THE NITROGEN CYCLE AND NITROGEN BUDGET IN RELATION TO POLLUTION

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Nitrogen is the essential element which most often limits plant productivity and life on this continent by its shortage. It is, therefore, somewhat odd that an element generally in short supply which also is relatively expensive to produce and handle, should cause pollution because of excess concentrations under certain conditions. Pollution is often considered to be strictly man made and to occur only when the normal processes of nature are disturbed. To some extent this is true, however in the case of N, there are many examples where concentrations in excess of those immediately required occur naturally.

Excess N can cause eutrification in lakes by the excess growth of algae. NO_3-N in cattle feed causes poisoning, vitamin A deficiency and abortion, and excess concentrations in drinking water result in methemogblobinaemia in infants. Now people are starting to worry about sub-lethal levels of nitrate, re: night blindness and possibly cancer. Wastage of N also is a misuse of an important essential nutrient. Both agriculture and the environment will greatly benefit from the proper use of this material.

The N cycle includes N fixation into organic materials in the form of microorganisms and addition of N to the soil by rainfall. The N from rainfall under our conditions ranges from 1 to 3 lb per acre with most of the material being in the ammonia or organic sources. The very low incidence of oxidized forms in rainfall indicates that the oxidized forms from vehicles do not yet influence our environment to a significant extent. The organic N in the soil is mineralized to ammonia and then to nitrate. Both these inorganic forms are utilized by plants for growth.

It is of interest that on terrestrial soils large amounts of growth are desirable. But in the water systems we want to keep plant life as low as possible. In our study of pollution, should we consider proper means of harvesting the vegetative material of lakes as well as keeping the eutrification from occurring. Plant materials are harvested by man and his machinery and by cattle. When these plant materials are processed either through industrial plants or through animal bodies, including humans, pollution can occur if the N is not returned to its normal source the soil or the atmosphere as N_2. Thus, we now have problems with sewage effluents and with manure disposal.

Nitrogen Economy of the Soil

The oxidized form of nitrogen, i.e. nitrate and nitrite are subject to leaching to lower depths in the soil and to the ground water and streams and to denitrification. The removal or loss of N from some soils are shown in Table 1. In one year of crop growth approximately 50 to 60% of available N is utilized by the plant, and if the above ground parts are harvested, it is removed from the soil. The 20 to 40% that is immobilized is slowly released over approximately 15 years and forms the revolving bank account of N which is the seat of soil fertility. A small proportion of this immobilized N is changed to humic constituents which can persist for hundreds of years.

Erosion, which in this table accounts for 1 to 15% of the total N losses from the soil can be very important in Saskatchewan, both from the aspect of losses from agricultural systems and the contamination of surface waters. Our surface soil contains on the average 0.3% nitrogen. This means that the top 6 inches contain approximately 6,000 lb of N/acre. The removal of a 1/10 inch of soil results in the loss of 100 lb of N. Extrapolated to only a square mile basis or 640 acres, means that 32 tons of N are transported away if a tenth of an inch of top soil is removed by wind or water erosion. Table 2 shows some quantitative data for N removal by water in Minnesota. Maximum losses as sediment occur under fallow. The 57 lb of N lost as sediment from fallow are in the same order of magnitude as the N removed by 1/10 of an inch of soil calculated earlier. At the opposite end of the scale is the effect of leaching of N out of hay (3 lb/acre).

The loss of organic materials by leaching from standing crops or the movement of animal residues is very important. Another paper at this meeting discusses the effect of slope on movement within the soil. The surface wash of manures, especially those on hilly ground and if applied in the winter are causing a fair amount of concern. I grew up in an area that was disected by a fair number of streams, and large numbers of the farmsteads of our area were situated near the banks of these streams. Large piles of manure resulting partly from cattle operations but primarily from the use of horses were piled on the banks of these streams. The use of the horse and binder concentrated the residues in straw piles, and after utilization of grain in manure-piles, a great proportion of this was washed directly into streams. I don't know to what extent this is occurring now. However, this isn't a research problem but one of legislation. We must get our organic waste disposal areas off sharply sloping areas, especially if they lead directly into streams.

A problem that must be dealt with is that of manure and sewage disposal in the winter on frozen ground. Because of our short growing season, I don't feel that it is practical that we can insist that manure be applied only to unfrozen ground. The extent of solubilization of organic wastes and physical movement during the spring when rapid runoff occurs is not known and must be investigated.

<u>Volatilization and leaching losses of added nitrogenous materials</u>

Fertilizer N has been implicated as a source of this nutrient relative to water pollution. D. Laverty at a similar symposium in Edmonton showed figures which indicated that N fertilizer only accounted for 3% of the production of grains in the three Western provinces. The figures for Saskatchewan would be much lower. In Wisconsin it has been estimated that fertilizer N accounted for 10% of the production. In other states where high levels of production are maintained by fertilization, it can account for 50% of the production. When it reaches these levels and is applied in concentrations in excess of that required for plant growth, fertilizer N must be considered as a possible pollutant.

A source of N for standing bodies of water that has recently come to the fore is that of adsorption of ammonia from the atmosphere. Misuse of urea fertilizer can result in extensive concentrations of ammonia in the atmosphere, however, the major source of atmospheric ammonia under our conditions would be feedlots. Table 3 shows the amount of N that can be adsorbed by water at various distances from a number of feedlots. This study was conducted in Colorado and no effect of climate was found on ammonia adsorption. Under their conditions the surface waters were not frozen for any extended periods. Similar studies have not been conducted under our conditions, but their studies should apply in Saskatchewan for at least 8 months of the year.

Studies on the same site in Colorado indicate the potential for N movement into the lower portion of the soil and the water table. This study was undertaken in an area that was drier than most of our conditions, but with slightly more permeable parent material. It indicates that dryland agriculture has resulted in the movement of N to lower depths in the soil and into the water tables. Dr. Doughty at Swift Current many years ago also observed that NO_3-N moved below the 4 ft depth under normal agricultural conditions in that area. The often quoted table of Stewart et al. (Table 4) indicates the importance of feedlots as a source of N in the soil profile. This is causing a great deal of concern. In many feedlots where conditions are kept uniformly moist, extensive nitrification doesn't occur. Nitrogen in the ammonia form is not readily leached and anaerobic conditions under a moist feedlot result in extensive denitrification such that the ground water does not receive much nitrogen if it does occur. A number of studies in the U.S. are delineating the soil type and management conditions under which denitrification is at a maximum and nitrate pollution of ground water a minimum.

In considering feedlot location, the possibility of eventual saturation of the adsorption sites with ammonia resulting in large volatilization losses and eventual leaching, as well as the possible leaching of low molecular weight organic N compounds must be considered.

Manure if properly handled can be a great asset, Table 5 indicates rates of organic N, expressed in lb of N/acre that are being recommended for use in Saskatchewan. The amounts of manure-N that can be applied for optimum production are shown in one column. The other column indicates the amount that can be applied on a continuous basis if pollution abatement is a maximum consideration. The lower figures are the maximum suggested for coarse textured soils, the higher figures for fine textured soils. The data in Table 6 indicate that manure from feeder beef has approximately 12 lb of N/ton. Spreading 6 ton of this manure per acre would allow maximum utilization of the manure over a wide area as possible on most of the soil types. Where pollution abatement is most important on fine textured soils, nearly 20 ton of manure could be applied per acre without causing crop damage or excess of leaching losses. This is equivalent to 10 feeder cattle at normally accepted conversion rates.

Soil processes and nitrogen movement

The settlers who broke up the native sod of Saskatchewan inherited a wealth of highly fertile soils with a high N content built up over many years. It was earlier pointed out that N fertilization plays a negligible role in our agriculture. Fixation by free living organisms can build up N slowly under virgin conditions by bacteria such as the clostridia by blue-green algae living either freely at the soil surface or in association with mosses and by native legumes. Recent studies on native grassland indicate a fixation level of 1 to 3 lb/acre per year.

Symbiotic fixation by cultivated legumes can be quite significant but this type of fixation does not contribute much to the N requirements of our wheat economy. Legumes generally are assumed to be especially useful from a pollution standpoint in that the N they fix is in an organic form and that they fix no N where inorganic N is present in the soil. The data in Table 4 substantiates this. Grass sod or alfalfa keeps mineral N low unless it is poorly managed. The source of the N for the majority of our agricultural crops is still the reservoir of soil organic matter. This is being rapidly depleted as shown by the data in Table 7 for three Black chernozemic soils. The rich soil at the Indian Head Experimental Station has lost 50% of its N during the last 77 years. Identical N losses are found at the two other sites studied. This loss is still occurring. Thus in the last twenty years the Indian Head soil lost 200 lb of N in the top 6 inches and probably another 200 lb beneath this, for a net loss of 400 lb or 20 lb/acre for the year. Extrapolation of these data to the next 20 years indicate that this soil should release from 10 to 15 lb of N annually from the original source built up over the years. The rest of the N required by crop growth must come from the decay of plant residues reincorporated into the soil, from N fixation, rainfall or from fertilizer N. The 10 to 15 lb figure is not the total N mineralized annually, but it is the net loss on an annual basis above that reincorporated or reimmobilized during plant growth.

On initially breaking of the soil, very large concentrations of N were released. It was not uncommon for people measuring NO_3-N under summerfallow conditions in soils such as this to encounter 200-300 lb/acre of available NO_3-N. Shutt in 1925 estimated that of the N released during the first 27 years cropping, only 1/3 was utilized by the plants. The other 2/3 was lost by leaching or denitrification. This meant that a large amount of N could have penetrated beneath the rooting depth. We don't know the speed with which this N moves through the subsoil, and the extent of denitrification during this process. However, under our rainfall conditions the movement would be quite slow and it is possible that our ground water is not yet showing the effect of these large concentrations of NO_3-N that moved beneath the rooting depth as much as 70 years ago.

Factors affecting nitrogen leaching

The two factors affecting N leaching are availability of NO_3 and net movement of water through the soil profile. Gardiner (1965, 1967) has developed equations by which NO_3 leaching can be calculated. He has found a good correlation simulated values and those determined in the field. I look forward to application of these calculations to our own conditions. We have a good record of NO_3-N in the soil and environmental parameters can be used to measure net movement of water through the soil profile under different cropping practices.

Our Soil Testing Laboratory has given us extensive information on the NO_3-N content in the top 2 feet of both summerfallow and stubble soil. Table 8 indicates that loams have slightly more NO_3-N than sands, and that the N supplying power of the soil is greatest in the thick Black soil zone. The Yorkton soil in this case contained an average of 130 lb of N in the top 2 feet. It is known that the next 2 feet will contain another 50 to 70 lb of N in the nitrate form. The N in the top 4 feet is considered to be available for plant growth. The N in fall under stubble conditions is shown in Table 9. The general trends are identical except that the plants have removed quite a bit of N. Again the loam soils on the thick Black soil zone contain the greatest concentrations of N and the Gray Wooded's the least.

A mineralization of 50 lb of N/acre over 40 million lb results in a net release of 2,000 million lb of NO_3-N (Table 10). In 1968, the only year in which the farmers of Saskatchewan used any significant concentrations of N fertilizer, 50 million lb of fertilizer were used accounting for only 2½% of the mineral N present on our cultivated lands. Denitrification losses have been estimated at 20% and would account for 400 million lb of N.

Under cropped conditions, the N content is not exceptionally high. Of great importance is the fact that the soil is usually dry. The spring period after a summerfallow year when the soil is already moist and there is a great deal of N is the time of year when leaching would be most probable. The LIFT program that came into effect a few years ago accentuated this problem. It is estimated that 8 million acres were double summerfallowed. After two years of summerfallow, the average N content would be much higher than the 50 lb/acre shown in this table. However, using this figure only, with an estimate of 20% leaching, one comes up with an estimate of 80 million lb of N moved beneath the root zone. Equivalent data could be taken if one calculated 100 lb N/acre and a leaching loss of only 5% of the N. We thus had very large amounts of N moving into the areas where it could potentially affect ground water and streams.

The value of the N must also be charged to the LIFT program. At a minimum estimate of 10¢/lb applied in the field, this means the LIFT program cost the farmers of Saskatchewan $8,000,000 in N that was lost due to leaching. The additional loss due to denitrification could easily double this figure. Professor Henry and Dr. Rennie in their talk at the SIA convention last year questioned the process of summerfallowing from the aspects of soil productivity This procedure must be very seriously questioned from the aspect of pollution and conservation of one of our most valuable resources, the N of our soil.

Nitrogen utilization and balance sheets under field conditions

One of the major problems relative to plant growth and pollution is the efficiency of utilization of both soil and fertilizer N. The availability of ^{15}N has made it possible to draw up N balance sheets in which some of the factors involved can be ascertained. Table 11 shows the result of an experiment on a Bradwell sandy loam and a Sutherland clay. These field soils were enclosed in 1 foot diameter cylinders which were 3 feet deep. Then the equivalent of 100 lb/acre (112 kg/ha) of N were added to the soil in the cylinder and it was cropped for four years. In some of the treatments two tons of straw were added, to others there were not straw additions.

There were no major effects on plant yield attributable to the straw. However, the 0-15 cm soil contained larger concentrations of N where straw was added. In the absence of straw, larger concentrations of N were found in the 30-90 cm depth. Because of drought there was low plant growth in the sandy soil and large quantities of NO_3-N remained after the first years cropping. This resulted in large N losses and after two years only 66% of the N originally added could be recovered. In the clay soil with greater moisture content, there was more plant growth and an N recovery of 80%. The losses on the sandy soil are attributed to leaching as well as denitrification. Those in the clay soil are attributed only to denitrification.

Nitrogen which is immobilized has relatively slow release rates as shown by the data in Table 12. Of the total 791 mg N added per cylinder in 1967, 125 were utilized by the plants. In 1970, 4.3 mg were utilized. Where straw had originally been added in 1967, a larger amount of organic N still remained in 1969 (183 mg). Of this 8.3 mg were released in 1969 and taken up by the plant and 6.5 in 1970. Growth during these two years utilized approximately 1/12 of the N that was present as organic N, indicating the slow turn-over rates of this material once it is incorporated in the soil.

The data in this table also indicates that in the sandy soils N was found in the lower depths indicating leaching to those depths and a loss of 11 to 14% of the N added as organic N during the two year cropping period, indicating that organic N is just as susceptible to loss after mineralization as is fertilizer N.

Leaching losses of NO_3-N were demonstrated in a loamy fine sand in Manitoba (Table 13). Under a brome grass field the NO_3-N was very low and only 1 cm of rainfall equivalent passed through the upper layers of the soil. Thus, losses were negligible. Similar low losses were observed under grain, but significant concentrations of N were released out of the summerfallow field and the site which contained the high concentration of organic residues. In this case, 3.8 cm of rainfall moved through the soil accounting for 35 kg/ha of N. Keeney and Gardiner (1971) in their review on the dynamics of N transformations in soil state that the amount of N required to bring a soil percolate to the 10 ppm critical NO_3-N level is 2.27 lb/acre inch. Thus, relatively low levels of soil NO_3-N can cause extensive NO_3-N at depth if the percolate reaches the water table unchanged. Further evidence for N movement is shown in data from our irrigation area in which wheat grown with 0 or 100 lb of added N/acre did not cause an increase in N at lower depths. The addition of 300 lb of N/acre such that more N was added than was required for crops resulted in a net movement of N out of the immediate surface to the 12 to 42 inch area in the sandy soils in the presence of controlled irrigation. On dry land the majority of the additional N stayed in the surface 7 inches of the silty soil. However, in the sand there was net movement of the N out of the surface under dryland agricultural conditions.

Conclusions

The handling of organic wastes relative to disposal on creek beds and sharply sloping lands is, I believe, basically a matter of legislation and extension. Feedlots in turn also probably should be located on relatively flat areas with the large area of agricultural soils as a buffer. The use of the soils for pollution abatement will be affected by the economics of manure spreading as well as the possible nutrient losses through the soil system. However, continuous cropping of the soils should make feasible the application of quite large amounts of material. The suggested levels probably can be handled quite satisfactorily on soils with good cation exchange and moisture holding capacity. Both the feedlot and the manure disposal area should be a significant distance from large bodies of water to prevent ammonia adsorption by the water, and of course, from extensive areas of settlement. This is no problem in many areas of Saskatchewan and should be an excellent reason for the development of a fairly large number of moderate sized feedlots in our province.

Our soils were and are still among the richest in the world. They have, however, been subjected to exceptional mismanagement both in relation to soil erosion and the possibility of nutrient leaching. The biggest single factor in this mismanagement is the continued use of large acreages of summerfallow. Rennie and Henry in discussing the viewpoint of soil management specialists relative to the diversification of Saskatchewan agriculture concluded that the soils were operating far below their productivity capacity, and stated that the effective lid placed on production by moisture deficiency is at a much higher level of production than many people realize. It is well known that elimination of summerfallow would result in greater production. This accentuates the problem of surplus grain and points out the need for further diversification of our agriculture.

We have long known that summerfallow is exceptionally bad from an erosional standpoint. The loss to agriculture by erosion and by leaching during the summerfallow year as well as the possible pollution hazards going with this loss are very strong reasons for cutting back on the summerfallow acreage. The extensive use of summerfallow is often justified on the basis of moisture conservation. What is often not noted is the fact that the extensive cultivation during the summerfallow, and the high available moisture results in an accelerated breakdown of soil N such that large concentrations of N accrue. In the short term this allows the farmer to grow crops without additions of N. But this has come about only by very drastic depletion of the N reserves of our soil. These cannot be allowed to go much lower for we will run into major structural deficiency problems as is the case in the Gray Wooded soil.

The low yields attributed to stubble crops can be partly attributed to different management practices. If the stubble crop was seeded early in the spring and fertilized according to soil tests recommendations, in many cases the stubble yields would be much higher than they are at present. I realize that distribution of labor, weed control and surplus production are all factors that must be taken into consideration in such a decision. Research could help in alleviating the problems of summerfallow. The possibility of seeding pelletized grains in the fall such that they make maximum utilization of moisture and the development of a winter wheat are two possibilities that should be investigated in detail.

The factors affecting N movement in the soil are being studied in detail in Swift Current and at Lethbridge where the effects of N movement are being considered relative to environmental factors. These data will help in our understanding of the N transformations of soil.

Table 1. Nitrogen economy of soil.

Removals/Losses	Magnitude
Crop Uptake	50-60%
Gaseous loss (denitrification / volatilization)	10-30%
Erosion	1-15%
Immobilization	20-40%
Leaching	0-10%

Table 2. Two year average soil and associated nitrogen losses from a Barnes loam (Holt, R.F., 1969).

Cropping Treatment	Crop	Average Annual Soil Loss (Tons/A)	Nitrogen Sediment (lbs/A)	Nitrogen Runoff Water (lbs/A)
Fallow	None	7.0	56.7	—
Continuous Corn	Corn	1.8	11.5	0.70
C-O-H	Corn	0.4	3.8	1.08
C-O-H	Oats	0.5	4.6	0.67
C-O-H	Hay	0.0	0.0	3.10

Table 3. Absorption of NH_3-N by water surfaces.

	NH_4-N (kg/ha)
No feedlots or irrigated field within 3 km, no large feedlots or cities within 15 km	3.9
200 unit feedlot (0.8 - 4 km)	9.1
800 unit feedlot (0.2 - 0.6 km)	15
SW of 9,000 unit feedlot (0.5 km)	17
NW of 90,000 unit feedlot (2 km)	34

Table 4. NO_3-N in 20-ft profiles and water at surface of water table (Stewart et al., 1967).

	20 ft soil	Water table	
	NO_3-N	NO_3-N	
	lbs/acre	Mean (ppm)	Range (ppm)
Virgin grassland	90	11.5	0.1-19
Dryland	261	7.4	5-9.5
Irrigated land (except alfalfa)	506	11.1	0-36
Irrigated land (alfalfa)	79	9.5	1-44
Feedlots	1,436	13.4	0-41

Table 5. Recommended Rates of Manure (expressed in lbs. N per acre) for Optimum Crop Production, and Maximal Rates of Application for Pollution Abatement

Crop	Yield per acre	Lbs N from manure to be applied for optimum production	Max. lbs N from manure** that can be applied on a continuous basis without causing crop damage or excessive leaching losses
Alfalfa	2 tons	0 - 30	50 - 100
Red Clover	2 tons	0 - 30	50 - 100
Legume-Grass Mixtures	2 tons	50	50 - 100*
Grasses	1.5 tons	70	70 - 210
Corn Silage (irrigated)	6 tons	100	100 - 210
Cereals for Fodder	2 tons	100	100 - 150
Oats	60 bus.	70	70 - 210
Barley	45 bus.	70	70 - 210
Wheat	30 bus.	70	70 - 210
Peas	30 bus.	30	70 - 210
Rapeseed	20 bus.	70	70 - 210

** Lower maximum for coarse-textured soils, higher maximum for fine-textured soils

* Rates higher than 50 lbs N, on a continuous basis will reduce the legume component in mixtures

Table 6. Approximate composition of fresh manure with normal quantity of beddding or litter (Knott, 1956).

Source	Moisture %	N	P_2O_5 (lb/ton)	K_2O
Hen	73	22	18	10
Hog	87	11	6	9
Feeder Beef	75	12	7	11

Table 7. Observed decline of carbon and nitrogen in Black Cernozemic soils sampled at the Indian Head Experimental Farm, at Quinton, and Hafford

Location	Years of cultivation	Nitrogen (% of soil)	Nitrogen (% of virgin)	Carbon (% of soil)	Carbon (% of virgin)	Reference
Indian Head	0	0.43	100	--	--	Shutt, 1925
"	27	0.31	72	--	--	Newton, Wyatt, and Brown, 1945
"	38	0.26	61	--	--	Shutt, 1925
"	56	0.22	51	--	--	Newton et al., 1945
"	77	0.21	49	--	--	McIver, private communication
Quinton	0	0.45	100	5.4	100	Martel, 1972
"	15	0.34	76	3.5	65	"
"	60	0.23	51	2.2	41	"
Hafford	0	0.60	100	7.3	100	"
"	30	0.38	63	4.3	59	"

Table 8. NO_3-N in summerfallow (lb/acre per 24" depth) in 1967-69.

Soil zone/texture	Sandy loam	Loam (till)	Clay (lacustrine)
Brown	40	60	62
Dark Brown	64	76	58
Black	78	91	69
Thin Black	-	130	111
Gray Black	76	72	86
Gray Wooded	51	55	75

Table 9. NO_3-N in stubble, Fall, 1967-68-69 (0-24").

Soil zone/texture	Sandy Loam	Loam	Clay
Brown	25	36	33
Dk Br	32	48	31
Black	35	50	31
Th Bl	—	75	49
Gr Bl	34	32	35*
Gray	19	24	21

*Tisdale

Table 10. Microbial transformation of N in Saskatchewan cultivated soils.

	Acre	Per Annum/ acre	Lbs (M)
Mineralization	40 M	50	2,000
Fert-N (1968)			50
Loss (Denitrification) (10%)		5	200
LIFT Program Effects			
Double Summerfallow	8 M	50	400
Leaching (Ground-water streams)		10	80

Table 11. Nitrogen balance sheet for fertilizer N added to Bradwell and Sutherland soils.

		Soil and Treatment			
		Bradwell		Sutherland	
		112N	112N + Straw	112N	112N + Straw
		mg N/cylinder		mg N/cylinder	
1967-68	Plants	165	155	389	402.9
	Roots	9.9	9.2	8.5	7.1
Soil	0-15 cm	152.0	219.3	112.4	197.9
(1968)	15-30 cm	56.2	42.8	50.7	32.5
	30-90 cm	140.1	90.3	31.7	21.4
Original added, 1967		791.7	791.7	791.7	791.7
% Recovery		66.1	65.2	74.8	83.6

Table 12. Nitrogen balance sheet for fertilizer N added to Bradwell and Sutherland soils.

	Soil and Treatment			
	Bradwell		Sutherland	
	112N	112N + Straw	112N	112N + Straw
	mg N/cylinder			
1969-70 Plant 1969	5.9	8.1	4.9	6.8
1970	4.3	6.5	2.3	3.2
% of that added, 1969	8.1	7.9	7.7	6.3
Soil 0-15 cm	88.3	118.6	68.8	123.4
15-30 cm	4.1	9.9	12.7	8.3
30-90 cm	9.2	13.6	5.6	3.7
Original added, 1969	125.4	183.1	93.0	159.5
% Recovery	89.2	85.5	101.4	91.1

From McGill, 1971.

Table 13. Volume of leachate and its nitrate content at four sites on loamy fine sand (Hedlin, 1971).

Month	Soil under			
	Brome	Grain	Fallow	Old refuse site
	NO_3-N (ppm)	NO_3-N (ppm)	NO_3-N (ppm)	NO_3-N (ppm)
June	1.1	1.0	3.9	59.2
July	2.3	2.4	10.1	43.0
August	0.0	1.8	13.6	69.3
September	0.4	0.3	17.4	117.2
October	0.7	0.7	22.3	118.3
Leachate in terms of rainfall - cm	1.0	3.0	3.9	3.8
N (kg/ha)	0.07	0.4	5.6	35.3