VOLATILE N LOSS FROM DECOMPOSING GREEN MANURE

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Introduction

There has been a resurgence of interest in the use of annual legumes as green manure crops to replace conventional summerfallow in the spring wheat production systems of western Canada (Biederbeck and Slinkard 1988). One proposed strategy is to chemically desiccate the legume in mid-summer and leave the residue standing until the following spring to maintain surface cover and trap snow. A potential drawback of this approach is the loss of volatile N from green manure retained on the soil surface. Because they have relatively high N concentrations and are applied to the soil at an immature growth stage when much of the assimilated N may exist in labile form, green manures may be particularly vulnerable to NH_3 volatilization losses. Ladd and Amato (1986) suggested ammonia volatilization as a possible explanation for incomplete recovery of 15N applied as legume residues to the surface of a calcareous soil under Australian conditions, but this effect has not been verified. Since N inputs from dinitrogen fixation are one of the primary benefits from legume green manures, potential volatile losses of N from these materials are of particular concern and merit quantification.

The objective of the present study was to measure volatile loss of ammonia and related N compounds from decomposing green manure. This objective was addressed by incubating lentil (Lens culinaris) green manure under controlled conditions and measuring volatile N generation in a flow-through chamber. Lentil is the annual legume currently recommended as a green manure crop in western Canadian wheat production systems (Biederbeck and Slinkard 1988).

Materials and Methods

Three consecutive experiments were conducted in a greenhouse to measure NH_3 volatilization from lentil green manure as a function of placement, air flow rate, and green manure composition, respectively. In all experiments, 36 g of plant material was applied to 10 kg of soil (sandy loam, pH in 0.01 M $CaCl_2$ = 6.2, organic C = 1.62%, field capacity=21%) inside sealed acrylic chambers (15 cm X 20 cm X 120 cm). Air was continuously passed through the chambers above the soil surface and subsequently scrubbed of volatile ammonia using 0.1 M HCl.

Experiment 1 was conducted to determine the effect of green manure placement on NH_3 evolution. The experiment included 3 treatments replicated 2 times: i. green manure incorporated into the soil to a depth of approximately 5 cm, ii. green manure placed onto the soil surface, and iii. green manure suspended above the soil surface on nylon mesh. Green manure material, obtained from the above-ground portion of hydroponically-grown lentil (Lens culinaris cv. 'Indianhead') harvested at flowering, was dried at 70°C and cut into 4 cm lengths (Table 1). This material was applied to moist soil in accordance with the designated treatments and moistened by sprinkling with distilled water. An additional chamber containing no green manure was similarly established to determine background emission of NH_3 from the soil. The chambers were sealed, fitted with acidic scrubbers, and air flow through the chamber was established at a rate of 0.07 chamber volumes min^{-1}.

After 28 days of incubation, the chambers were opened, and the residues and soil surface were allowed to dry for two days. The residues were then moistened with distilled water, airflow was re-established, and the treatments were incubated for 14 days. The residues were dried a second time, moistened with distilled water, and incubated for an additional 14 days.

Experiment 2 was conducted to determine the influence of air flow rate (0.09, 0.27, and 0.52 chamber volumes min^{-1}) on NH_3 volatilization from green manure applied to the soil surface. The treatments were established as before except that the airstream was saturated with water prior to entering the chambers to prevent differential drying rates among treatments. The various treatments, each replicated 2 times, were incubated for 17 days and acid traps (0.1M HCl) were sampled after 4, 7, 11, and 17 days to determine NH_3 evolution.

Experiment 3 was established to determine whether residue composition influenced volatile N losses. This experiment included three replicates of each of two treatments: i. hydroponically-cultured lentil material described earlier, and ii. lentil (*Lens culinaris* cv. 'Laird') obtained at the flowering stage from a field plot at the Lethbridge Research Station (Table 1). Treatments were established as before and flow rates were adjusted to 3.6 l min^{-1} (0.5 chamber volumes min^{-1}). Incoming air was saturated with water by bubbling through distilled water to prevent drying of the residue. The treatments were incubated for 14 d and sampled for NH_3 analysis after 2, 5, 7, 9, and 14 d.

In all three experiments, the concentrations of NH_3 and related N compounds in the acid traps (0.1 M HCl) were determined by steam distillation. In all cases, NH_3 emission from the soil alone was negligible indicating that volatile N recovered was derived exclusively from the green manure.

Results and Discussion

Experiment 1

NH_3 evolution from incorporated green manure was negligible. After 28 d, cumulative N volatilization amounted to 0.3 mg, representing less than 0.05% of the N applied (Fig. 1). In contrast, an average of 35 mg N $chamber^{-1}$, representing 3.6% of the N applied, had been volatilized after 28 days from non-incorporated green manure. In the early stages of decomposition, the surface-applied green manure exhibited higher volatile losses than the suspended GM, presumably because of more rapid microbial proliferation. In the 14-d incubation period following the initial drying/wetting cycle, accumulated N volatilization from the suspended-green manure (6.4 mg N $chamber^{-1}$) was significantly higher than that in the surface-green manure treatment (2.8 mg N $chamber^{-1}$). The second drying/re-wetting cycle had little influence on NH_3 loss and during the third incubation period, N volatilization in the surface and suspended green manure treatments continued at a gradual rate (average = 0.2 mg N $d^{-1} chamber^{-1}$). Over the three incubation periods, approximately 4.6% of the N applied in non-incorporated green manure was lost to the atmosphere, most of the losses occurring early in the decomposition process.

While this experiment demonstrates significant volatilization of NH_3 from decomposing green manure, the estimates may be conservative because of relatively low air flow rates (0.07 volumes min^{-1}). Previous investigations have demonstrated maximum NH3 evolution from fertilizers at flow rates greater than 10 volumes min^{-1} (Vlek and Stumpe 1978; Kissel et al. 1977). A subsequent experiment (Experiment 2) was therefore established to determine the influence of this variable on NH_3 volatilization from green manure residues.

Experiment 2

Cumulative volatile NH_3 loss over the 17-d incubation period averaged 37, 60, and 67 mg N for flow rates of 0.09, 0.27 and 0.52 volumes min^{-1}, respectively (Fig. 2). The temporal pattern of N release did not appear to be influenced by rate of air flow.

The results suggest that estimates of potential volatile N loss obtained in Experiment 1 were probably conservative. Because N volatilization at different flow rates appears to be proportional, the relative comparison of N loss from the various placement treatments remains valid. This view is supported by earlier observations (Chao and Kroontje 1964) that amounts of NH_3 volatilized from soil at various flow rates are directly proportional.

Experiment 3

Both green manure materials exhibited similar temporal patterns of NH_3 loss: a lag during the first several days, a large flush over several days, followed by a slow but continued generation of NH_3 thereafter (Fig. 3). Amounts of NH_3 loss, however, were almost twice as high from the field-grown lentil green manure (181 mg N $chamber^{-1}$ over 14 days) than from the hydroponically-cultured green manure (95 mg $chamber^{-1}$). To some extent, this difference may be attributable to the slightly higher N content of the former green manure (Table 1). More important, however, may be the difference in soluble N concentrations in the respective green manure materials. When expressed as proportion of soluble N (excluding nitrate), volatile losses in the field-grown and hydroponically-grown green manure amounted to 38% and 47%, respectively. Other variations in residue composition, related to genotypic or environmental differences, presumably also affected the volatilization process. Regardless of the cause, the results demonstrate that green manures, even from the same legume species, may have profoundly different NH_3 volatilization rates.

General Discussion

The results provide direct evidence of significant NH_3 loss from legume green manure applied to the soil surface. As much as 14% of the N applied was volatilized within 14 d of application under the conditions of the experiments. Incorporation of green manure material into the soil prevented volatile loss of NH_3, in accordance with observations reported for N fertilizers (Hauck 1983). Unfortunately, immediate incorporation of green manure into the soil also greatly reduces its effectiveness as a measure for erosion control and snow trapping.

While the present experiment provides evidence for the potential loss of volatile N from green manure, actual losses occurring under field conditions will presumably be controlled by a number of variables including moisture and temperature (Freney et al. 1983). Though absolutes rates of volatile loss under field conditions will likely be limited by these factors, cumulative volatilization could conceivably be even higher than values we have reported because of the long duration of exposure to the atmosphere. In proposed western Canadian wheat production systems, for example, green manure desiccated in July would remain exposed to the atmosphere for up to 9 months before the subsequent crop is seeded. During this period, repeated wetting from precipitation or dew could presumably generate flushes of ammonium which, in turn, would be susceptible to volatilization. Subsequent drying may even enhance NH_3 by inhibiting the nitrification of ammonium to nitrate (Nelson 1982).

The volatile loss of N from green manure may explain the lower response of subsequent crops to green manure retained on the soil surface than to incorporated green manure (Biederbeck and Slinkard 1988; Varco et al. 1989). For example, results of a field experiment conducted at Swift Current in 1989 (Biederbeck, unpublished) showed that wheat yields after incorporated legume green manure averaged 2340 kg ha^{-1} compared to only 1820 kg ha^{-1} after green manure which was desiccated but retained on the soil surface (Table 2). Although volatilization may only remove a small proportion of the green manure N (14% in the case of our study), this fraction represents the most labile N which is most important for short-term fertility. Recent experiments in western Canada suggest, on the basis of ^{15}N techniques, that only 15% of the N applied as green manure is absorbed by a subsequent wheat crop (Janzen et al. 1990).

This study suggests that more intensive examination of the atmospheric N cycle under field conditions is necessary to quantify actual losses incurred and facilitate development of agronomic practices that fully exploit the nutritive benefits of green manure application.

Table 1. Nitrogen concentrations of lentil green manures used in three experiments.

Source	Variety	Experiment	Total	Nitrate	Ammonium	Soluble organic N
			------------- g kg^{-1}	---------------		
Hydroponic	Indianhead	1	27.2	0.7	0.1	7.3
Hydroponic	Indianhead	2,3	30.5	0.9	0.1	7.0
Field	Laird	3	36.1	0.5	0.1	10.5

Table 2. Effect of management of legume green manure on yield of subsequent wheat in 1989 at Swift Current Research Station

Previous crop and treatment	Grain yield kg/ha	Yield as % of yield on fallow
Summerfallow	2290	100
Continuous Wheat (N&P-fertilized)	1580	69
Annual Legumes*		
- Inoculated & incorporated at bloom	2340	102
- Inoculated & desiccated at bloom	1820	79
- Inoculated & grown to maturity	1530	67
- Uninoculated & incorporated at bloom	1580	69

* Mean of 4 annual legumes.

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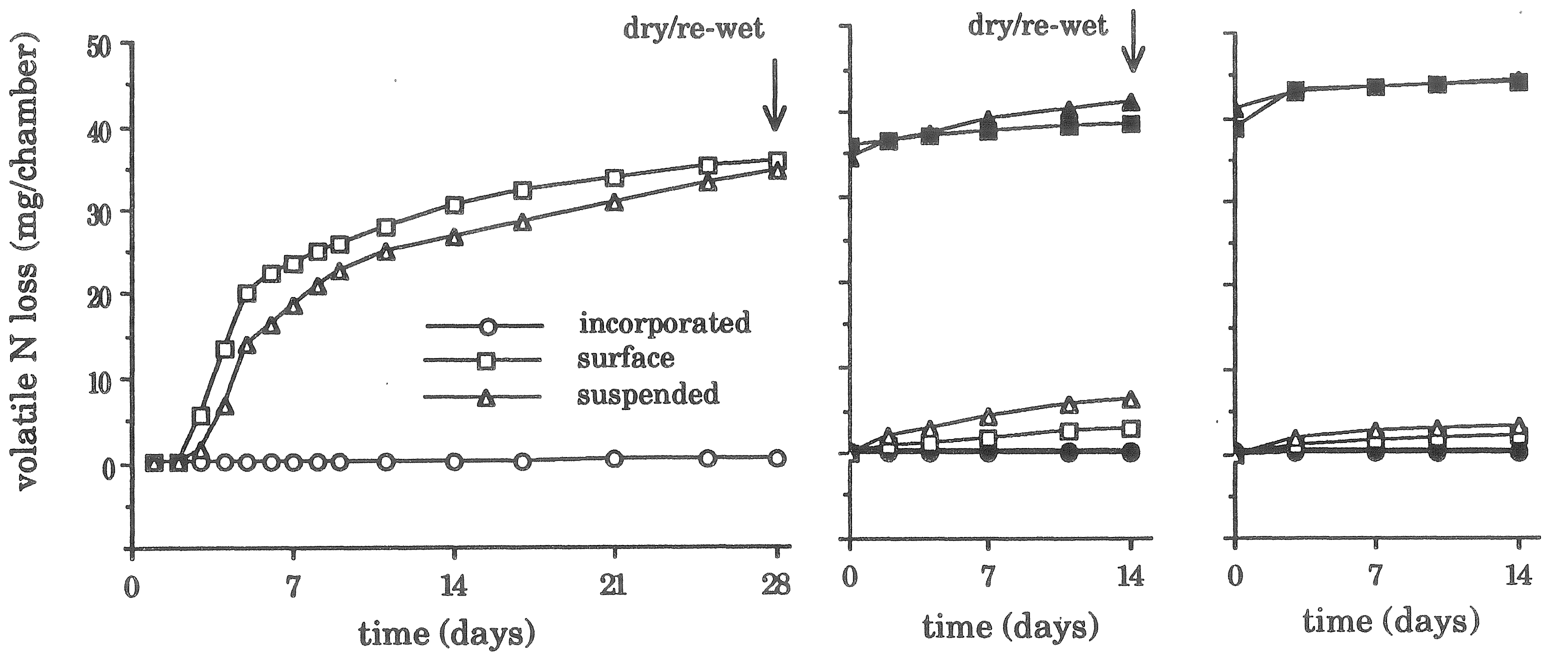
Figure Captions

Fig. 1. Cumulative NH_3 evolution from decomposing green manure over three incubation periods as influenced by residue placement. (Closed symbols represent amounts accumulated over successive incubation periods.)

Fig. 2. Cumulative NH_3 evolution from decomposing green manure as influenced by air flow rate. (The effect of flow rate on accumulated evolution after 17 days was significant at P=0.06 as determined by analysis of variance.)

Fig. 3. Cumulative NH_3 evolution from hydroponically- and field-grown lentil green manures. (The effect of green manure source on accumulated evolution after 14 days was significant at P=0.0002.)



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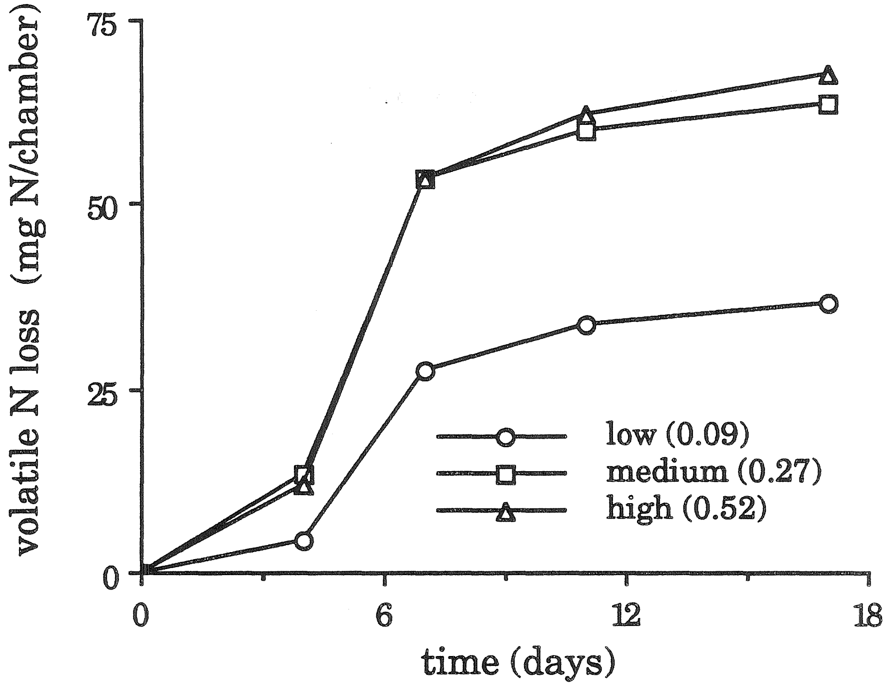

Fig. 2. Cumulative NH_3 evolution from decomposing green manure as influenced by air flow rate.

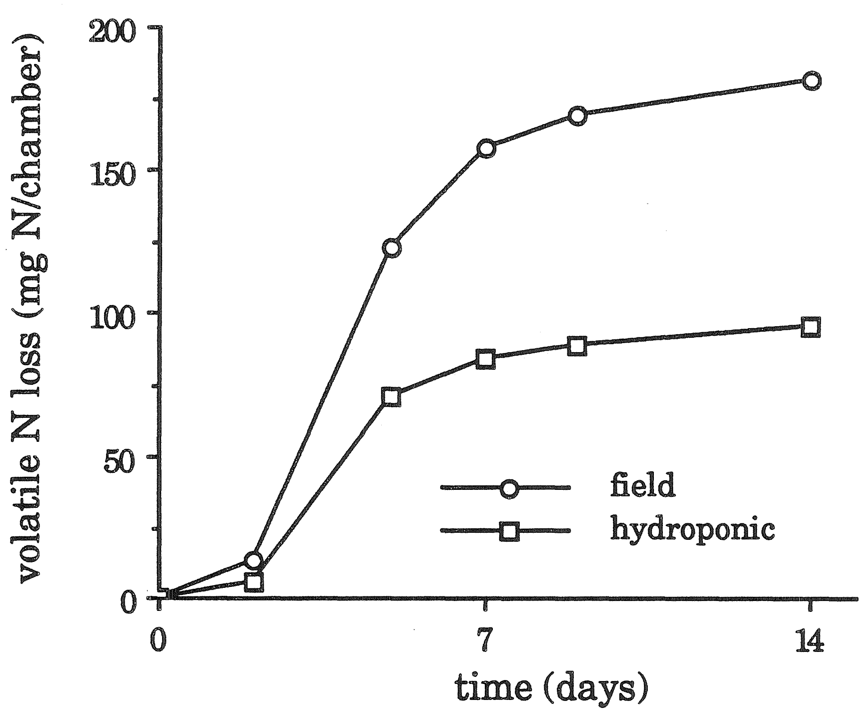

Fig. 3. Cumulative NH_3 evolution from hydroponically- and field-grown lentil green manures.