996. Irrigation was applied at Day 9 (34 cm. over 120 h). Duration of experimental period: 14 days. Percent of initial N released: 74%.

Treatment	Biomass turnover (% of initial)	N turnover (% of initial)	N turnover, kg/ha/da	N turnover, total kg/ha)/N initial (kg/ha)
1 irrig. (day 9, 34 cm)	4.6%/da	5.3%/da	23 kg/ha/da	321/433

CONCLUSIONS

Ammonia volatilization was measured for the first time in an orchard cover crop in California. This process does not appear to be a major source of nitrogen loss from decomposing vetch cover crop hay. At most, it represented about 0.5% of total N in the vetch, and the values corresponded to 1-2% of N released over the 2- or 3-week periods of the two experiments.

Without irrigation, the rates of cover-crop decomposition and N turnover were extremely low. With increasing irrigation, the rates of decomposition and N release increased. There did not seem to be a great difference in decomposition whether the irrigation was applied at the time of mowing, or delayed until one week later. It is likely that soil moisture regime from rainfall is also an important factor in the orchard. In a dry year, irrigation will play a more important role in facilitating cover-crop turnover than in a wet year. In general, it would be useful to irrigate at least once during the first 1-2 weeks after mowing. The precise limits of when and how long to apply irrigation are not yet known

The timing of mowing should if possible be coordinated with the time of N use by the almond trees, and should take place about 2-4 weeks before peak periods of demand.

In our experiments, there was higher N turnover in the field as compared to the greenhouse, even for irrigation treatments of comparable volumes. The method of irrigation may influence the microbial activity important for decomposition and mineralization. In the orchard, overhead sprinkler irrigation is applied over a relatively long time period in the orchard, compared with relatively rapid flood irrigations in the greenhouse. Another explanation for this difference may be the presence of organisms in the orchard setting that play a role in nutrient cycling, beyond the microorganisms, worms, etc. that we brought back to the greenhouse inside the soil cylinders. Each PVC cylinder had a lip to discourage lateral movement of worms and other decomposers, but the spread of fungi or mobile organisms would not be prevented. In addition, there may be a difference in the wetting-and-drying cycles of the orchard environment that could favor more rapid decomposition of surface soil organic matter.

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