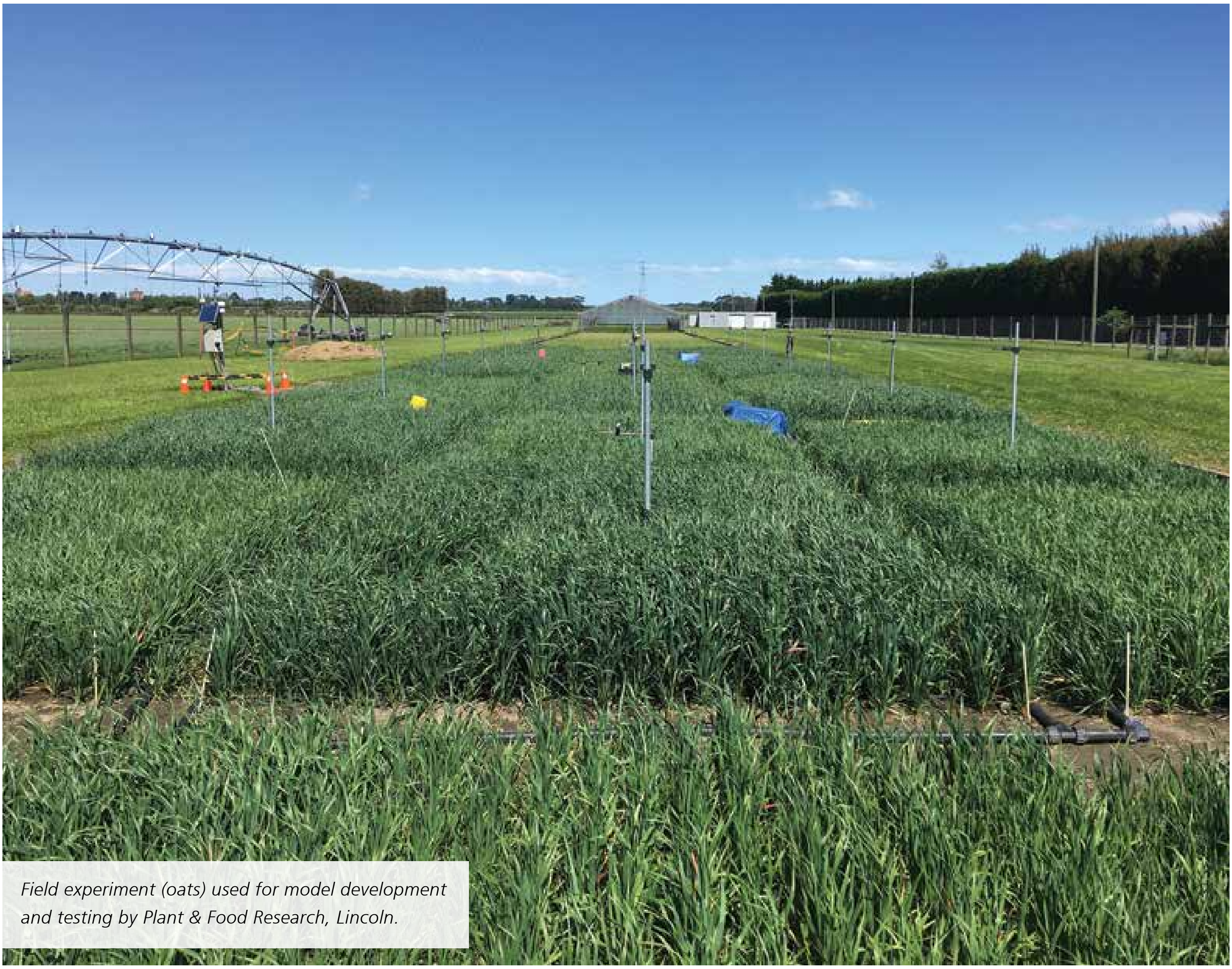

Field experiment (oats) used for model development and testing by Plant & Food Research, Lincoln.

The power of combining field trials and modelling

Combining field trial data with simulation models can offer new insights into complex plant-soil interactions, such as how catch crops perform under different locations, sowing dates and weather conditions.

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Gathering scientifically robust data from agricultural field trials is a vital step in understanding how biological, chemical and physical processes interact in the natural environment. Field experiments enable us to test and answer specific research questions through replication (multiple plots with identical treatments). This helps us gauge natural variability and the probability of obtaining a repeatable result.

However, results from specific field experiments cannot be immediately extrapolated to other management and environmental conditions. Key factors such as local climate, inter-annual weather variability, soil type and management can all influence the myriad processes that lead to a site-specific and time-specific result (e.g. crop yield).

This is where simulation models can help, by expanding our understanding of complex plant-soil-climate interactions. Detailed data from multiple trials can be used to develop and test computer models that represent plant and soil processes. The models can then, for example, be applied to determine effects using long-term historical weather data. Thus, we can predict the level of variability in crop performance from year to year (e.g. in dry, normal and wet seasons), as well as from different climates, soil types and management interventions.

Practical context: catch crops

An example of this synergy between field experiments and models is the recent catch crop work developed in the Forages for Reduced Nitrate Leaching (FRNL) programme*, which illustrates the added value of these approaches.

Winter grazing systems are inherently subjected to greater risk of nitrogen (N) leaching losses because of the large amounts of N excreted by grazing livestock onto bare soil during wet and cold months[1]. Recent field trial work has shown that sowing a catch crop of oats directly after winter forage grazing (i.e. in June, July or August) can significantly reduce the risk of N leaching. In addition, farmers can benefit from additional biomass production when oats are taken through to green-chop silage maturity (50 percent ear emergence) or beyond[2, 3].

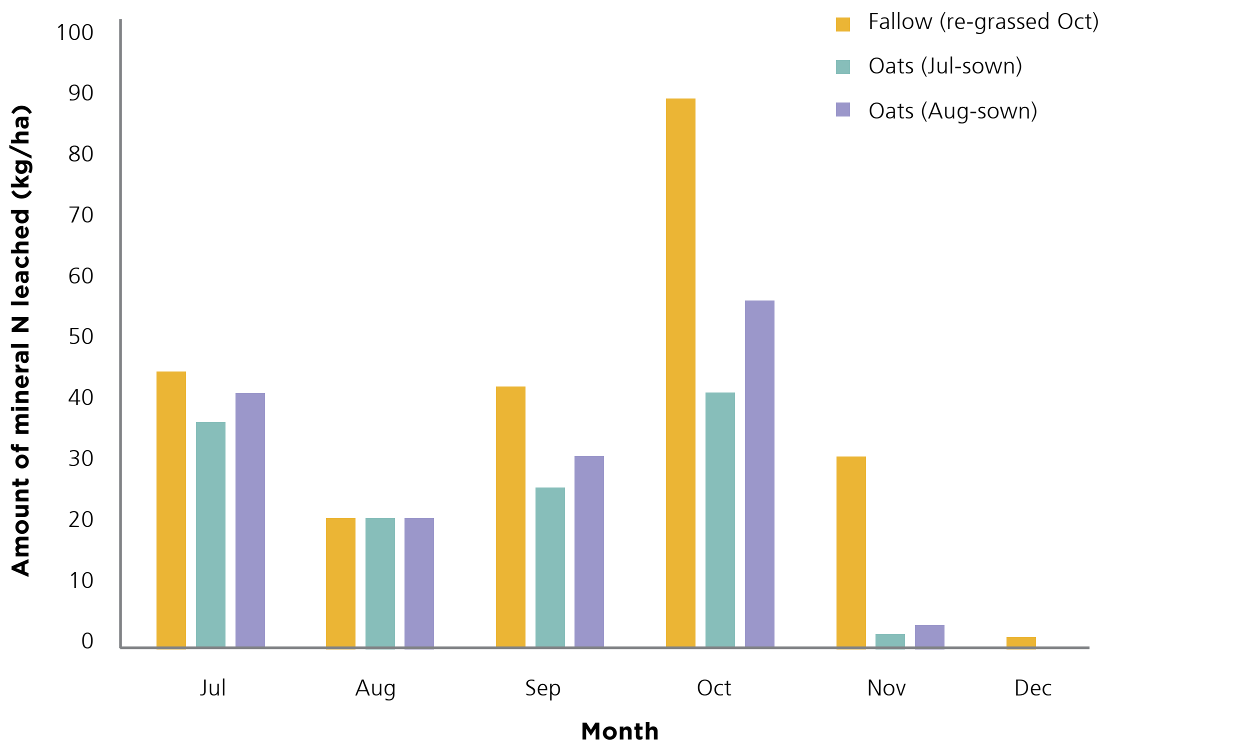
This reduction in N leaching is because some of the N is taken up by the crop biomass, instead of leaching when drainage events occur[4, 5]. For example, a recent field trial in Lincoln, Canterbury, showed that sowing oats in July or August reduced total mineral N (nitrate-N + ammonium-N) leaching losses by 33 to 44 percent compared with a conventional fallow (bare soil) situation (*Figure 1*).

In *Figure 1*, we can see the importance of time of sowing and seasonality of weather events affecting both N leaching and crop growth. Note the degree of monthly variability, and the reductions in N leaching occurring from early spring (September), mainly when oats were sown in July (green bars). These conditions are unlikely, for environmental and operational reasons, to be the same every year.

So, how much could the benefits of catch crops differ under contrasting locations, sowing dates and weather conditions? To help clarify this, we applied the Agricultural Production Systems sIMulator-NextGeneration (APSIM-NextGen) model platform[6] to

"Our simulation results show oat catch crops could effectively reduce N leaching in all four regions, but results largely depended on weather conditions."

Figure 1. Monthly amount of mineral N leached from a stony soil after urine application (300kg N/ha in July) and July- or August-sown oats, compared with conventional fallow



test how winter-sown catch crops might perform under a diverse set of conditions. Newly developed fodder beet and oat models were set up in APSIM-NextGen that allowed simulation of winter forage-catch crop rotations over consecutive climate years and across different locations.

How models function

Agricultural systems models come in a variety of types, reflecting different uses and needs. Computer models combine information to help us understand a given process or system. This then enables us to estimate how the process or system responds if conditions change. So, the more we know about the system, the more robust the model, and the better the model predictions will be.

Model results are used to infer how much we know about the system and help guide new studies. They also allow us to extrapolate experimental findings to other locations and conditions. Models can also be used to devise recommendations about management practices or, potentially, to aid directly with on-farm decision-making.

Models are always a simplified (partial) representation of the system to tackle a specific question and, therefore, are useful only for the particular purposes for which they were originally designed. This is because agricultural systems are both complex and dynamic. It is virtually impossible to collect and consider all data at experimental or farm level, so computer models provide the environment to integrate and make sense of vast quantities of information.

Models take into account a limited amount of detail of a system; thus, selecting an appropriate one is highly important[7]. This is why models must be constantly tested against measured datasets and updated to ensure they perform adequately for the given purpose.

New insights by combining data and models

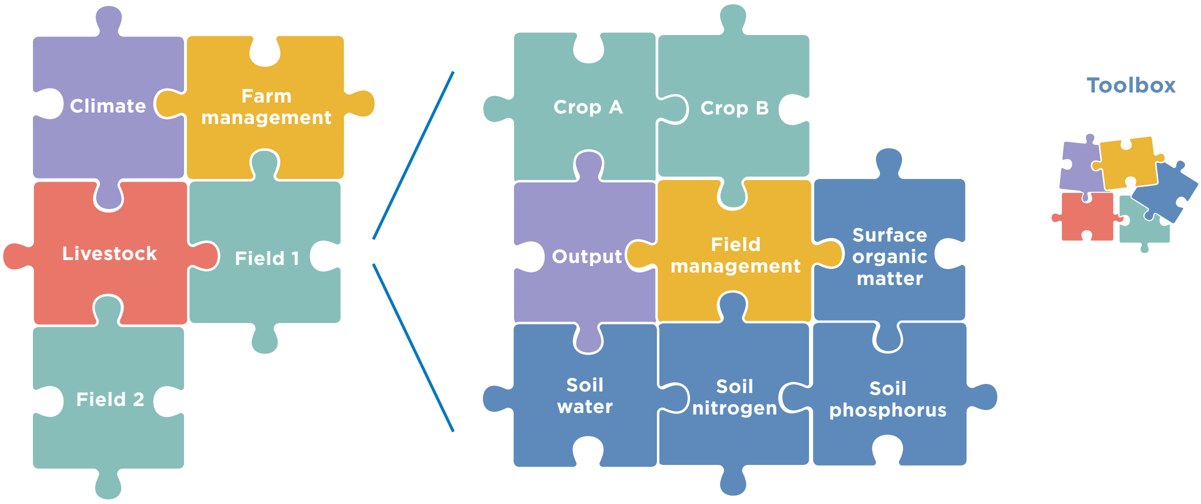
In FRNL, an APSIM-NextGen model (*Figure 2*) was used to represent a sequence of fodder beet followed by an oats catch crop. Modelling took into account weather conditions over 25 years (1975 to 2000), four climatic zones and catch crops sown in four months (June to September). *Table 1* shows the simulated reduction in N leaching at 80cm soil depth by the presence of an oat catch crop instead of a fallow (bare soil) condition.

Our simulation results show oat catch crops could effectively reduce N leaching in all four regions, but results largely depended on weather conditions (particularly rainfall timing and intensity). This expands knowledge gained from our field experiments. The results provide an estimate of gains from early sowing, when operational conditions allow.

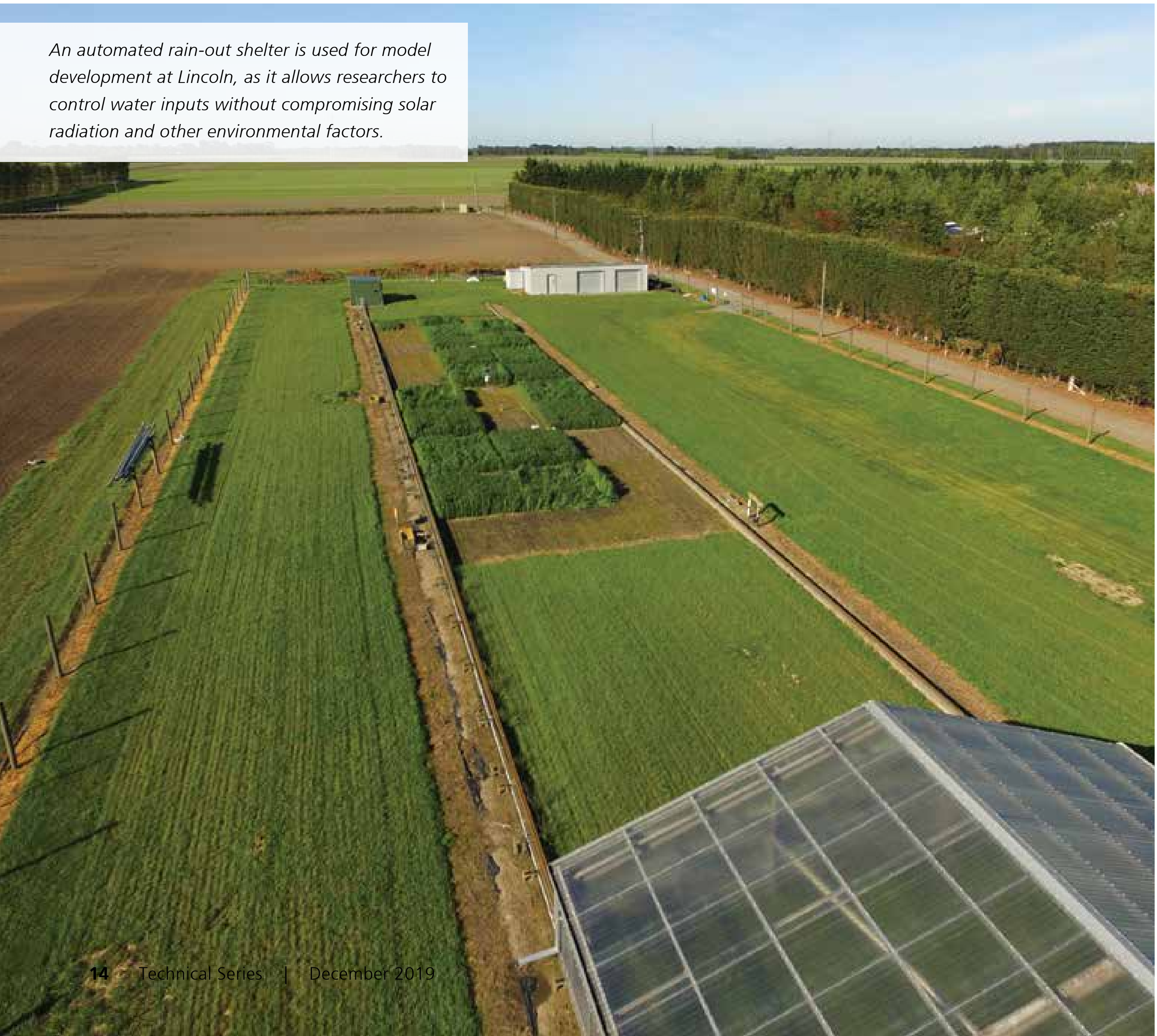
The model results give us a quantitative basis to evaluate the cost/benefit of management options, and to understand seasonal variability, which are useful to inform on-farm decisions. For example, although median values of N leaching reduction for Canterbury were approximately 41 percent, unfavourable weather years can result in values as low as 10 percent, while

Catch crop sowing date trial at Plant & Food Research, Lincoln. The trial compared ryecorn vs oats, sown in July and August 2016.

Figure 2. A conceptual representation of APSIM-NextGen



Note: The farm and each field (left) are built from a combination of models found in the toolbox (right). The APSIM-NextGen infrastructure connects all selected model pieces together to form a coherent simulation[8].



An automated rain-out shelter is used for model development at Lincoln, as it allows researchers to control water inputs without compromising solar radiation and other environmental factors.

up to 65 percent was estimated for favourable weather conditions. This represents a large year-to-year variability and highlights the extra information that models can provide. It also indicates that future work is needed to identify actions that can be taken for conditions where catch crops are limited in their effectiveness.

Conclusions

In the context of winter-sown catch crops, using modelling has helped us to quantify the importance of inter-annual variability, timing of sowing and location differences in how effective catch crops can be to mitigate N leaching.

For farmers, this implies that, weather and operational

Catch crop cereal species trial at Plant & Food Research, Lincoln. The crop was sown in June 2017, and yields were measured at various maturity stages: green-chop, whole crop and grain.

Table 1. Simulated paddock-scale N loss reductions by oat catch crops relative to fallow conditions after grazed fodder beet on a low-water-holding-capacity soil

	Southland			Canterbury			Hawke's Bay			Waikato		
Sowing date	Low rain[1]	Mid rain[2]	High rain[3]	Low rain[1]	Mid rain[2]	High rain[3]	Low rain[1]	Mid rain[2]	High rain[3]	Low rain[1]	Mid rain[2]	High rain[3]
June	25%	22%	29%	65%	41%	35%	41%	20%	27%	34%	34%	23%
July	22%	17%	27%	53%	33%	30%	31%	7%	22%	28%	27%	14%
August	12%	8%	19%	41%	26%	23%	18%	4%	11%	20%	19%	7%
September	5%	0%	3%	18%	14%	10%	0%	2%	3%	12%	6%	2%

[1]≤25th percentile of long-term average rainfall; [2]>25th percentile and <75th percentile; [3]≥75th percentile.

Note: colours correspond to different ranges of effectiveness.

0-5% | 6-10% | 11-20% | 21-30% | 31-40% | 41-50% | 51-60% | 61-70%

conditions permitting, there is great value in sowing catch crops as early as possible after the grazing events because reductions in N leaching are of greater magnitude. Annual/ seasonal weather conditions (e.g. amounts and timing of rainfall) will largely influence catch crop effectiveness, with both good and challenging years, so outcomes are better appreciated over multiple years.

Finally, this catch crop work illustrates the power of linking field trials with agricultural systems models. The synergy between field experimentation and modelling can and will be used in future to help answer other research questions.

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KEY POINTS

- Field trials generate valuable experimental data for understanding agricultural system responses under 'close to reality' conditions.
- These experimental data can then be used to build models that represent, in a simple way, aspects of 'real world' systems to address specific questions.
- Linking field data and modelling for winter-sown catch crops has unveiled the importance of inter-annual variability, timing of sowing and climate on N leaching mitigation.

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