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Nitrate Levels in Tile Drainage Water of Fertilized and
Unfertilized Field Plots

By:

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MANAGEMENT PERSPECTIVE

This report investigated the nitrate levels in precipitation and in tile effluents including the effect of nitrate-nitrogen on corn development and yield in a pair of field plots. The plots were kept under grass with zero input of fertilizer or manure for more than five years. The levels of nitrate in tile effluents from both plots were compared with the nitrate input from precipitation where the influences of nitrogen fertilizer on the corn development and yield were evaluated in terms of length and width of corn leaf, stem size and height of corn between the fertilized and the unfertilized plots.

The results indicated that the nitrate deposition from precipitation was about 42 times higher than that removed by tile effluents. The influences of nitrogen fertilizer showed about a 20% increase in corn development and greater than 50 % increase in corn yield compared to the unfertilized plot. The results may aid in determination of nitrogen application rates for economic return and environmental benefits.

Continued development and use of mathematical models to determine what combination of factors should be used to maximize the efficiency of N use under different conditions of soils, weather, types of N source, time and rates of fertilizer application.

Teneur en nitrates de l'eau des canalisations en terre cuite provenant de parcelles de terrain fertilisées et non fertilisées

H. Y. F. Ng et R. P. Rudra

SOMMAIRE À L'INTENTION DE LA DIRECTION

Ce rapport concernait sur les teneurs en nitrate des précipitations et des effluents des canalisations en terre cuite, et notamment l'effet du rapport nitrate-azote sur le développement et le rendement du maïs dans deux parcelles de terrain. On a gardé celles-ci recouvertes d'herbe pendant plus de cinq ans sans apport de fertilisant ou de fumier. On a comparé les teneurs en nitrate des effluents des canalisations en terre cuite des deux parcelles avec l'apport en nitrate des précipitations, et on a évalué les effets des fertilisants azotés sur le développement et le rendement du maïs pour ce qui est de la longueur et de la largeur des feuilles, de la taille des tiges et de la hauteur des plantes, en comparant les valeurs obtenues pour les parcelles traitées avec un fertilisant et non traitées.

Les résultats indiquent que le dépôt de nitrate des précipitations était environ 42 fois supérieur à la quantité enlevée par les effluents des canalisations en terre cuite. L'effet des fertilisants azotés correspondait à une augmentation d'environ 20 % du développement et de plus de 50 % du rendement du maïs, par rapport aux valeurs des parcelles non traitées. Ces résultats peuvent faciliter la détermination des taux optimaux d'application d'azote pour obtenir un bon rendement au moindre coût, tout en protégeant l'environnement.

On devrait continuer à développer et à utiliser des modèles mathématiques en vue de déterminer la combinaison de facteurs préférables pour maximiser l'efficacité de l'utilisation de N dans différentes conditions de sol, de température, de sources de N, ainsi que de moment et de taux d'application de fertilisant.

ABSTRACT

Nitrate levels in precipitation and in tile effluents were monitored on a pair of field plots to document the status of input from precipitation and soil fertility. The field plots with imperfect drained Concestoga silt loam soil were established in Elora Research Station of the University of Guelph. The plots were kept under grass with zero input of nitrogen (fertilizer or manure) for the more than five years. Nitrate concentration monitoring began in April 1997 and throughout 2000. Herbicide of Round Up (1:2, dicamba:atrazine) was applied at 7 L/ha to both plots on April 27 2000 to control weeds. Both plots were planted with corn (*Zea mays L.*), Pioneer 3905, on May 31, 2000 under no-till practices. Fertilizer (12.5-100-80 (kg/ha), N-P-K) was applied incorporated to the seed rows on one plot (referred to as W3) while the other plot (referred to as W4) was unfertilized. Side dressing of 28% (28 mg/L nitrate/ha) of urea ammonia nitrate mixed with water was band applied at 165L/ha to the corn row of the W3 on July 5, 2000. The average nitrate concentrations for precipitation, tile effluents of W3 and W4 from April 1997 to May 2000, respectively, were 1.031, 0.123 and 0.116 mg/L and the average nitrate concentrations in precipitation, tile drains of W3 and W4 from June to December 2000 after fertilization on W3 respectively, were 0.546, 1.558 and 0.209 mg/L. The cumulative nitrate loss of 0.47 kg/ha for W3 compared to 0.44 kg/ha for W4 from April 1997 to May 2000 was almost equal and the nitrate input from precipitation over the same period was 19.5 kg/ha which suggested that nitrate losses from W3 and W4 were practically contributed from precipitation input. In contrast, cumulated nitrate loss of 2.75 kg/ha for W3 was 91% higher compared to 0.241 kg/ha for W4 over the same period, from June to December 2000.

The nitrate input from precipitation of 3.26 kg/ha from June to December 2000 was comparable to the nitrate loss of 2.75 kg/ha from W3, suggesting that the nitrate loss from W3 plot was virtually contributed by applied fertilizer. The influence of nitrogen fertilizer on corn physiological development and yield were investigated. The length and width of leaf and size of stem measured on W3 plot with fertilizer input of 18.8 kg N/ha (12.5 kg N/ha plus side dressing of 6.3 kg N/ha of Urea ammonia), were about 20% larger with the exception of stem height, which was 37% taller compared to the unfertilized plot, W4. The overall average yield of stalk and cob by weight were 53% higher for W3 compared to W4.

RÉSUMÉ

On a surveillé la teneur en nitrates des précipitations et des effluents de canalisations en terre cuite de deux parcelles de terrain afin de documenter l'apport des précipitations et la fertilité du sol. Les parcelles de terrain (silt loameux Concestoga imparfaitement drainé) étaient situées dans la station de recherche d'Elora de l'Université de Guelph. On a gardé celles-ci recouvertes d'herbe pendant plus de cinq ans sans apport de fertilisant ou de fumier et on a surveillé les concentrations de nitrate d'avril 1997 à la fin de 2000. On a appliqué de l'herbicide Round Up (1:2, dicamba:atrazine) à 7 L/ha sur les deux parcelles le 27 avril 2000 afin de limiter la croissance des mauvaises herbes, avant d'y planter du maïs (*Zea mays L.*) Pioneer 3905 le 31 mai 2000 par semis direct. On a appliqué des fertilisants (N-P-K : 12,5-100-80 kg/ha) incorporés aux rangs de semis d'une des parcelles (appelée W3), alors que l'autre parcelle (appelée W4) n'a reçu aucun fertilisant. De plus, le 5 juillet 2000, on a aussi pratiqué, sur les rangs de maïs de W3, un épandage en bandes latérales de 28 % (28 mg/L nitrate/ha) d'ammoniac à l'état d'urée et de nitrate mélangés à de l'eau, à raison de 165 L/ha. Les concentrations moyennes de nitrate des précipitations et des effluents des canalisations en terre cuite de W3 et de W4 (avril 1997 à mai 2000) étaient respectivement de 1,031, 0,123 et 0,116 mg/L, alors que les concentrations moyennes de nitrate dans les précipitations et les effluents des canalisations en terre cuite de W3 et W4 (juin à décembre 2000), après l'application de fertilisant sur W3, étaient respectivement de 0,546, 1,558 et 0,209 mg/L. La perte cumulée de nitrate de 0,47 kg/ha de W3 était presque égale à celle de 0,44 kg/ha de W4 (avril 1997 à mai 2000), et l'apport de nitrate des précipitations pendant la même période était de 19,5 kg/ha, ce qui semble indiquer que les pertes de nitrate de W3 et W4 étaient pratiquement comblées par l'apport des précipitations. Par contre, la perte cumulée de nitrate de 2,75 kg/ha de W3 était supérieure de 91 % à celle de 0,241 kg/ha de W4 pendant la même période (juin à décembre 2000).

L'apport de nitrate des précipitations de 3,26 kg/ha, de juin à décembre 2000, était comparable à la perte de nitrate de 2,75 kg/ha de W3, ce qui permet de croire que la perte de nitrate de W3 était pratiquement comblée par l'application de fertilisant. On poursuit l'étude des effets des fertilisants azotés sur le développement physiologique et le rendement du maïs. Avec un apport de fertilisant de 18,8 kg N/ha (12,5 kg N/ha et un épandage en bandes latérales de 6,3 kg N/ha d'ammoniac à l'état d'urée), par rapport aux valeurs de la parcelle W4 non traitée, la longueur et la largeur des feuilles mesurées dans W3 étaient supérieures d'environ 20 %, et la hauteur des tiges, de 37 %. Par rapport à celui de W4, le rendement d'ensemble moyen en poids des tiges et des épis de W3 était supérieur de 53 %.

MANAGEMENT PERSPECTIVE

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Next steps Continued development and use of mathematical models to determine what combination of factors should be used to maximize the efficiency of N use under different conditions of soils, weather, types of N source, time and rates of fertilizer application.

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The influence of nitrogen fertilizer on corn physiological development and yield were investigated. The length and width of leaf and size of stem measured on W3 plot with fertilizer input of 18.8 kg N/ha (12.5 kg N/ha plus side dressing of 6.3 kg N/ha of Urea ammonia), were about 20% larger with the exception of stem height, which was 37% taller compared to the unfertilized plot, W4. The overall average yield of stalk and cob by weight were 53% higher for W3 compared to W4.

NITRATE LEVELS IN TILE DRAINAGE WATER OF FERTILIZED AND UNFERTILIZED FIELD PLOTS

by

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ABSTRACT

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KEYWORDS: Nitrate loss, Tile flows, Precipitation, Corn.

INTRODUCTION

Nitrate contamination of surface and ground waters is of environmental concern. High inputs of N fertilizer are required to support intensive row-crop agriculture, particularly for corn in the Midwest of United States and the Eastern provinces of Canada (McRae, et al., 2000), where fertilizer application rates are typically 100 to 200 kg N/ha per year (David, et al., 1997). The intensive agriculture and widespread cultivation of leguminous crops has led to additional quantities of nitrogen being deposited into terrestrial and aquatic ecosystems. The principal form of anthropogenic nitrogen accounting for about 60 percent of the total is inorganic fertilizer. Typically, less than half of the nitrogen fertilizer applied is taken up by plants, and the rest is lost to the air, dissolved in surface water or lost into groundwater (Vitousek et al., 1997).

This report investigates the nitrate in tile flows resulting from precipitation before and after fertilization on plots. The plots were established under grass cover for more than five years. Corn (*Zea mays* L.) was grown on two plots with fertilizer input to one of the plots in May 2000, while the other plot remained unfertilized. Nitrate in precipitation and in tile flows was monitored together with soil moisture content and temperature and recorded for 45 months (April 1997 to end of 2000). The purpose of this study is to establish levels of nitrate input from precipitation and soil fertility as well as the effect of nitrate on crop development and yield. The results may aid in determining or improving nitrogen application rates.

Study site and subsurface tile drain layout

The study site comprised two paired plots with an area of 0.0836 ha (27.5 m wide by 30.5 m long) located at the Elora Research Station (43° 38' 02" N 80° 24' 50" W), Elora, Ontario. The tile layout is shown in Figure 1 (A). The tiles of 102 mm in diameter are inter-connected in a closed loop design with one outlet at the corner of the plot (Figure 1 (A) and (B)). The tile flow for the fertilized plot is referred to as W3, and W4 for the unfertilized plot. Both plots were kept under grass, with zero input of nitrogen (fertilizer or organic manure) and herbicides for more than five consecutive years. The soil type of the plot is primarily an imperfectly drained Concestoga silt loam. There is a discontinuous sand layer at the level of the drain and it extends at some locations to a depth of 4 m. Below 4 m there is a tight hard till which provides a low permeability barrier to seepage downward.

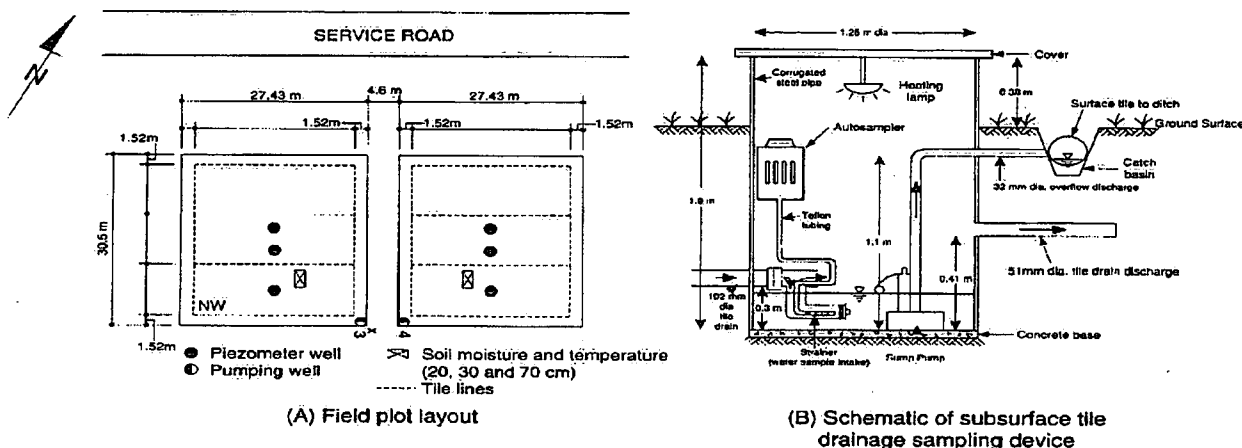


Figure 1. Field plot design and tile drainage sampling device

A 1.25 m diameter, 1.9 m deep galvanized well with a cemented bottom was established on each plot to receive the tile drainage from the plots (Figure 1(A)). The inverted tile slope referenced to the outflow at the well is 0.008%. The spacing between cross-connected tiles is 9 m. The invert of tiles is 1.1 m below the ground surface.

Tile flow samples were collected by an ISCO model 2900 autosampler with 24-500 ml bottles (Figure 1 (B)). The autosampler is activated by a water level sensor. When the water level in the well rises to a preset level, the autosampler is activated to start sample collection. The samples were collected during 24 hour interval at 500 ml each.

The tile flow volume was measured by a calibrated sump pump. When the water level in the well rises to a preset level, the sump starts to discharge the water out from the well. When the water level returns to the preset level, the sump stops. The tile flow volume was calculated from the duration of pump operation, multiplied by the sump's discharge rate. The discharge rates of the sump pump were 1.1623 L/s and 1.1598 L/s for W3 and W4, respectively.

To prevent the sampling well being flooded, an emergency discharge pipe was installed at 0.41 m from the bottom of the well (Figure 1 (B)).

Precipitation sampling and measurement

During summer, rainwater samples were collected by a rainwater collector (Hohener Enterprises Ltd. Richmond Hill, Ontario). During dry periods, the rainwater collector bucket stays covered to prevent entry of unwanted dry particulate matter into the bucket. Moisture sensing grids are employed in conjunction with a solid state control circuit to operate the motor driven cover at the onset and end of a rainfall event. A heated tipping bucket rain gauge model P-1000 (Geneq Inc.) was used to gauge volume of rainfall or precipitation year round. During winter, precipitation sample was collected from the heated rain gauge. A heated funnel collector of the rain gauge directs snow melt to the tipping bucket assembly connected to a sampling jar located inside the heated W4. Each tip of the bucket is recorded by a Campbell Scientific 21 Series Data Logger and the records are converted to precipitation amount by a computer.

Soil moisture and temperature

Hourly soil moisture and temperature at depths of 20, 30 and 70 cm in each plot (Figure 1 (A)) were measured by a Time Domain Reflectometer (TDR) and a temperature sensor. The records were stored in a Campbell Scientific 21 data logger and retrieved by a computer.

Water table monitoring

Three piezometric wells were installed at the centre of each plot (Figure 1(A)) to monitor the fluctuation of the water table depth. A weekly reading of water table depth for each well was obtained by using a Solinst Levellogger from May 2000 to the end of 2000. One of the piezometric wells in the fertilized plot (W3) malfunctioned throughout the experimental period.

Nitrate analysis

Precipitation and tile flow samples were stored at 4°C prior to the laboratory determination of nitrate concentration by an ion chromatography method (Environment Canada, 1994). Samples were composed to reduce the number of tests. The number of composite samples for laboratory analysis for a month ranged from two to five samples. The detection limit of the nitrate analysis by the ion chromatography method is 0.01 mg/L.

Field experiments in 2000

Planting and agronomy

Prior to planting corn, herbicide Roundup, a product of glyphosate, was applied at 7 L/ha on April 27, to both plots to control weed. The plots without tillage were seeded with corn (*Zea mays* L.), Pioneer 3905 at 50,000 seeds/ha at 75 cm wide row and at 51 cm spacing, on May 31, 2000. After seeding, a total of 36 rows of corn were planted on an area of 0.0594 ha (27 m x 22 m) of each plot. The Pioneer 3905 (Pioneer Product Info. www.pioneer.com, 2000) is a widely adapted agronomically consistent hybrid. It offers a very good drought tolerance and stays green. It also results in solid yields, above average stalks

and performs when challenged by a short growing season. It is also highly resistant to wilt and head smut.

Fertilizer (12.5-100-80 (kg/ha), N-P-K) was applied and incorporated to the seed rows on the fertilized plot (W3) while the other plot (W4) was unfertilized. Side dressing of 28% of urea ammonia nitrate contained in water was band applied at 165 L/ha to the corn row on the fertilized plot on July 5, 2000.

Harvesting

The purpose of harvest was to compare the corn yield by the weight of corn stalk and cobs between the fertilized and unfertilized plots. The corn was harvested by random sampling procedures. Results of harvest are given under the Results and Discussion section. The random sampling procedures were setup as follow:

1. Five rows of corn measured at 5 m each were randomly selected from the W3 and W4 plots.
2. Each plant of the corn rows was manually cut at ground level, bundled and weighed at the time of harvest.
3. Four plants including stalk and cobs from each of the five rows of the W3 and W4 were randomly selected and mixed as a random sample in a batch.
4. The batch sample was weighed before oven dried in the Hotpack oven at 80°C for 8 days.

RESULTS AND DISCUSSION

Relative flows

Figure 2 shows that very low precipitation fell in 1997, 1998 and 1999, compared to 2000. The sum of the monthly precipitations for the years of 1997, 1998, 1999 and 2000, respectively, were 392.7mm, 539.5 mm, 507.2mm and 1405.1 mm. The low tile flows depicted in 1997, '98 and '99 resulted from this low precipitation.

Figure 3 gives the relative tile effluent volumes to precipitation (P). Table 1 presents the ratio of tile effluents, from W3 and W4, for the period from April 1997 to December of 2000. On average, the tile effluent volumes from both plots for 1997, '98, '99 and '00, respectively, were 17%, 12%, 13% and 20% of the volumes of precipitation. The ratio W3/W4 was constant, with an average value of 1.02 for 1997-2000, indicating that the effluents from both plots depend on precipitation.

Table 1. Ratio of tile flow between W3 and W4

Month	Year			
	1997	1998	1999	2000
Jan	nd	1.06	0.94	0.99
Feb	nd	1.06	0.98	1.04
Mar	nd	1.06	1.00	1.06
Apr	1.05	1.03	0.86	1.01
May	1.05	1.07	1.06	1.04
Jun	0.95	1.05	1.11	1.04
Jul	0.95	0.94	1.13	1.07
Aug	0.94	1.04	0.93	1.02
Sep	0.98	0.96	0.97	1.01
Oct	1.04	0.87	1.08	1.09
Nov	0.96	1.07	0.93	1.04
Dec	1.07	1.08	1.15	1.15
Average	1.01	1.02	1.01	1.05

nd = no data.

Figure 2. Volumes of precipitation and tile effluents

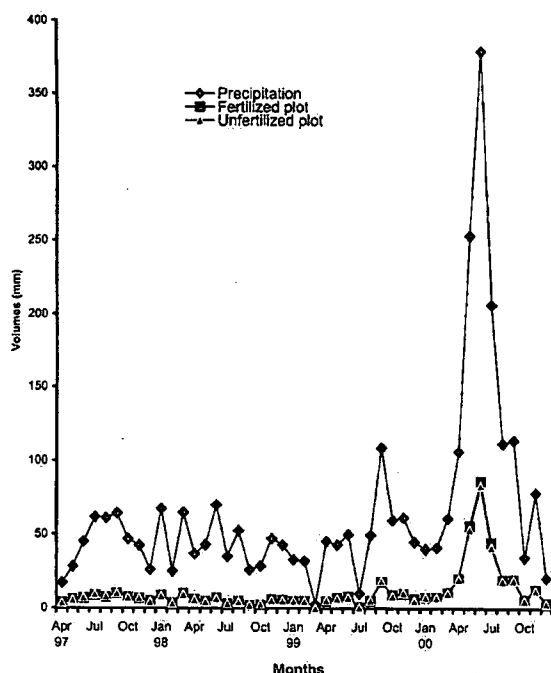
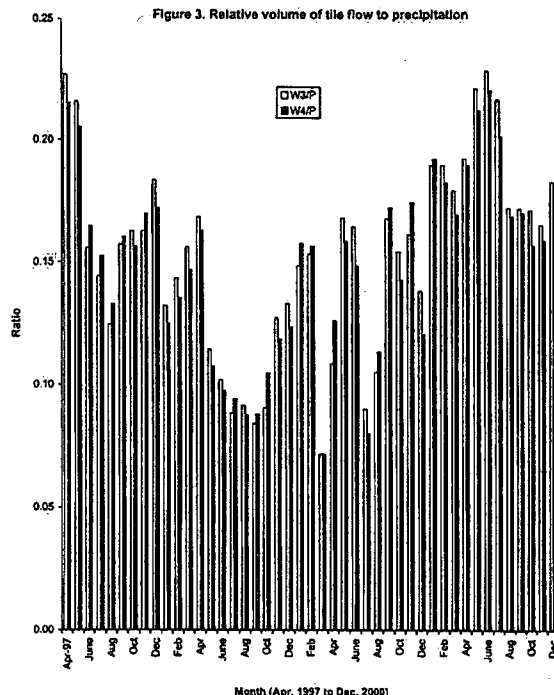


Figure 3. Relative volume of tile flow to precipitation



Monthly flows, nitrate concentrations and losses

Figures 4a and 4b compare the mean nitrate concentrations between precipitation and tile effluents. The nitrate concentration was an arithmetic mean calculated for the number of composite samples in the month. A significant contrast of nitrate concentrations in precipitation emerged compared to tile effluents. The nitrate concentration in precipitation was more than two orders of magnitude higher (April 1997 - May 2000) than that of tile flows of W3 and W4. Figure 4b shows that the concentration of nitrate for W3 increased significantly after fertilization on May 31, 2000. It remained persistently higher than that in precipitation and in W4 as well. The mean concentrations of nitrate from June to December 2000 for precipitation, W3 and W4, respectively, were 0.546 mg/L (ranges 0.312 - 0.781 mg/L), 1.558 mg/L (ranges 0.426 - 5.090 mg/L) and 0.209 mg/L (ranges 0.110 - 0.270 mg/L). The high concentration of nitrate detected in the fertilized plot, W3 (Figure 4b) may be explained as a leftover nitrate throughout the cropping cycle. The leftover of nitrate in the soil combined with nitrate in incoming water from precipitation displaces those solution already in the soil pores to flow to a drainage effluent (Burns, 1975; Chaney, 1990) or leach to deeper soil zone.

Figure 5 compares the monthly precipitation load and tile loss. The precipitation load and tile loss were expressed as an unit area loss (kg/ha). The nitrate loss was calculated as a product of water volume and the nitrate concentration. Thus, nitrate loss from tile effluent depends on the volume of flow and the soil moisture content. Figure 5 showed that there were hardly any nitrate losses for W3 and W4 in 1998 and 1999 as a result of low precipitation in both years (Figure 2). The average (between 20 to 70 cm) soil moisture content and soil temperature for W3, respectively, were 49.4% ('97), 44.7% ('98), 45.7%('99) and 13.5 °C, 10.1 °C and 9.9 °C. Similarly, the average soil moisture content and soil temperature for W4, respectively were 54.2%('97), 62%('98), 55.6('99) and 13.6 °C, 10.1 °C and 9.9 °C. The soil temperatures between W3 and W4 were practically identical. Dry weather had been experienced elsewhere throughout Southern Ontario, particularly during the years of 1998 and 1999. The accumulated nitrate losses for W3 and W4 (from April 1997 to May 2000 before the W3 fertilization), respectively, were 2.4% ($0.47 \times 100 / 19.51$) and 2.3% ($0.44 \times 100 / 19.51$) of the precipitation input. The surplus of nitrate input from precipitation may be interpreted as the nitrate which is attracted to the clay particulate and to some extent held back against being washed out until the soil becomes favourably moist (Wong et al., 1987).

Figure 4a. Average NO₃ concentrations in precipitation, fertilized and unfertilized plots

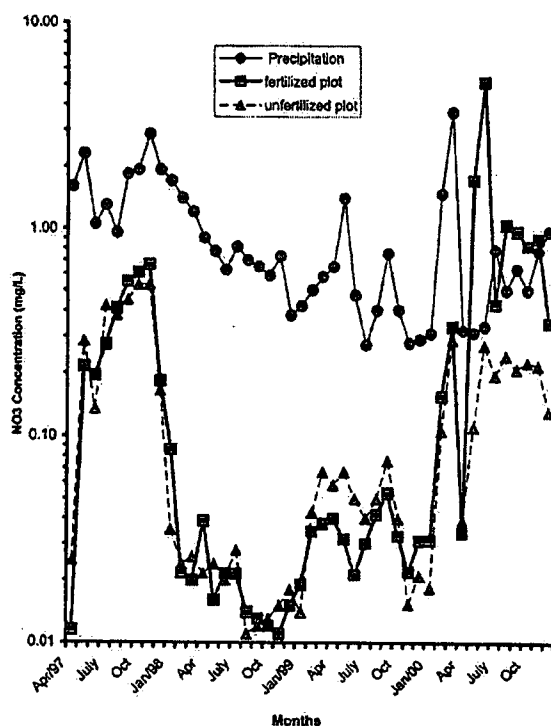
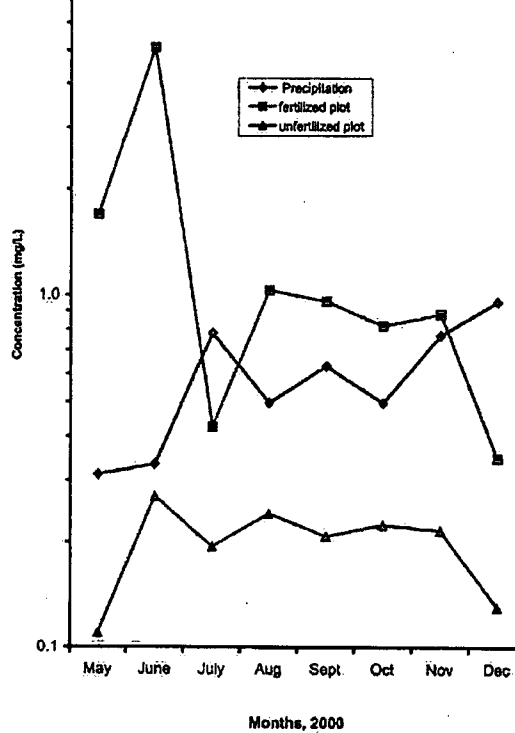


Figure 4b. Mean NO₃ concentrations, after fertilization of W3, for the months of May to December 2000.



In contrast, the accumulated nitrate loss for W3 subsequent to fertilization from June to December 2000 increased to 4.22 kg/ha from 0.47 kg/ha prior to May '99. The loss is comparable to 4.08 kg/ha of the input from precipitation. The increase of nitrate loss for W3 can be seen as a result of fertilizer applied in May and the increase of moisture supply. The cumulative precipitation from June to December was 565.4 mm and the average soil moisture content during that period was 65%. The moisture content was averaged at depths between 20 and 70 cm. The average of monthly nitrate loss 0.055 kg/ha from June to December 2000 for W4 was about 5 times higher compared to the monthly nitrate loss of 0.010 kg/ha subsequent to May '00. During the same period, the total precipitation was 565.4 mm as noted earlier and the average concentration of nitrate in precipitation was 0.546 mg/L (range 0.312-0.781 mg/L), thus more than 2.6 time higher compared to the nitrate concentration of 0.209 mg/L (range 0.110-0.270 mg/L) for W4. This suggests that the increase loss of nitrate for W4 resulted from moisture supply as well as the concentration of nitrate in precipitation. The average of soil moisture content for W4 from June to December 2000 was 63.4%.

Effect of fertilizer on corn development

Nitrogen fertilizer influences the yield of crops in four ways, that is, the leaf area, crop development, crop quality and side effects. The leaf area and crop development involve the quantity of yield. For this reason, physiological development of corn was observed during the vegetative stages. The vegetative stage begins with the seeding date on May 31, 2000. This stage lasts until the silking occurs, which in this experiment occurred 74 days after seeding (August 13) for the fertilized plot and about 80 days for the unfertilized plot. The second stage starts when the corn enters the reproductive stage. At this stage the length and width of the leaf, heights of plant, size of stems, were measured on a weekly basis. A total of nine measurements were conducted between July 12 and September 26, 2000. Nine healthy plants were sampled from each of the W3 and W4 plots. The value of a measured parameter was determined by an

arithmetic mean. Figure 6 and Table 2 show the corn development between the fertilized and unfertilized plots. It is obvious that the length, width and size of stems of corn were all longer and larger by about 20% for the fertilized plot, compared to the unfertilized plot. The stem height was much taller on the fertilized plot, by about 37%, compared to the unfertilized plot.

Figure 5. Cumulative nitrate loading from precipitation and nitrate loss from effluents of W3 and W4

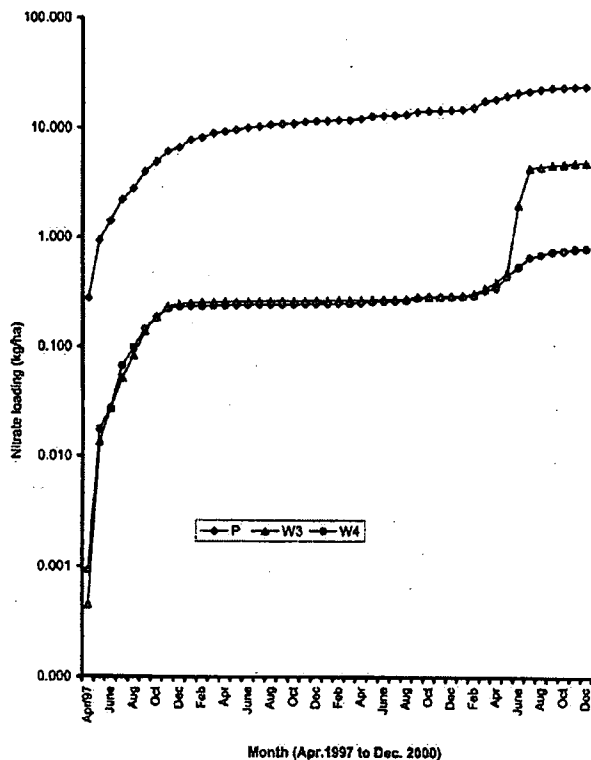


Figure 6. Comparison of physiological development of corn between the fertilized and unfertilized plot

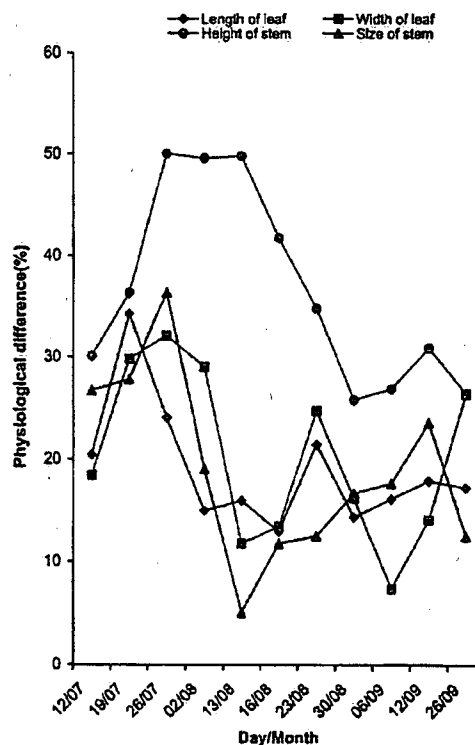


Table 2. Corn development between fertilized and unfertilized plot.

2000 dd/mm	Average length of leaves				Average width of leaves				Average height of stem				Average stem size			
	W3 (cm)	Std. (cm)	W4 (cm)	Std. (cm)	W3 (cm)	Std. (cm)	W4 (cm)	Std. (cm)	W3 (cm)	Std. (cm)	W4 (cm)	Std. (cm)	W3 (cm)	Std. (cm)	W4 (cm)	Std. (cm)
12/07	32.1	4.2	25.5	3.8	3.8	1.2	3.1	1.1	27.6	3.7	19.3	5.4	1.5	0.9	1.1	0.4
19/07	39.6	7.6	26.0	8.6	4.7	0.9	3.3	0.8	42.4	4.8	27.0	9.1	1.8	0.6	1.3	0.5
26/07	47.1	4.9	35.8	9.4	5.3	1.6	3.6	1.1	64.8	9.9	32.4	9.9	2.2	0.6	1.4	0.5
02/08	53.9	4.6	45.8	8.8	6.5	0.7	4.9	0.8	100.3	12.5	50.6	13.3	2.1	0.4	1.7	0.5
13/08	60.3	3.4	50.7	6.3	6.9	0.8	6.0	0.7	157.4	16.9	79.1	29.3	2.0	0.5	1.9	0.5
16/08	57.9	3.8	50.4	6.0	6.8	0.5	5.8	1.3	177.4	10.1	103.4	13.2	1.7	0.2	1.5	0.3
23/08	56.5	5.9	44.4	10.8	6.7	1.2	5.8	1.3	178.3	8.7	116.3	25.1	1.6	0.2	1.4	0.2
30/08	58.6	5.0	50.2	7.2	7.7	0.7	6.2	0.7	181.4	11.8	134.7	16.2	1.8	0.2	1.5	0.2
06/09	59.0	3.5	49.5	4.3	7.4	0.6	6.3	0.5	180.8	4.0	132.2	14.0	1.7	0.2	1.4	0.3
12/09	58.2	4.5	47.8	6.8	6.8	0.8	6.1	1.0	178.3	17.1	123.3	15.1	1.7	0.2	1.3	0.2
26/09	58.4	4.9	48.3	5.9	7.1	0.9	6.1	0.8	174.0	11.9	128.1	12.3	1.6	0.3	1.4	0.3
Ave.	52.8	4.8	43.1	7.1	6.3	0.9	5.2	0.9	133.0	10.1	86.0	14.8	1.8	0.4	1.4	0.4
Std.	9.3	1.2	9.6	2.2	1.2	0.3	1.3	0.3	61.7	4.6	45.8	6.9	0.2	0.2	0.2	0.1

Mortality of corn seed

The number of corn plants at matured stage on W3 and W4 were counted. The number of corn plants counted was 520 plants more on W3 than on W4, a difference by 20%. The low mortality rate of seed

germinated on W4 appeared to be due to the fact that the soil of W4 was over-saturated with water. Several depression areas of W4 were waterlogged during the germination period. The results of plant counts are summarized in Table 3.

Table 3. Summary of mortality of corn seed:

	Fertilized plot	Unfertilized plot
Virtue planting		
Seeding rate (seed/ha)	50,000	50,000
Actual plot area (ha)	0.0836	0.0836
Effective seeded area (ha) = 27m x 22 m	0.0594	0.0594
Total # of seed per plot = 50,000 x 0.0594	2970	2970
Total # of seeded rows per plot	36	36
Total number of matured plants counted	2763	2243
Average number of plants per row	84	66
Standard deviation	35.3	40.6
Seeds germinated (%)	94	75

Corn yield

Corn was harvested on October 25, 2000 by the random sampling procedures described earlier. The yields for W3 and W4 were evaluated in terms of the weight of wet and dry stalk and cob by a mixed batch. Table 4 summarized the results of harvest in mixed batch.

Table 4. Summary of random harvest of mixed batch.

Row	W3 mixed batch		W4 mixed batch	
	# of plant (per row)	stalk and cobs (kg)	# of plant (per row)	stalk and cobs (kg)
1	25	10.2	20	3.0
2	21	8.1	16	3.6
3	22	9.1	20	3.9
4	20	10.2	11	3.5
5	18	7.8	18	3.9
Average	21	9.1	17	3.6
Mixed batch	20	10.1 (0.51kg/plant)	20	4.4 (0.22kg/plant)

The difference between the wet and dry weight of mixed batch determined the moisture content of the corn mass. Table 5 shows that mixed batch of dried stalk and cob for W3 was 3.8 times (73.8 %) higher in weight compared to W4. The weight of wet stalk and cob of W3 was almost 1.8 times (56%) higher in yield compared to that of W4.

Table 5. Corn yields of wet and dry mass

	W3	W4	W3-W4	Ratio (W3/W4)	(W3-W4)/W3 (%)
Mixed batch of wet stalk and cob (kg)	10.1	4.4	5.7	1.8	56.4
Mixed batch of dry stalk and cob (kg)	6.1	1.6	4.5	3.8	73.8
Difference between wet and dry (kg)	4.0	2.8	1.2	1.4	30.0
Overall average					53.4

CONCLUSIONS

As shown in Figure 5, the observations of nitrate loss in tile effluents over the 45 month period from April 1997 to May 2000, 19.5 kg/ha nitrate were deposited from precipitation and about 0.47kg/ha and 0.44 kg/ha, respectively, were removed from W3 and W4. The balance would build up in the soil column (Gast

et al. 1978; Baker and Johnson, 1981). As shown in Figures 4a and 4b, when favourable moisture supply occurred, this reserve was washed out from soil pores.

The effect of fertilizer N on corn development and corn yield, given in Tables 2, 3 and 4 for the fertilized and unfertilized plots facilitates evaluation of the optimal yield. The efficiency of fertilizer use for W3 was evaluated in terms of the ratio between N input and the total yield. Total yield estimated for W3 is 1983 kg/ha (2763 plants x (.0836/.0594 ha) x 0.51 kg/plant). The total applied N was 18.8 kg/ha (12.5 kg N/ha applied in addition to 6.3 kg N/ha urea ammonia side dressing, regardless of the precipitation input prior to May 2000). The result is 105 kg (stalk and cobs) per kg of applied N.

As shown in Tables 4, 5 and Figure 6, the physiological development and the yield of corn, on average, varied from 19% for stem sizes to 53% for wet and dry mass between W3 and W4. This implies that the baseline levels of nitrate can sustain corn growth but do not increase the yield.

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REFERENCES

- Baker, J.L. and H.P. Johnson. 1981. Nitrate-Nitrogen in tile drainage as affected by fertilization. *J. Environ. Qual.*, Vol. 10. No.4, 1981.
- Burns, I.G. 1975. An equation to predict the leaching of surface applied nitrate. *Journal of Agricultural Science*, 85, 443-454.
- Chaney, K. 1990. Effect of nitrogen fertilizer rate on soil nitrogen content after harvesting winter wheat. *Journal of Agricultural Science* 114, 171-176.
- David, M.B., L.E. Gentry, D. A. Kovacic and K.M. Smith. 1997. Nitrogen balance in and export from an agricultural watershed. *J. Environ. Qual.* 26:1038-1048.
- Environment Canada, 1994. Manual of analytical methods, National Laboratory for Environmental Testing. Chapter 3, Volume I.
- Gast, R.G., W.W. Nelson, and G.W. Randall. 1978. Nitrate accumulation in soils and loss in tile drainage following nitrogen application to continuous corn. *J. Environ. Qual.* 7:258-262.
- Goss, M.J., E.G. Beauchamp and M.H. Miller. 1995. Can farming system approach help minimize nitrogen losses to the environment? *J. Contam. Hydrology.* 20:285-297.
- McRae, T., C.A.S. Smith and L.J. Gregorich. 2000. Environmental sustainability of Canadian agriculture: Report of the Agri-Environmental Indicator Project. A summary. Agriculture and Agri-Food Canada, Ottawa, Ont.
- Vitousek, P. M., J. Aber, R. W. Howarth, G. E. Likens, P.A. Matson, D.W. Schindler, W. H. Schlesinger and G.D. Tilman. 1997. Human alteration of global nitrogen cycle: cause and consequences. *Ecological Application* 7. p 737-750.
- Wong, M.F.T., A. Wild, A.S.R. Juo. 1987. Retarded leaching of nitrate measured in monolith lysimeters in south-east Nigeria. *Journal of Soil Science* 38, 511-518.

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