MEASURING AND MODELLING THE FATE OF FERTILIZER AND SOIL NITROGEN IN A CROPPING SYSTEM

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ABSTRACT

Future trends in New Zealand cropping, anticipate an increased use of fertilizer nitrogen (N). In order to more efficiently utilise N in cropping systems, a better understanding of the N processes and their significance under New Zealand conditions, is required. To achieve such understanding, several small scale experiments were conducted.

Preliminary experiments, investigating the fate of N-15 urea applied to barley and oats, were conducted using soil cylinders. Total recovery of N-15 in plant and soil components varied between 50 to 90 percent. Initial urea N transformations were rapid, and most of fertilizer N uptake by plants occurred in the first five weeks following its application at sowing. Plants took up a greater proportion of their total N as native soil N. N-15 assay on soil and plant samples containing N-15 in excess of about 1 atom percent, was performed satisfactorily with emission spectrometry. The data obtained by the use of soil cylinders, were representative, particularly of short term field behaviour.

A five-week study was undertaken to account for the extent and pattern of immobilisation and leaching of N-15 urea applied to a barley crop. Two irrigation treatments (wet and normal) were imposed. Approximately 90% of the applied N was recovered. One week after application, 86% of urea N had been hydrolysed, while after two weeks 36% of it had been immobilised into organic matter. The increased leaching of N from the wet lysimeters compared with the normal lysimeters was at the expense of plant N uptake, having little effect on the amount of N immobilised. Net mineralisation of native soil N was calculated as 1.2 kgN/ha/day.

Using the data obtained from the preceding investigation, a five-week N model was developed. The model successfully predicted the increased leaching of fertilizer N from the wet compared with the normal lysimeters. The reduced plant uptake of fertilizer N, resulting from this increased leaching from

the wet lysimeters, was also quite successfully modelled. The model indicated that the amount of fertilizer N leached was strongly dependent on the timing of rainfall in relation to the time of fertilizer application.

A crop season model was developed by extending the five-week model to cover a full growth season of a barley crop, and the model was verified with data from a large scale field trial. The model prediction for N leaching losses, demonstrated better accuracy than for plant N uptake. The model has the potential to provide a continuous evaluation of possible adverse effects caused by unanticipated factors such as excessive rainfall, on plant N uptake.

The crop season model was further developed to predict long term changes in the N cycle of a double cropping system, in a soil that was previously under pasture. The model predicted quite accurately the N loads as well as the N concentrations in tile drainage effusing from experimental field plots. In general, the measured and predicted data for nitrate concentrations in tile drainage of field plots indicated that nitrate concentrations in tile effluent usually exceed 15 to 20 mgN/litre, regardless of fertilizer addition. The addition of fertilizer could increase these levels two-fold but only for a short time. The utility of the model as a research tool was illustrated.

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LIST OF SYMBOLS

Symbol		Units
B	Reduction factor that accounts for soil temperature and moisture effects on rate constants (dimensionless).	
ENM	Effective net mineralisation over rooting depth Z	kgN/ha
ETp	Evapotranspiration estimate (Priestley and Taylor, 1972)	m
k_i	Rate constant for immobilisation	d^{-1}
k_L	N leaching coefficient (dimensionless)	
k_m	Rate constant for mineralisation	d^{-1}
$\underline{k}_m$	Coefficient for effective net mineralisation of native soil N	d^{-1}
k_n	Rate constant for nitrification	d^{-1}
k_p	Rate constant for plant N uptake	m^{-1}
k_u	Rate constant for urea hydrolysis	d^{-1}
$(k_x)_m$	Maximum value for a coefficient k_x when $B = 1$	d^{-1}
m_1	Mineralisation rate coefficient at optimum conditions of soil temperature and moisture ($B = 1$), for the short-cycle organic N of native soil N origin	d^{-1}

M_2 Constant rate of mineralisation at optimum conditions of soil temperature and moisture, from the long-cycle organic N of native soil N origin .... kgN/ha/d

N_a Fertilizer derived ammonium N content in unit soil area over rooting depth Z ...... kgN/ha

$\underline{N}_a$ Ammonium N content of native soil N origin, in unit soil area over rooting depth Z ... kgN/ha

ΔN_L Daily leaching losses of fertilizer and native N from rooting depth Z .... kgN/ha

$\underline{N}_m$ Daily amount of N mineralised from native soil organic N pool ($\underline{N}_o$), over rooting depth Z .... kgN/ha

$\Sigma \underline{N}_m$ Total amount of N mineralised over the 2 year period (1978-80) from soil organic N pool ($\underline{N}_o$), over rooting depth Z .... kgN/ha

N_n Fertilizer derived nitrate N content in unit soil area over rooting depth Z ...... kgN/ha

$\underline{N}_n$ Nitrate N content of native soil N origin, in unit soil area over rooting depth Z ... kgN/ha

N_o Fertilizer derived organic N content in unit soil area over rooting depth Z ...... kgN/ha

$\underline{N}_o$ Organic N content of native soil N origin, in unit soil area over rooting depth Z ... kgN/ha

$\underline{N}_{o1}$ Short-cycle organic N of native soil N origin, in unit soil area over rooting depth Z .... kgN/ha

$\underline{N}_{o2}$ Long-cycle organic N of native soil N origin, in unit soil area over rooting depth Z .... kgN/ha

ΔN_p Daily plant uptake of fertilizer N ...... kgN/ha

$\Delta \underline{N}_p$ Daily plant uptake of native N .... kgN/ha

N_u Amount of urea in unit soil area over rooting depth Z .... kgN/ha

Θ Volumetric water content when drainage has just ceased (dimensionless)

q Drainage flux density .... $m\ d^{-1}$

STE Reduction factor for sub-optimal soil temperature (dimensionless)

SSE Reduction factor for sub-optimal soil moisture content (dimensionless)

T Transpiration .... m

Z Rooting depth .... m