MILLENNIUM TILLAGE TRIAL

No. 80  July 2008

Nitrate leaching over winter (2001 – 2007)

Key Points

- Nitrogen (which in the form of nitrate is very soluble) can be lost via leaching from soil when water, in excess of plant requirements enters soil and drainage occurs.
- Over a seven year period (2001-07), winter leaching losses from the Millennium Tillage Trial site averaged 28 kgN/ha/year under a range of different tillage practices on winter fallowed soil. Growing forage crops through winter reduced this average loss by nearly 50% to 15 kgN/ha/year.
- Significant amounts of nitrogen can be leached from permanently fallow soil where no plants are grown, even where no fertiliser is applied. This shows the important role of plants in taking up N.
- Timeliness and type of tillage method used for sowing autumn crops (also slug and grass grub control) can have important implications for ensuring good crop establishment. The potential for loss of N via leaching is increased where plant cover is poor. Less N may be leached where crops are sown early and slugs/grass grubs are controlled effectively.

Introduction

Nitrogen (N) is essential for plant growth. Soils store and supply large amounts of N in a mineral form that is readily available for plant uptake, but a large component is tied up within the organic matter and is only released slowly with the help of soil organisms (e.g. earthworms and micro-organisms). Where the amount of ‘plant available N’ stored in the soil is insufficient for optimal plant growth, N fertilisers are commonly applied.

Nitrogen can be applied in various fertiliser forms (e.g. urea, ammonium or nitrate), but soon after application soil micro-organisms usually convert it into the nitrate form. In this form, N is at risk of being lost if it is not taken up by a plant, because nitrate is extremely soluble and is transported by water through the soil profile. Where nitrate is transported to below the root zone and toward the groundwater, the process is known as leaching. Nitrate can also leave soil in water via surface runoff (e.g. into streams and other waterways).

Excessive amounts of nitrate in surface waters can cause environmental problems as: N encourages plants to grow where they are not wanted (e.g. in rivers and lakes); high levels of nitrates in drinking water become a human health hazard. For the farmer, N lost in leaching or run-off is an economic loss.

Leaching occurs where the amount of water entering the soil is greater than the amount that it can store, resulting in drainage below the root zone. Mostly (at least under non-irrigated conditions) this happens over the winter period in New Zealand. Any factors that will affect the amount of N released from the soil organic matter and the soil drainage (e.g. soil type, cultivation practices, plant presence/absence) can influence the amount of nitrate leaching that occurs in a given location.

The Millennium Tillage Trial was established in October 2000 to determine the potential (or otherwise) of minimum and no-tillage production systems to sustain soil quality, maintain arable crop performance, minimise adverse impacts on the environment and monitor the effects of different tillage techniques on winter nitrate leaching.

Methods

The trial is described in Arable Extra No. 77. The trial has 6 tillage treatments (based on different combinations of spring & autumn tillage) plus a ‘control’ of uncultivated permanent pasture alongside a permanent fallow (repeat herbicide applications, no plant cover) treatment. Each of the main plots have been split to compare winter cover crops to no cover crop (winter fallow) treatments. Each treatment is replicated three times, giving a total of 42 treatment plots.

The three main tillage methods used were:

1. No-tillage (Nn): No cultivation, seeds direct drilled.
2. Minimum tillage (Mm): Disced (0-10cm), harrowed & rolled twice (at right angles) prior to sowing.
3. Intensive tillage (Ii): Mouldboard ploughed (0-20cm), maxi-till (0-10cm), harrowed & rolled x 2.

Main crops (Table 1) were sown each spring and harvested at maturity in mid to late summer. Forage rape was grown as a winter cover crop (2002-07). Grain yields for the main crops grown in each year were presented in Arable Extra No. 77. It also contains details about the individual crop management practices, fertiliser and irrigation rates, crop residue management practices, pest and weed control and sheep grazing practices.
Table 1. 2001 2002 2003 2004 2005 2006 2007

<table>
<thead>
<tr>
<th>Spring crop harvested</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>101</td>
<td>107</td>
<td>15</td>
<td>120</td>
<td>15</td>
<td>126</td>
<td>124</td>
</tr>
<tr>
<td>Wheat</td>
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<tr>
<td>Peas</td>
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<td>Barley</td>
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<td>Barley</td>
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<tr>
<td>Barley</td>
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</tr>
<tr>
<td>Total kg/N/ha applied to main crop*</td>
<td>133</td>
<td>107</td>
<td>15</td>
<td>120</td>
<td>30</td>
<td>141</td>
<td>206</td>
</tr>
<tr>
<td>Winter cover crop sown</td>
<td>Forage oats</td>
<td>Forage rape</td>
<td>Forage rape</td>
<td>Forage rape</td>
<td>Forage rape</td>
<td>Forage rape</td>
<td>Forage rape</td>
</tr>
<tr>
<td>Total kg/N/ha applied to cover crop</td>
<td>32</td>
<td>Nil</td>
<td>Nil</td>
<td>15</td>
<td>15</td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>Total N applied to tillage treatment plots (kg/ha/yr)</td>
<td>142</td>
<td>104</td>
<td>110</td>
<td>47</td>
<td>118</td>
<td>137</td>
<td>48</td>
</tr>
</tbody>
</table>

*Starter plus side dressing fertiliser

The amount of nitrate leached (to 60cm depth) from the main tillage treatments has been measured during each winter of the trial. This is done after sufficient rainfall triggers a drainage event, by extracting soil water under a vacuum via specially designed suction cups that are installed in the soil at 60cm depth.

The amount of fertiliser N applied to the tillage treatment plots is shown in Table 1. The permanent fallow plots had no fertiliser applied. The permanent pasture plots only received N fertiliser on two occasions (15 kgN/ha in July 2001 and 24 kgN/ha in August 2002).

Results and Discussion

For all of the tillage treatment plots, overall N leaching losses were low where winter forage cover crops were grown (average = 15 kg N/ha leached per winter between 2001 and 2007), but were considerably higher in the absence of a cover crop (i.e. winter fallow, average = 28 kg N/ha leached per winter between 2000 and 2007; Fig 1).

Winter 2006 (mid-May to mid-September) was wetter than average (long-term average = 250mm) and markedly higher amounts of nitrate leached from all treatments, with the exception of the PP plots (Fig 2). The amounts of N leached under each of the tillage treatments were similar in most years except for the very wet year of 2006 where the Nn plots had the greatest amount of leaching (approx 100 kg N/ha) followed by the II and then the Mm plots (Fig 2).

Figure 1. Average amounts of N lost via leaching from each treatment for winters from 2001 to 2007 inclusive where PP = Permanent pasture; PF = Permanent fallow; II = Intensive tillage; Mm = Minimum tillage; Nn = No tillage; "*+" = cover crops present over winter; "*" = no cover crop (winter fallow).

The PF plots consistently lost the most N via leaching each year, even though no N was added to these plots (Fig 2). The soil N in the PF plots thus had to originate from the mineralisation (release by biological activity) of N from the soil organic matter. Meanwhile the permanent pasture plots lost the least amount of nitrate (Figs 1 and 2) owing to continuous uptake of mineral N by the actively growing pasture. The large differences in N leached between the PP and PF plots highlights the important role of plants in taking up soil N during winter, thereby lowering the risk of leaching nitrate.

In 2006 (and similar trends were found in most other years) winter cover crop establishment was lowest in the Nn plots (58 plants/m²; mainly due to slug damage), next highest in the II plots (70 plants/m²) and highest in the Mm plots (77 plants/m²). As poor plant establishment leads to fewer plants being present there is a reduction in opportunity for N uptake. This may partly explain why more N was leached from the Nn than the II and Mm treatments in 2006. Soil cultivation releases some soil N (via mineralisation), but the incorporation of cereal crop residues into the soil in the Mm and II plots could also result in some immobilisation (or temporary tie up by micro-organisms) of soil N. In comparison, in the no-tillage plots the residues remained on the soil surface and did not have the equivalent amount of close contact with the soil (so N tie up is less likely).

Where N is immobilised it is not available for leaching.

Early sowing of forage rape and effective control of slugs/grass grubs can help to ensure good crop establishment and reduce the risk of nitrate leaching losses during very wet winters.

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