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Field studies on gaseous nitrogen losses from soils under continuous wheat versus a wheat-fallow rotation*

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Key words Acetylene inhibition technique Denitrifier counts Dinitrogen Nitrous oxide Potential denitrification rates ^{15}N balance sheet

Summary Field studies were conducted over a period of two years (April to November inclusive) to assess gaseous losses of nitrogen ($\text{N}_2\text{O} + \text{N}_2$) using the acetylene inhibition technique from two Black Chernozemic soils (Hoey cl and Hamlin cl) under continuous wheat (W-W) and wheat-summerfallow (W-F) rotations. Gaseous N losses from cropped fields were very low in both years ranging from 2 to 3 kg N.ha $^{-1}$.yr $^{-1}$; up to 60% of this nitrogen was generally lost during the early spring period (April to May). Losses of N from the W-F rotation were two to five times higher than from the continuous wheat rotation. The contribution of lower soil horizons towards gaseous N losses was negligible; the marked decrease in N_2O flux with soil depth followed similar decreasing patterns of organic carbon, denitrifier counts and potential denitrification rates.

^{15}N -labelled balance studies were carried out on microplots established on the same two sites during the 1981 growing season. Cumulative nitrogen losses measured during the period May 26 to August 31 using the acetylene technique were 1.8 ± 0.7 and 1.2 ± 0.3 kg N.ha $^{-1}$ at the Hoey and Hamlin sites, respectively. These results agree closely with the amount of nitrogen which could not be accounted for in the N balance studies (2.3 ± 3.1 and 1.2 ± 2.1 kg N.ha $^{-1}$, respectively). While the acetylene technique is highly labour intensive, these studies indicate it has an advantage over the ^{15}N balance approach, namely, the capability to assess short-term response of denitrification to rainfall events in particular.

Introduction

Present cropping patterns on the prairies of Western Canada involves a year of summerfallow followed by one or more years of crop. Out of 36 M ha of improved cropland in the prairies, 11 M ha are summerfallowed, 22 M ha are cropped and the rest is under pasture¹⁵. During the fallow year, all plant growth is controlled by frequent cultivation; moisture is stored as a hedge against drought, mineralization of N is accelerated, and thus the mineral N reserves are replenished. However, the summerfallow practice is associated with inefficient water storage (75–90% of the precipitation is lost through evaporation, surface runoff or leaching), accelerated wind and water erosion, salinization and long-term losses of soil fertility. Therefore, serious concerns about its use have

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been frequently expressed^{6,12,14,15}. Under summerfallow conditions, both moisture and NO_3^- -N accumulate and these favour denitrification. However, the quantitative field data on gaseous N losses are lacking primarily because of the unavailability of techniques for directly measuring gaseous N losses in the field.

The acetylene inhibition technique²² has been developed as a means of assessing gaseous N losses and has been successfully used in recent laboratory and field studies^{2,4,7,18}. This method has been validated by ^{15}N measurements in anaerobic soil system¹¹ and by ^{13}N measurements in a soil-water slurry¹⁶ under laboratory conditions.

The object of the present investigation was to measure gaseous N losses from soils under a wheat—summerfallow (W-F) rotation as compared to continuous wheat cropping system (W-W). The study was carried out at two different Black Chernozemic soil sites. A validation of the acetylene inhibition technique was carried out on the same sites by comparing the gaseous N losses with the amount of unaccounted fertilizer N in ^{15}N -balance studies.

Materials and methods

Some of the properties of the two Black Chernozemic soils, Hoey and Hamlin, in which the field plots were established, are given in Table 1.

In May 1980, the 25 ha fields were seeded to wheat. In the spring of 1981 the cooperating farmer at both experimental sites reseeded half the field to wheat and summerfallowed the other half. The wheat was fertilized at $50 \text{ kg N} \cdot \text{ha}^{-1}$ (as urea) at seeding time. The selection and design of sampling sites for removing undisturbed cores every week have been reported earlier². The procedure in brief followed for measurement of gaseous N losses included the removal of two undisturbed soil cores from each of the four earlier selected replicate areas using 6 cm diam. \times 15 cm long slotted aluminium cylinders. The soil contained in the cylinders was placed in individual jars together with a glass vial containing 2 ml of 2 N NaOH (to absorb CO_2). Each jar was then sealed and 5% (v/v) C_2H_2 was injected into one of the duplicate jars after first removing an equal amount of air. After a 24-h period a 1-cm³ gas sample was withdrawn from all jars and the N_2O concentration measured using a 5710-A HP-chromatograph. Correction for the solubility of N_2O in the soil water was carried out¹⁰. The jars were then opened and the soil moisture and mineral N ($\text{NO}_3^- + \text{NO}_2^-$)-N, $\text{NH}_4^+ - \text{N}$ were determined as described earlier².

Air temperatures were supplied by the Saskatchewan Research Council weather station on the University Campus. Soil temperatures in the field were those measured at 6- to 7-cm soil depth at the time the soil cores were taken, and rainfall was recorded for both sites.

The contribution of lower depths of the soil profile towards gaseous N losses was studied by taking soil cores from A, B and C horizons three times during May 1982. Disturbed horizon samples were also collected at the 3rd sampling time; these were passed through a 4.5-mm sieve at field moist conditions and stored at 4°C before determining the potential denitrification rates (PDR) and denitrifier counts.

The soil slurry method of Smith and Tiedje¹⁷ was used to assess PDR. Three samples (80 g oven-dry basis) were taken from each horizon, mixed with $100 \mu\text{g NO}_3^- \cdot \text{N} \cdot \text{g}^{-1}$ soil (as KNO_3) and placed in a 600-ml flask. Deionized water was then added to make a slurry (amount of water determined experimentally ahead of time). A glass vial containing 5 ml of 2 N NaOH was hung in each flask. The flasks were sealed with rubber stoppers (having tubes with serum caps in the centre) and then twice evacuated and flushed with He. Then 10% (v/v) C_2H_2 was injected after removing an equal amount of

Table 1. Important characteristics of the Orthic Black Chernozemic soils of the fields used in the experiment

Horizon (cm)	Depth (cm)	Texture	O.C.§ (%)	pH sat. paste	E.Ce (mS/cm)	Saturation moisture (%)	Total N (%)	B.D.† (g/cm ³)	Moisture (% w/w) at kPa		
									33‡	1500 ^Δ	
<i>Hoey Clay Loam</i>											
A	0-15	CL	4.48	7.2	0.35	50.0	0.48	1.10±0.07	25.1±1.9	23.4±2.6	12.1
B	15-39	CL	0.93	7.7	0.31	46.0	0.10	1.36±0.10	19.7±2.0	17.3±2.3	8.9
C	39+	CL	0.50	7.6	0.37	44.0	0.06	1.35±0.11	17.9±5.0	15.0±3.9	9.3
<i>Hamlin Clay Loam</i>											
A	0-13	CL	4.31	7.3	0.39	55.8	0.38	0.96±0.11	31.9±3.0	26.8±2.5	16.3
B	13-35	CL	1.12	7.2	0.46	50.0	0.14	1.26±0.06	23.1±1.7	18.7±1.3	11.3
C	35+	CL	0.49	8.1	0.89	42.0	0.10	1.27±0.11	18.9±4.2	16.1±4.0	11.6

§ Organic carbon determined by an improved dry combustion method²⁰

† Bulk density: mean of eight replicates

‡ Means of four undisturbed cores (5 cm diam, 5 cm long)

Δ Measured on disturbed soil samples

He. The flasks containing soil slurries were incubated on a rotary shaker at 25°C and 1-cm³ gas samples were withdrawn for N₂O analysis every 30 minutes for three hours. The PDR were calculated from N₂O-N accumulated during this period and reported as ng N₂O-N.g⁻¹ soil.h⁻¹.

Denitrifier counts were made by the most probable number (MPN) technique using microtitre plates (Costar #3524) after 7 days anaerobic incubation in Nitrite Nutrient broth²¹. Anaerobic conditions were obtained in a vacuum desiccator under 100% He atmosphere¹⁹ and the absence of nitrite upon the addition of N-1-Naphthyl-ethylenediamine dihydrochloride reagent²¹ was used to identify positive microtitre wells.

Microplots were established at each of the field plot locations by pushing four aluminium cylinders (20 cm diam. × 45 cm long) into the soil before seeding wheat in May, 1981. Special care was taken to avoid soil compaction by pushing the cylinders slowly into the soil with a hydraulic device mounted on a truck. A solution (10 ml as ammonium sulphate, 5.4% ¹⁵N excess) containing the N equivalent to 50 kg N.ha⁻¹ was uniformly mixed throughout the plough layer of each cylinder.

The wheat was then seeded. Gaseous N losses were measured as described above by taking soil cores weekly from the area around each cylinder (which received a similar N treatment as urea and was seeded at the same time). At the end of the growing season, the wheat crop was harvested, the cylinders removed, and representative soil samples taken from the 45–60 cm depth. In the laboratory, the cylinders were cut open and the soil was sectioned into 0–15, 15–30 and 30–45 cm depths, weighed and air dried. Soil subsamples, ground to pass a 10-mesh (2-mm) sieve, were extracted with 2 M KCl for mineral-N analysis. Additional 100-mesh samples were digested for total N analysis. Plant samples were separated into grain, straw and root + crown, dried at 60 ± 1°C, weighed, ground to pass 100-mesh sieve, and digested for total N. The Kjeldahl digestion and distillation methods described by Rennie and Paul¹³ were followed. Isotope ratio analysis was performed on an Atlas GD 150 mass spectrometer.

Results

Gaseous losses of N

The cumulative gaseous nitrogen losses for each of the three-month periods ending in August and November 1980 for both the Hoey and Hamlin soils were very small (Table 2) and totalled less than 1 kg N.ha⁻¹. This very low rate of N₂O loss was due primarily to abnormally dry conditions which prevailed during this period². During April and May 1981 the rate of N₂O and emission from the Hoey soil was several fold higher than that for the Hamlin – in part due to high soil moisture from snowmelt at the former site (Fig. 1 and 2). However, after the field, to be seeded to wheat (W-W), was cultivated to prepare for seeding increased soil aeration and increased evaporation of soil water probably reduced both the number of anaerobic sites and accordingly lowered N₂O emissions as compared to the wheat-summerfallow (W-F) adjacent field.

Gaseous N losses on the fallowed field reached approximately 150 g N.ha⁻¹ day⁻¹ during a short period in May, then dropped close to that for the cropped field (Fig. 1). The very rapid increase in rate of N₂O-N emissions on the fallowed field in early July was associated with two 30 mm rains; the rate of N₂O-N emissions reached approximately 100 g N.ha⁻¹.day⁻¹ on the cropped field and was approximately sixfold higher on the fallowed field. The fallowed field maintained a relatively high rate of N losses throughout the remainder of the

Table 2. Cumulative gaseous nitrogen losses (kg N.ha⁻¹) from wheat-wheat (W-W) and wheat-fallow (W-F) fields from Hoey cl and Hamlin cl experimental sites during the study period

Management system	Year 1		Year 2				Total	
	June, July & August 1980	Sept., Oct. & Nov. 1980	April & May 1981	Total 1981	June, July & August 1981	Sept., Oct. & Nov. 1981		April & May 1982
<i>Hoey Clay Loam</i>								
W-W	0.50 ± 0.03a	0.34 ± 0.07a	1.27 ± 0.14a	2.11 ± 3.20a	1.65 ± 0.21a	0.43 ± 0.01a	1.76 ± 0.18a	3.84 ± 0.34a
W-F	0.50 ± 0.03a	0.34 ± 0.07a	2.42 ± 0.38b	3.26 ± 0.30b	17.80 ± 0.96b	3.35 ± 0.23b	2.60 ± 0.21b	23.84 ± 0.69b
<i>Hamlin Clay Loam</i>								
W-W	0.49 ± 0.09a	0.40 ± 0.02a	0.42 ± 0.04a	1.31 ± 0.13a	1.09 ± 0.10a	0.54 ± 0.03a	0.71 ± 0.15a	2.34 ± 0.06a
W-F	0.49 ± 0.09a	0.40 ± 0.02a	0.30 ± 0.02a	1.19 ± 0.07a	2.28 ± 0.90b	0.96 ± 0.07b	0.89 ± 0.07a	4.13 ± 0.07b

In each column within each site, the values are significantly different at $P < 0.05$ (using Duncan Multiple Range Test) when not followed by the same letter

Analysis of variance: Year × Season, Rotation, Year × Season, Year × Rotation, Season × Rotation, and Year × Season × Rotation (in Hoey only) are significant at $P < 0.01$

summer; this is reflected in the tenfold higher total losses on the summerfallow as compared to the adjacent seeded field at the Hoey cl site (Table 2). Relatively small differences in surface soil moisture content (Fig. 1) which in turn affect the air-filled porosity (total porosity – volumetric moisture), are responsible for very large differences in denitrification rates; the increased accumulation of inorganic N, particularly NO_3^- -N on the fallow fields may also be another causative factor.

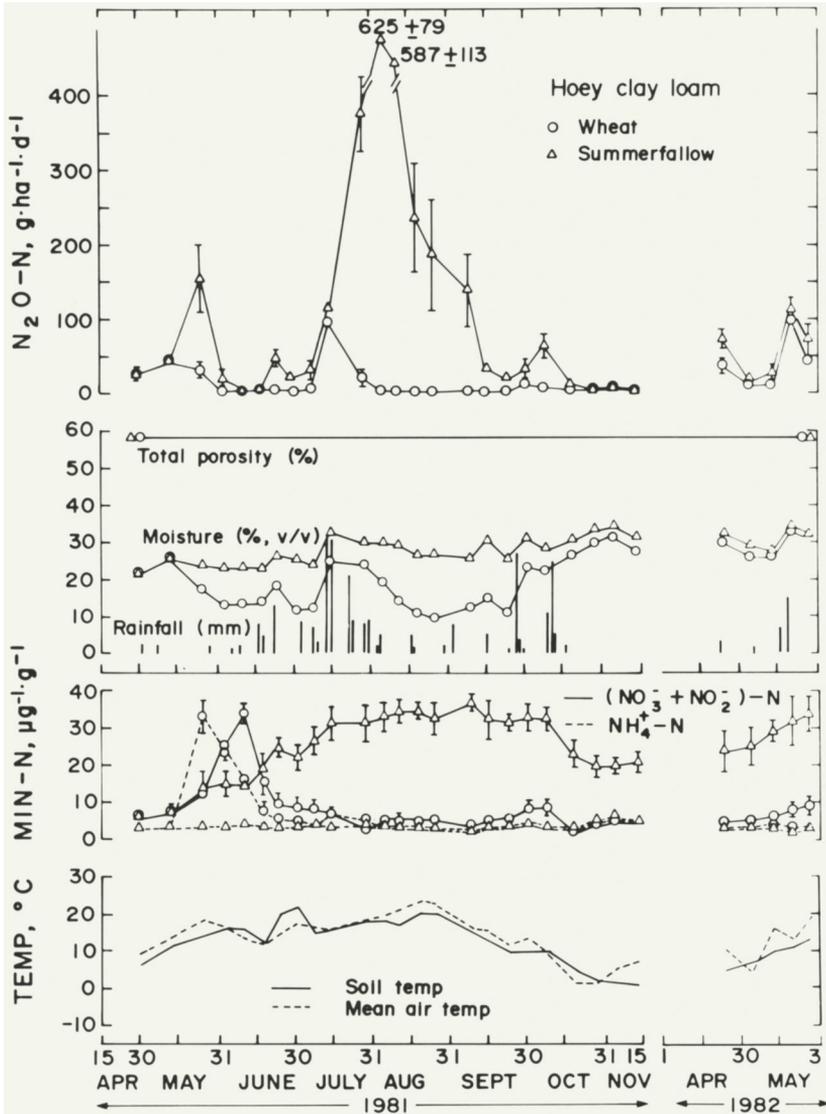


Fig. 1. Measurements of gaseous N loss ($\text{N}_2\text{O-N}$), soil moisture, rainfall, mineral N and air soil temperature of Hoey cl under wheat and summerfallow for the period April 1981 – May 1982. I indicates S.D.

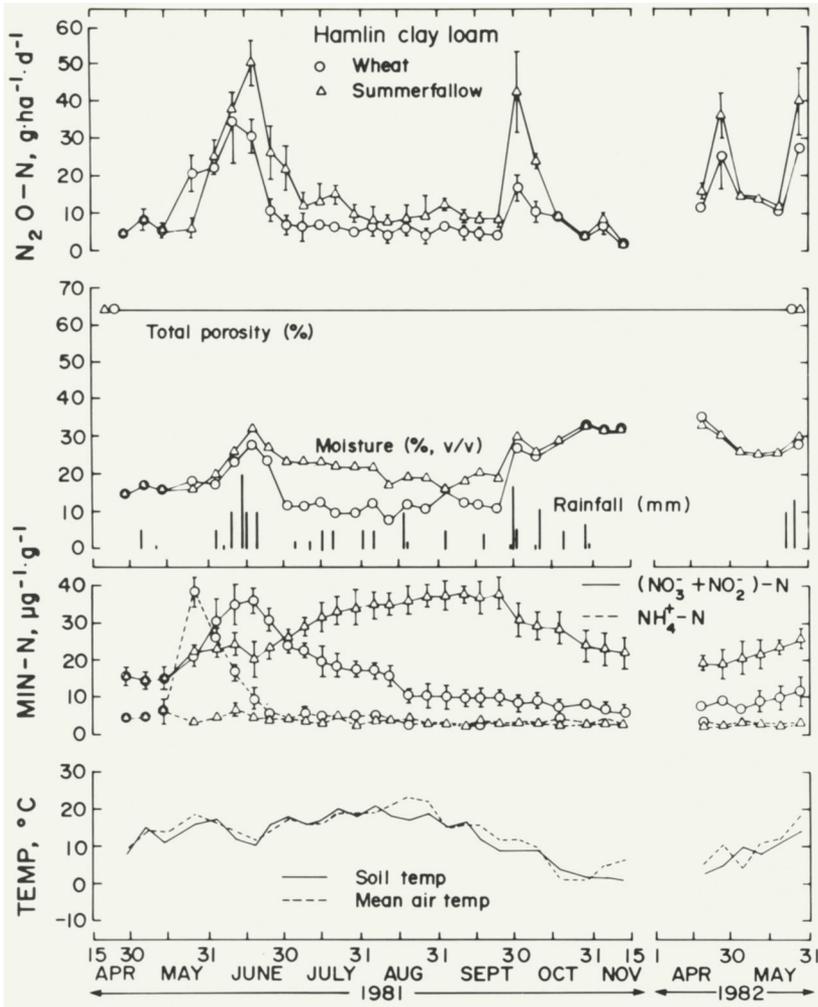


Fig. 2. Measurements of gaseous N loss (N_2O-N), soil moisture, rainfall, mineral N and air and soil temperature of Hamlin cl under wheat and summerfallow for the period April 1981 – May 1982. I indicates S.D.

The data obtained at the two sites during the spring of 1982 indicate that even though both soils had very similar moisture contents and accordingly similar air filled porosity and in addition received almost identical amounts of rainfall, the loss of nitrogen in the gaseous form on the Hoey was greater than twice that for the Hamlin soil. These data suggest that the potential denitrification capacity of the Hoey soil is significantly greater than that for the Hamlin. At both locations the rate of denitrification was highest for the fallow probably due to the much higher inorganic N level and moisture content of the Ap horizons of both fallow fields.

Contribution of lower soil horizons

The contribution of lower soil horizons to gaseous N evolution was studied by sampling the A, B and C horizons in both the seeded and summerfallowed fields at both locations in May 1982 (Table 3). The data obtained at sampling time I and II reflect gaseous N₂O emission rates under the moisture conditions existing in the field at the various depths at the time of sampling. Similar conclusions can be drawn from either set of soil core data. The N₂O fluxes primarily originated from the A horizon material. Rates of N₂O emission were relatively low at the first sampling due primarily to the somewhat drier soil conditions, particularly in the A horizon. A 5% increase in percent water by volume in the Hoey A horizon between sampling times I and II resulted in an eightfold increase in the rate of N₂O evolution. In contrast, moisture content in the surface of the Hamlin A horizon remained constant between sampling times I and II, and the rate of N₂O evolution was essentially the same.

Increasing the moisture content to just under the saturation percentages (sample time III) differentiated the fallow and stubble N₂O-N evolution rates for both soils. This is attributed to the greater inorganic N content of the fallow soil (care was taken to remove all visible crop residues from the stubble soils to ensure that immobilization of N was not a factor affecting denitrification rates). It can be concluded that under conditions favouring denitrification, *i.e.* sampling III, the lower soil horizons contributed on a relative basis from 5–10% of the total evolved N₂O-N from the A horizon material. The data also again confirmed the very much higher denitrification rates characteristic of the surface Hoey versus that of the Hamlin soil.

Similar trends were obtained for gaseous N loss rates from the sampling III cores and the PDR of both the Hoey fields. However, very different trends were noted for the PDR in the Hamlin soils, the reasons for which are not obvious. While the denitrifier counts were highly variable, they followed a similar trend to that of the sample III cores.

Nitrogen fertilizer balance studies

Microplots established on both the Hoey and Hamlin field sites in 1981 were set out as an alternate means of estimating nitrogen losses. The ammonium sulphate-N applied at a rate of 50 kg N.ha⁻¹ was approximately equivalent to 2.5 times the amount of inorganic nitrogen present in the 0–15 cm depth in both the Hoey and Hamlin soils at the time of seeding. Plant uptake of fertilizer N on the Hoey and Hamlin soils was 56 and 27%, respectively (Table 4), reflecting the dry conditions prevailing at the latter location. The plant uptake data confirm that in general the nitrogen taken up in the grain is equal to or slightly less than the total uptake in the straw, roots and crowns.

Thirty-nine percent of the added fertilizer nitrogen remained in the Hoey soil and 71% in the Hamlin soil; from 75 to 80% of this was present in the organic form at harvest time.

Table 3. Gaseous N losses from lower soil horizons and selected indices of potential denitrification rates during May, 1982§

Horizon	I (Cores)				II (Cores)				III ^Δ (Cores)				III (Disturbed)		
	N ₂ O-N (g ha ⁻¹ d ⁻¹)	NO ₃ ⁻ -N (μg g ⁻¹)	Moisture (%, w/w)	N ₂ O-N (g ha ⁻¹ d ⁻¹)	NO ₃ ⁻ -N (μg g ⁻¹)	Moisture (%, w/w)	N ₂ O-N (g ha ⁻¹ d ⁻¹)	NO ₃ ⁻ -N (μg g ⁻¹)	Moisture (%, w/w)	N ₂ O-N (g ha ⁻¹ d ⁻¹)	NO ₃ ⁻ -N (μg g ⁻¹)	Moisture (%, w/w)	PDR† (ng N ₂ O-N g ⁻¹ h ⁻¹)	PDR†	Denitrifier counts‡ × 10 ³ g ⁻¹
<i>Hoey: Wheat (W-W):</i>															
A	12.2±4.0	6.6	25.9	100.7±2.1	8.2	30.4	406.6±32.4	7.2	39.5	183.7±32.2					793.0±219.0
B	4.9±1.9	7.8	21.3	6.6±0.6	5.9	23.2	28.2±1.8	5.7	38.5	15.1±2.8					3.9±0.9
C	1.7±0.4	5.8	17.9	4.0±0.5	5.2	18.3	5.3±0.7	4.7	38.2	6.3±1.2					0.6±0.3
<i>Hoey: Fallow (W-F):</i>															
A	28.7±9.2	29.2	25.3	108.8±16.3	31.7	31.0	633.5±55.8	27.3	39.6	274.3±29.5					1373.0±393.0
B	4.5±0.6	19.0	20.1	5.5±0.3	17.5	19.9	28.8±3.1	16.0	39.3	17.4±3.6					2.2±0.9
C	4.1±0.3	14.3	20.1	2.1±0.2	15.8	20.6	4.1±0.9	15.2	38.3	6.7±1.6					0.9±0.2
<i>Hamlin: Wheat (W-W):</i>															
A	13.9±4.9	9.0	26.9	10.2±2.6	9.8	26.6	104.6±14.7	6.8	39.7	143.0±18.0					670.0±810.0
B	6.5±0.6	4.2	20.7	4.1±1.0	4.8	18.5	14.8±2.0	3.6	38.7	14.0±2.0					2.1±0.3
C	3.0±0.9	1.8	14.5	2.2±0.5	4.8	16.7	4.3±1.0	3.4	39.2	6.4±0.8					0.8±0.3
<i>Hamlin: Fallow (W-F):</i>															
A	14.3±3.4	21.7	27.1	11.2±3.6	23.7	27.1	123.3±17.5	20.0	40.3	193.0±27.4					1200.0±300.0
B	3.6±0.4	24.5	20.4	3.2±1.0	24.0	22.6	14.6±2.7	20.5	38.9	17.1±2.2					3.4±1.3
C	0.9±0.2	17.3	16.0	1.7±0.2	17.0	18.1	4.6±1.3	16.2	39.0	9.8±2.8					0.9±0.2

§ All values are means of three replicates. Respective dates for I, II and III are May 4, 21 and 28 for Hoey and May 12, 19 and 26 for Hamlin soil

Δ Extra water was added to soil cores before sealing

† PDR = Potential denitrification rates obtained from soil slurry technique¹⁷

‡ Denitrifier counts determined by 'Most probable number' technique^{19,21}

Table 4. Fertilizer nitrogen balance sheets for Hoey cl and Hamlin cl soils – 1981 growing season†

Recovery in	Hoey clay loam		Hamlin clay loam	
	Fert. N kg.ha ⁻¹	Recovery %	Fert. N kg.ha ⁻¹	Recovery %
Grain	13.6±2.8	27.2±5.6	6.3±1.7	12.5±3.5
Straw	12.4±1.2	24.7±2.4	5.0±1.1	10.1±2.2
Root + Crown	2.2±0.2	4.3±0.4	2.2±0.7	4.3±1.3
Total Plant	28.1±3.5	56.2±6.9	13.5±1.7	27.0±3.4
Soil 0–15 cm	15.1±0.7 (1.8±0.6)†	31.0±1.4 (3.7±1.2)	32.7±1.4 (7.3±1.9)	65.5±2.7 (14.5±3.8)
Soil 15–30 cm	2.2±1.0 (1.1±0.6)	4.3±2.1 (2.2±1.2)	2.3±1.1 (1.3±0.3)	4.6±2.1 (2.6±0.6)
Soil 30–45 cm	0.2±0.3 (0.9±0.5)	3.6±2.7 (1.7±1.0)	0.3±0.2 (0.1±0.1)	0.5±0.4 (0.3±0.1)
Soil 45–60 cm	0.2±0.3 (0.1±0.2)	0.3±0.5 (0.2±0.3)	N.D.	N.D.
Soil Profile	19.6±2.0 (3.9±1.4)	39.1±4.1 (7.7±2.8)	35.3±1.8 (8.7±1.9)	70.5±3.6 (17.4±3.7)
Total	47.7±3.1	95.4±6.1	48.8±2.1	97.5±4.2
Unaccounted	2.3±3.1	4.6±6.1	1.2±2.1	2.5±4.2
Losses by A.I.T.‡	1.8±0.7	—	1.2±0.3	—

† Figures in parenthesis are Fert.-N present as mineral N = (NH₄⁺ + NO₃⁻ + NO₂⁻)-N

‡ Gaseous N losses measured directly by 'acetylene inhibition technique' during this period (May 26 to August 31, 1981). N.D. = Not done.

Only trace amounts of the fertilizer nitrogen moved below the 45 cm depth in the Hoey or below the 30 cm depth in the Hamlin soil. Downward movement of nitrogen in cropped soils is generally very limited under dryland agriculture in the Northern Great Plains^{1,9}. Only minimal amounts of fertilizer nitrogen were unaccounted for at harvest time; the 2.3 and 1.2 kg N unaccounted for in the balance sheets for the Hoey and Hamlin soils, respectively, are approximately equivalent to the cumulative gaseous nitrogen measured during the growth period using the acetylene inhibition technique (1.8 and 1.2 kg N.ha⁻¹, respectively). In comparing these relative values it should be noted that the balance studies only include a measure of the applied fertilizer N losses and do not include losses of soil nitrogen. However, as mineral soil nitrogen was

relatively low at both locations, it can be concluded that the nitrogen balance studies support reasonably well the C_2H_2 estimates of nitrogen losses. The latter technique, however, has a major advantage, namely, the capability of assessing short term denitrification rates which occur shortly following a local rainfall event.

Discussion

The total amount of nitrogen lost as $(N_2O + N_2)$ -N during this two-year period of study suggests that the soils, when cropped to wheat lost a very small amount of nitrogen, in the vicinity of $2\text{--}3 \text{ kg N}\cdot\text{ha}^{-1}\cdot\text{yr}^{-1}$ (Fig. 3). In a few other recent studies it was also found that N_2O -N emissions from fields seeded to different crops were generally low; the cumulative N losses were: $1.2 \text{ kg N}\cdot\text{ha}^{-1}\cdot\text{yr}^{-1}$ averaged from six Iowa soils seeded to soybeans⁵; $1 \text{ to } 5 \text{ kg N}\cdot\text{ha}^{-1}\cdot\text{yr}^{-1}$ under wheat on similar soils⁴; $3 \text{ to } 6 \text{ kg N}\cdot\text{ha}^{-1}\cdot\text{yr}^{-1}$ under wheat on a Elstow Dark Brown Chernozemic soil^{2,3}. While this level of losses are insignificant to the agricultural industry, cropped soils clearly serve as a source of atmospheric N_2O which in turn may result in the catalytic destruction of stratospheric ozone layers and thus increase the harmful environmental factors including skin cancer⁸. In contrast the losses from soils under wheat-fallow rotation were two to five times

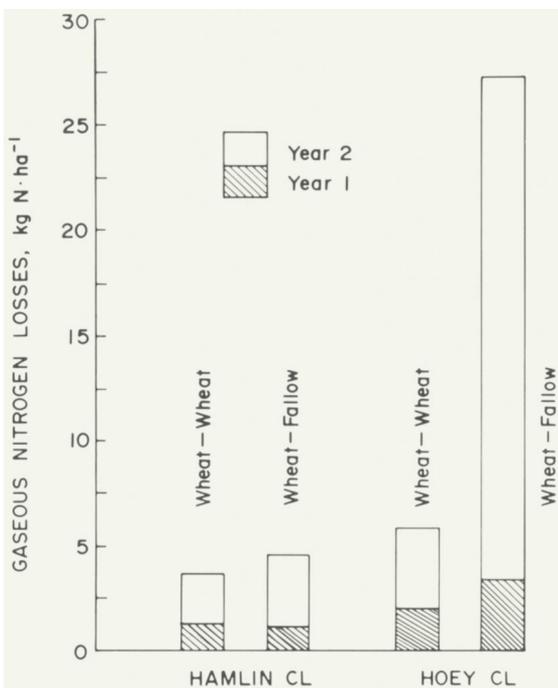


Fig. 3. Amount of gaseous nitrogen lost from Hamlin cl and Hoey cl soils under wheat-wheat and wheat-fallow rotations.

higher than from the cropped fields ranging from 5 kg N.ha⁻¹ from dry Hamlin soil to 27 kg N.ha⁻¹ in normal Hoey soil (Fig. 3). In other studies conducted on Saskatchewan soils, summerfallowed fields lost 2 to 20 kg N.ha⁻¹ in 180 days^{2,3,7}.

Conclusions

Gaseous losses of nitrogen from soils cropped with wheat were shown to be relatively small, and in the vicinity of 1–3 kg N.ha⁻¹.yr⁻¹. Losses of N₂O-N from summerfallow fields were 2–5 times higher than when the same field were cropped. The results of the present study therefore conclusively support the earlier concerns expressed about the use of summerfallow practice on the prairies^{6,12,14,15} in that this practice is associated with substantially increased denitrification losses.

The rate of gaseous N losses increased from 6 to 10 times following rainfall events. Therefore air-filled porosity was shown to be a major factor influencing N₂O-N emission from the soil. Very wide ranges in levels of NO₃⁻-N in the soil were not necessarily associated with any significant change in gaseous N losses.

The contribution of lower soil horizons towards gaseous N losses was negligible. The marked decrease in N₂O flux with soil depth followed similar decreases in organic carbon, denitrifier counts and potential denitrification rates.

A nitrogen balance study was carried out in association with weekly acetylene inhibition technique gave similar estimates of growing season losses of N.

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References

- 1 Aulakh M S and Rennie D A 1983 The influence of nitrogen immobilization on denitrification rates. *In* 1983 Annual Meetings, American Society of Agronomy, Absts. p. 152.
- 2 Aulakh M S, Rennie D A and Paul E A 1982 Gaseous nitrogen losses from cropped and summer-fallowed soils. *Can. J. Soil Sci.* 62, 187–195.
- 3 Aulakh M S, Rennie D A and Paul E A 1982 Gaseous N losses from soils under zero-till as compared to conventional-till. *In* 1982 Annual Meetings, American Society of Agronomy, Absts. p. 183.
- 4 Aulakh M S, Rennie D A and Paul E A 1983 The effect of various clover management practices on gaseous N losses and mineral N accumulation. *Can. J. Soil Sci.* 63.
- 5 Bremner J M, Robbins S G and Blackmer A M 1980 Seasonal variability in emission of nitrous oxide from soil. *Geophys. Res. Lett.* 9, 641–644.
- 6 Campbell C A, Nicholaichuk W and Warder F G 1975 Effects of a wheat-summer-fallow rotation on subsoil nitrate. *Can. J. Soil Sci.* 55, 279–286.
- 7 Chatarpaul L, Paul E A and Colaco W 1980 Denitrification in Saskatchewan soils under field conditions. *In* Abstracts of the 80th Annual Meeting, American Society of Microbiology, Miami Beach, Florida, May 11–16, 1980.

- 8 Council for Agricultural Science and Technology 1976 Effect of increased nitrogen fixation on stratospheric ozone. Report No. 53, Iowa State University, Ames, Iowa, U.S.A.
- 9 Myers R J K and Paul E A 1971 Plant uptake and immobilization of ¹⁵N-labelled ammonium nitrate in a field experiment with wheat. *In* Nitrogen-15 in Soil-Plant Studies, pp. 55–64, Intern. Atomic Energy Agency, Vienna, Austria.
- 10 Moraghan J T and Buresh R 1977 Correction for dissolved nitrous oxide in the nitrogen studies. *Soil Sci. Soc. Amer. J.* 41, 1201–1202.
- 11 Paul E A and Victoria R L 1978 Nitrogen transfer between the soil and atmosphere. *In* Environmental Biogeochemistry and Geomicrobiology, Vol. 2, W.E. Krumbein Ed., pp. 525–541, Ann Arbor Science, Ann Arbor, Michigan, U.S.A.
- 12 Rennie D A and Ellis J G 1978 The shape of Saskatchewan. Sask. Institute of Pedology Publ. M41, Univ. of Saskatchewan, Saskatoon, Sask., Canada 61 p.
- 13 Rennie D A and Paul E A 1971 Isotope methodology and techniques in soil-plant nutrition and plant physiology. University of Saskatchewan Press, Saskatoon, Sask., Canada 142 p.
- 14 Rennie D A, Racz G J and McBeath D K 1976 Nitrogen losses. *In*: Proc. Western Canada Nitrogen Symposium. pp. 324–353. Calgary, Alberta, Canada.
- 15 Rennie D A, Beaton J D and Hedlin R A 1980 The role of fertilizer nutrients in Western Canadian agricultural development. Canada West Foundation, Calgary Publ. No. 80–139, 95 p.
- 16 Smith M S, Firestone M K and Tiedje J M 1978 The acetylene inhibition method for short-term measurement of soil denitrification and its evaluation using nitrogen-13. *Soil Sci. Soc. Am. J.* 42, 611–615.
- 17 Smith M S and Tiedje J M 1979 Phases of denitrification following oxygen depletion in soil. *Soil Biol. Biochem.* 11, 261–267.
- 18 Sorensen J 1978 Denitrification rates in marine sediment as measured by the acetylene inhibition technique. *Appl. Environ. Microbiol.* 36, 139–143.
- 19 Staley T E and Griffin J B 1981 Simultaneous enumeration of denitrifying and nitrate reducing bacteria in soil by a microtiter most-probable-number (MPN) procedure. *Soil Biol. Biochem.* 13, 385–388.
- 20 Tiessen H, Bettany J R and Stewart J W B 1980 An improved method for the determination of carbon in soils and soil extracts by dry combustion. *Comm. Soil Sci. Pl. Anal.* 12, 211–218.
- 21 Volz M G 1977 Denitrifying bacteria can be enumerated in nitrite broth. *Soil Sci. Soc. Am. J.* 41, 549–551.
- 22 Yoshinari T, Hynes R and Knowles R 1977 Acetylene inhibition of nitrous oxide reduction and measurement of denitrification and nitrogen fixation in soil. *Soil Biol. Biochem.* 9, 177–183.