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SCIENCE IN ACTION

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Does sowing rate affect persistence?

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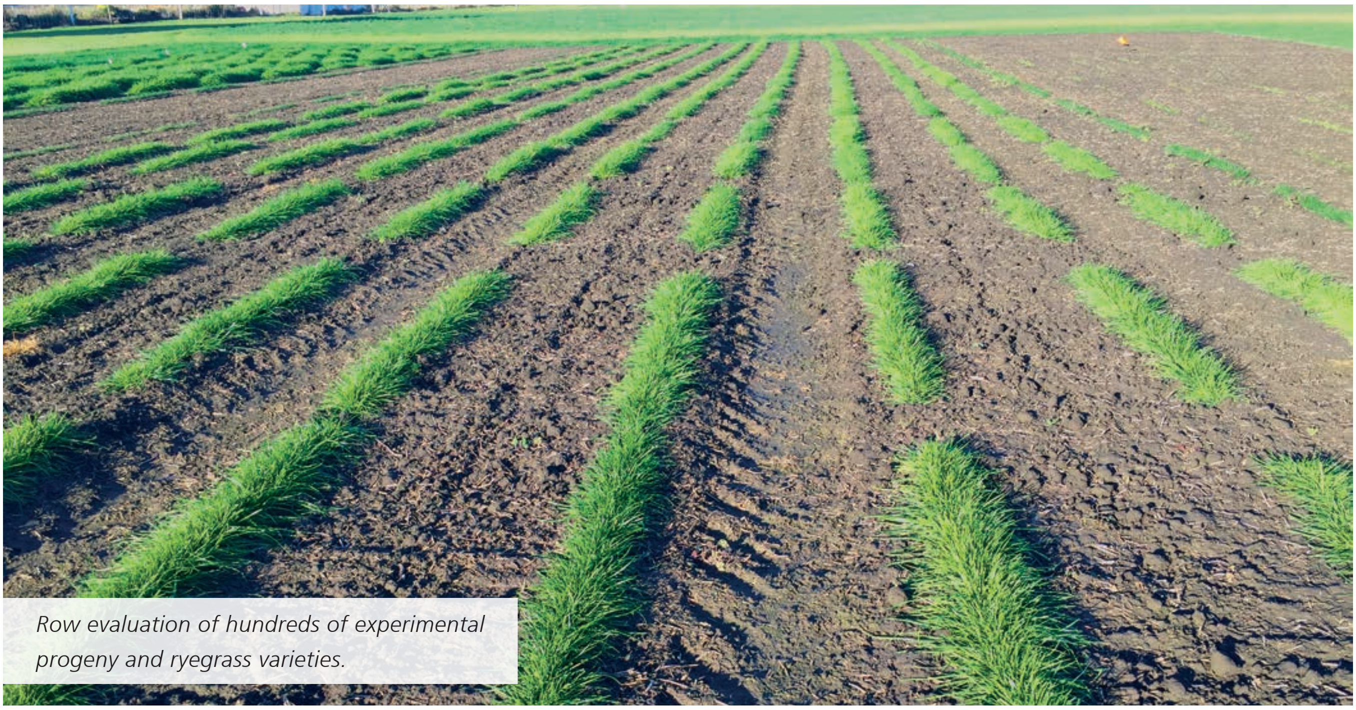
Plant breeding for the future

New Zealand dairy farmers today are more productive than ever thanks to the ongoing development of genetically-superior plant species. But how does our country's rate of genetic gain stack up internationally? And what challenges do we face in our efforts to breed forages that not only provide better yield, persistence and feed quality, but also reduce our environmental footprint?



Row evaluation of hundreds of experimental progeny and ryegrass varieties.

Alan Stewart, plant breeder,
PGG Wrightson Seeds

KEY POINTS

- New Zealand seed companies develop new cultivars of many pasture and fodder species f=unded by royalties from our relatively small local seed industry.
- Genetic gain in yield of perennial ryegrass has averaged 0.76 percent per annum, worth $15 to $20/hectare/year.
- New molecular technologies, such as genomic selection, are expected to increase the rate of genetic gains in plant breeding in the future.
- Endophyte associations increase the complexity of ryegrass breeding but provide critical protection against pasture pests.
- Selecting for persistence is an important aspect of ryegrass breeding programmes.

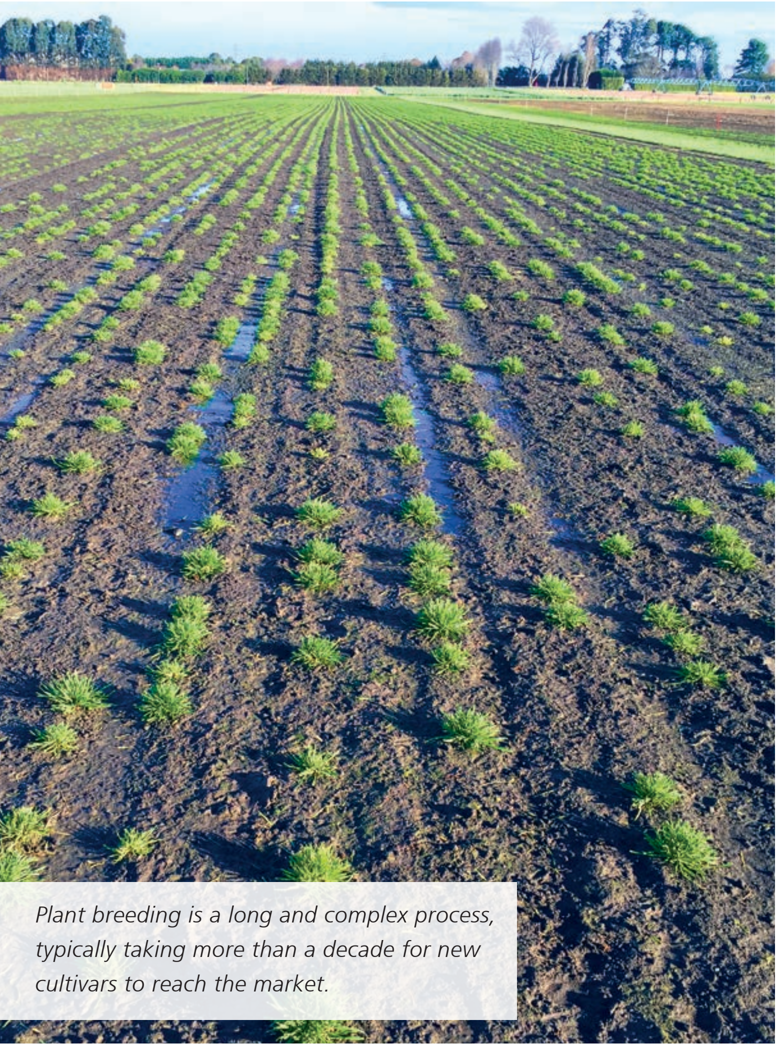
Our unique conditions

The international competitiveness of New Zealand dairy farming depends heavily on low-cost pastures and fodder crops fed *in-situ*. While perennial ryegrass and white clover are the most widely-sown pasture species, others such as brassicas, lucerne, chicory, plantain, fodder beet and maize are used to fill seasonal feed gaps. The genetic improvement of all these species, along with the genetic improvement of dairy cows, are essential for providing sustainable long-term productivity improvements for dairy farming.

Although many of our pasture species are also bred overseas, New Zealand has unique requirements that mean, in general, our perennial cultivars must be bred locally. There are no climatic zones in Europe similar to northern New Zealand, and no regions in the world with the same pest spectrum.

YEAR	ACTIVITY
YEAR 1	10-100 crosses of cultivars and/or breeding lines
YEARS 2-4	Evaluate 10,000 or more progeny in the field under grazing for 2 or more years
YEAR 5	Intercross the best plants to create 50 or more potential new cultivars
YEARS 6-8	Yield test throughout NZ by private companies & through Forage Value Index, under grazing
YEARS 9-10	Multiplication of one new cultivar to generate quantities of commercial seed

Figure 1: Most new cultivars require at least 10 years to develop, at a cost of more than $1 million, before they are ready for market. Cross-breeding is required first to create progeny, then to identify those with superior traits compared to the best cultivars. Potential new cultivars are then put through rigorous plot and large-scale trials to confirm their performance under a wide range of conditions (seasonal and geographical). If the resulting cultivar is deemed valuable to the industry, it then takes a further two years to generate seed for sale.



Plant breeding is a long and complex process, typically taking more than a decade for new cultivars to reach the market.

In addition, no other country breeds ryegrasses containing the endophytes necessary for our conditions and most countries breeding perennial ryegrass have much colder winters. There are no overseas-bred cultivars with a high level of performance in DairyNZ's Forage Value Index (**dairynz.co.nz/FVI**). Similarly, for clover breeding, few countries depend upon white clover as much as New Zealand does. Our country is also unique in breeding and using forage chicory and plantain.

In annual fodder crops like brassicas, some cultivars are developed overseas, but our unique pest and disease spectrum means most cultivars must also be bred locally. The situation is different in maize and fodder beet, where almost all cultivars are developed overseas. Even so, local trialling is required to determine the highest-yielding cultivars under New Zealand conditions.

Plant breeding: complex, costly and lengthy

About $40 million/year is invested in the plant breeding industry across many species. Plant breeding is a long and complex process (*Figure 1*) – few cultivars are developed in less than 10 years and each cultivar costs more than $1 million before it reaches the market. Perennial ryegrass breeding is particularly complicated due to the presence of endophytic fungi (e.g. AR1, AR37) and the need to incorporate these into the cultivars. Therefore, perennial ryegrass breeding programmes must also be supported by endophyte development research programmes. Fortunately, we are in a very good position in New Zealand, due to our legislation and funding models.

Cultivar development work is financed by private company investments using royalties collected on seed sales. Government

DairyNZ researchers measuring ryegrass tiller density for the Genetic Gain experiment. This experiment will determine how much gain has been achieved in pasture production from perennial ryegrass breeding in New Zealand.

research funding supports a range of more challenging new pre-breeding technologies and scientific research, and the AgResearch Margot Forde Germplasm Centre in Palmerston North. This is a national genebank which actively collects new genetic resources and maintains a large collection of seed for perpetuity.

How do we measure success?

The success of any forage breeding must be assessed in terms of farm productivity gains. In practice, yield, forage quality and persistence are usually assessed in replicated plots under cutting or grazing, with verification on-farm. To be good enough to make it to farmers, a plant cultivar must:

- have an appropriate seasonal yield distribution
- provide high feed quality
- persist under real conditions in mixtures with clovers and herbs
- exhibit acceptable resistance to key diseases (e.g. crown and stem rust)
- contain appropriate endophyte strains which transmit effectively to the seed
- achieve adequate seed yields.

Mean annual yields of new perennial ryegrass varieties, and their associated endophytes, have improved by more than 2625 kilograms per hectare (kg/ha) (19 percent) since 1990, equating to an average genetic gain of 0.76 percent/year. Breeders have concentrated their efforts on providing additional cool-season growth and on improving performance in and recovery from dry summers. These efforts have resulted in a winter genetic gain of 1.0 percent/year, compared with 0.8 percent for early spring, 0.5 percent for late spring, 1.1 percent for summer and 1.3 percent for autumn[1]. Part of this lift in summer and autumn performance has resulted from improved endophytes, such as AR37, providing better insect resistance during summer and autumn.

Similarly, white clover yields in ryegrass swards have improved by more than 1.0% per year[2], an excellent achievement considering the increased production and competitiveness of the modern ryegrass/endophyte combinations.

The increase in dry matter production from ryegrass swards, attributed to genetic gain, is estimated to contribute an additional $15 to $20/ha in farm profitability compounded each year since 1990[3]. Adding other traits to the analysis could increase this. Conversely, in some regions such as the upper North Island, the environment is limiting the persistence of new cultivars so these gains cannot always be captured. The factors limiting persistence are complex: plant survival can be influenced by insect pests, endophyte type, overgrazing, genetic effects, soil effects, pasture pulling, grazing management, weeds, warm summer temperatures, drought, pugging, diseases and local environment. To date, there is little evidence that the increased yields gained from breeding have led to reduced persistence – indeed some modern cultivars are more persistent[1,4].

To improve persistence, breeders select plants and endophytes under the most stressful conditions of drought, grazing and insect pressure, across different soils and often in northern New Zealand. The breeders evaluate performance over many years and under varying grazing conditions. However, in many difficult environments it may be necessary to use alternative species to ensure persistence.

In addition to genetic gains in dry matter yield, breeders have also developed a diversification of cultivar types and endophytes

Persistence testing of ryegrass varieties.

Evaluation of crown rust on ryegrass single plants.

Crossing of perennial ryegrass plants in the glasshouse.

to provide late-flowering types and tetraploids. Compared with diploid mid-season flowering types, later-flowering diploids are potentially worth an extra $54/ha/year and late-flowering tetraploids worth an extra $232ha/year to dairy farms due to greater metabolisable energy content[5].

Comparing NZ's gains globally

Given our funding model, how does genetic gain in New Zealand compare with that achieved overseas and with large international breeding programmes for crops like maize? In Ireland, where endophytes are not used, genetic gain for perennial ryegrass yield has been 0.35 percent/year to 0.52 percent/year, depending upon management[6]. Meanwhile, genetic gains as high as 2.3 percent/year have been achieved for major crops such as hybrid maize grain[7]. That is because maize receives multimillion-dollar annual investments in breeding, perhaps more than a thousand times larger than for ryegrass, with cultivars developed as hybrids to capture the hybrid vigour. As yet, hybrids are only in the research phase for ryegrass due to difficulty creating ryegrass hybrids.

It is fair to say New Zealand pasture breeding has made reasonable progress, considering that pasture breeding is complicated and must account for endophytes, multiple grazing events (perennial versus annual crops) and diverse swards, and that it has a significantly smaller budget compared to major crops. Yet, our rates of genetic gain must improve further to ensure pasture performance meets the demands from animals of higher genetic merit, an array of stresses, increased climatic variability and increasing environmental concerns.

Currently, breeders use a range of strategies to increase genetic gain and persistence, including:

- designing robust breeding programmes
- maximising the use of new germplasm and novel endophytes
- researching the use of new technologies, e.g. as genomic selection
- selecting plants for persistence in the most challenging environments
- selecting for feed quality to maximise animal performance.

Plot evaluation of new ryegrass varieties near Christchurch.

The future breeding of forages faces many challenges. It will be essential to increase genetic gain for yield, persistence and feed quality, while at the same time reducing the environmental footprint of all species used on farm. Plant breeding programmes take many years, so it is crucial that changes are incorporated early to meet future demands in a changing world. Ensuring access to all suitable germplasm and endophytes, and adoption of new molecular technologies such as genomic selection, will be vital for successful plant breeding programmes.

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Choosing the best method of disbudding and pain prevention

Disbudding and dehorning are painful procedures for calves, which is why it's important to ensure adequate pain relief is given to avoid any suffering. Using pain prevention prior to disbudding or dehorning not only reduces calves' pain and stress, it also makes the animals easier to handle during the procedure and can improve their feed intake and weight gain. Here we look at different methods of disbudding and pain prevention and consider the risks and benefits of each.

Mhairi Sutherland, AgResearch

Methods of disbudding

Cattle are dehorned or disbudded to reduce the risk of injury to other cattle and stock handlers. Disbudding is performed on calves when horn buds are easily palpable, at approximately 5 to 10mm long. However, once the horns grow too large for disbudding techniques, they must be removed by amputation (dehorning)[1]. Most farmers (96 percent) use hot iron cautery to disbud calves. Although it is rare (only two percent use it), the second most common practice is the application of a caustic paste.

Cautery disbudding is usually carried out on calves that are four to six weeks old[1], when the horns are still small and haven't yet attached to the skull. This method involves pressing a hot cautery iron, heated using electricity or gas, onto the horn buds for several seconds. This destroys the horn bud tissue. It is common practice to rotate the cautery iron to cut the skin around the bud, then flick out the horn bud tissue. However, some operators leave the horn bud tissue in place after cautery. Leaving the horn bud tissue in place increases the risk of infection and the likelihood (by nine percent) that scurs – incompletely destroyed or developed horn buds – will develop (unpublished data).

Caustic or chemical disbudding involves applying an alkali – typically one with a sodium or calcium hydroxide base – to the horn bud region as a paste. This paste causes a chemical burn that destroys the germinal tissue of the horn bud[2]. The Animal Welfare (Painful Husbandry Procedures) Code of Welfare (2005) recommends this procedure is performed when the calves' horn buds are just palpable, usually at 7 to 10 days of age. Moreover, shaving the horn bud region and applying a ring of petroleum jelly around the base of the horn bud can help reduce the paste from spreading, reducing injury to surrounding tissues. However, DairyNZ does not recommend using caustic paste because there are significant welfare risks involved. Through rubbing, calves can easily spread caustic paste to other parts of their bodies, and

KEY POINTS

- All methods of disbudding cause pain, so farmers should always use pain prevention.
- From October 1, 2019, it will be mandatory to use a local anaesthetic for disbudding and dehorning cattle of any age.
- Disbud calves when the horn bud is small – don't wait until the horns grow and require amputation.
- Use polled terminal sires for beef calves because this negates the need for disbudding. Polled dairy sires are available in New Zealand, are increasing in popularity and may provide the ultimate long-term solution.

"Whichever method is used, it is critical to ensure the animal has received sufficient anaesthesia before you begin disbudding."

onto other calves, which can result in painful burns. This risk is even greater in wet conditions, when treated animals should be kept inside.

Another method of disbudding is horn amputation, which can be performed in various ways, including a scoop dehorner or embryotomy wire[1]. These methods cause more pain than disbudding and have a greater risk of infection because more tissue is removed[1]. Therefore, DairyNZ recommends that farmers disbud calves when the horn buds are small.

A final note: whichever method of disbudding or dehorning you choose, it is important to perform the procedure correctly so regrowth does not occur.

Methods of pain prevention

All methods of disbudding and dehorning cause behavioural and physiological changes that indicate pain. For that reason, DairyNZ strongly recommends the use of pain prevention. Not only does pain prevention reduce the suffering and stress experienced by calves, it makes the animals easier to handle during the procedure, and can improve their feed intake and weight gain[3].

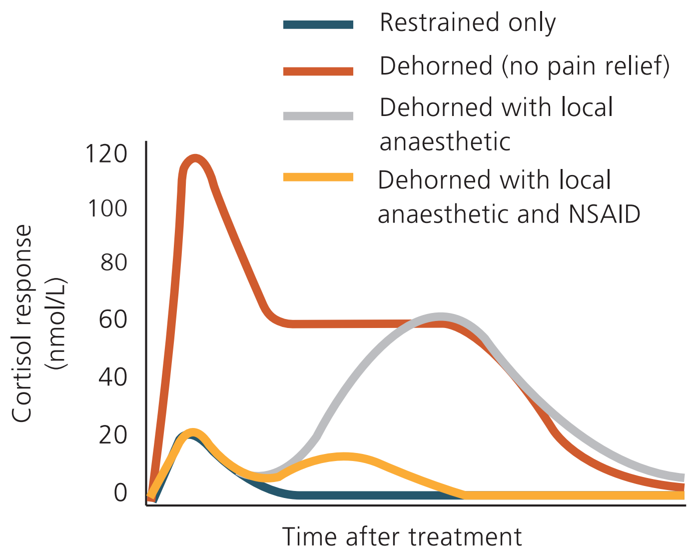
Cautery disbudding and amputation dehorning cause an immediate pain-related behavioural response in the animal, whereas the response to caustic paste is more evident sometime after application of the paste. Dehorning by amputation causes the greatest pain response[1], which re-emphasises the importance of early horn removal.

The most common pain prevention method is injecting a local anaesthetic (about 15 minutes before disbudding/dehorning) to create a regional nerve block. From October 1, 2019, it will be mandatory to use a local anaesthetic (at least) when disbudding or dehorning cattle of any age, according to the Animal Welfare (Care and Procedures) Regulations 2018. A person who fails to comply with this regulation can be fined up to $3000 and a body corporate up to $15,000, in the case of disbudding. In the case of dehorning, this fine increases to $5000 and $25,000 for an individual and body corporate respectively.

A local anaesthetic can be applied as a cornual nerve block, a ring block or a bleb. Whichever method is used, it is critical to ensure the animal has received sufficient anaesthesia before you begin disbudding. DairyNZ recommends you leave at least 15 minutes between injecting the local anaesthetic and performing the procedure. This allows enough time for the local anaesthetic to take effect. Another way to confirm effective anaesthesia is through the needle prick test: if the calf flinches when its skin around the horn bud is pricked with a needle, this tells you it needs more anaesthesia. Local anaesthetics are generally effective for two to three hours after being injected. Calves may

Stress responses

Figure 1: Stress responses
This figure shows the change in the stress response (cortisol concentrations - nanomoles per litre - nmol/L) of calves in four groups: those dehorned without pain relief, those dehorned with a local anaesthetic, those dehorned with a local anaesthetic and non-steroidal anti-inflammatory drug (information derived from Stafford and Mellor[8]), and those restrained only.



experience pain once the local anaesthetic wears off, mostly due to inflammation (*Figure 1*).

Post-operative pain prevention can be achieved by administering a non-steroid anti-inflammatory drug (NSAID); this reduces inflammatory pain. Giving calves both a local anaesthetic and a NSAID before disbudding or dehorning can eliminate their pain-related behavioural and physiological responses[1] (*Figure 1*).

Please note:

- The analgesia protocol for your farm must be developed and approved by your farm veterinarian.
- Lidocaine and NSAIDS can be administered only under veterinary supervision.
- Sedatives (as opposed to local anaesthetics) can currently be administered only by veterinarians.

Meanwhile, sedating calves can make it easier to administer a local anaesthetic – but it will not eliminate the pain of disbudding. If you're using a sedative, it's still essential to use a local anaesthetic as well[1]. Sedation comes with risks to the animal and handler (if they accidentally inject themselves), if veterinary instructions are not followed closely and if the animals are not monitored carefully before they become fully conscious.

In summary, a comprehensive pain mitigation strategy for disbudding calves could involve first sedating the calves so they don't struggle while receiving local anaesthetic; then giving a local anaesthetic and an NSAID to prevent the calves from feeling pain at disbudding and afterwards[1]. New animal welfare regulations will make it mandatory to use local anaesthetic in New Zealand, but it is also worth considering use of an NSAID for the calves' longer-term comfort.

Future options for disbudding

Several novel methods of preventing horn growth are being evaluated by AgResearch for use on dairy cattle, including cryosurgery andclove oil. (Note: it is currently illegal for farmers to administer clove oil.)

Cryosurgery involves freezing the horn bud cells with liquid nitrogen[4,5] (*Figure 2*). The stress response appears to be similar to disbudding using cautery, but cryosurgery appears to cause less tissue damage and potentially a lesser inflammatory response[4,5].

Injecting clove oil under the horn bud causes local cellular necrosis of the horn bud cells[6,7] *(Figure 2)*. Eugenol, the active ingredient of clove oil, has analgesic properties and has been shown to prevent horn growth in calves[6]. In trials, calves injected with clove oil appeared to experience less pain initially and, during the 48-hour post-treatment period, appeared to experience no more pain than calves disbudded by cautery without pain relief[7]. Two clear benefits of clove oil are that it does not involve tissue removal and it poses no risk of thermal damage to the brain.

Given these methods may have better welfare outcomes, how effective are they at preventing horn growth? Cryosurgery, when administered for 15 seconds per horn bud, had a 47 percent success rate at preventing horn growth[5]. Clove oil successfully prevented horn growth in 87 percent of calves (unpublished data). Both these disbudding methods are in the 'proof of concept' phase but, with refinement, may become more effective at preventing horn growth.

Polled cattle

Horn growth is a genetically-heritable autosomal recessive trait, and polled (hornless) cattle result from an autosomal dominant pattern of inheritance[9]. The polled trait is common in beef cattle but rare in dairy breeds – yet there are polled dairy sires available in New Zealand. Selecting for polled dairy cattle would provide an alternative to routine disbudding and potentially be the ultimate long-term solution.

Figure 2: Calves being disbudded using cautery (A), cryosurgery (B) and clove oil (C)

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Natural seepage wetlands: can they reduce nitrogen losses?

They may be generally disliked by farmers and thought of as troublesome ‘bogs’, but seepage wetlands have proven highly effective at preventing contaminants from reaching waterways. These so-called ‘kidneys of the land’ could serve as one useful tool in the dairy sector’s efforts to reduce nitrate leaching.

Kit Rutherford,
Lucy McKergow, Andrew Hughes, Fleur Matheson, National Institute of Water and Atmospheric Research (NIWA)

What are seepage wetlands?

Occurring naturally along stream banks or at the heads of streams, seepage wetlands are characterised by water-tolerant plants; saturated, organically-enriched, anaerobic soils; and standing water. They are generally disliked by farmers because of the risk of livestock and vehicles getting stuck and because they're unproductive. However, these areas are useful sinks for nitrogen (N), phosphorus (P), sediment and pathogens washed off paddocks.

Seepage wetlands are mainly fed by subsurface water flow from springs that emerge from a single point, or by seepage emerging from the ground along a line or surface without a distinct origin. Their degree of saturation ranges from temporary dryness to permanent saturation with standing water.

Seepage wetlands typically have three layers: a dense mat of plant roots (generally native grasses, rushes, sedges and raupo[1]) at the top, sitting over a porous, anaerobic, saturated organic soil, which lies on top of a less permeable soil layer, such as clay. They are located at the change of slope where particulate solids, including mineral sediments and organic matter, accumulate. Being small (10 to 5000 square metres), seepage wetlands are rarely identified in regional wetland inventories or managed any differently from surrounding pasture. However, one study found seepage wetlands that covered only five percent of a catchment area[2] intercepted more than 20 percent of runoff[3].

Constructed (man-made) wetlands attempt to mimic seepage wetlands and optimise contaminant trapping and removal by forcing water to pass through shallow flooded beds of emergent aquatic plants such as raupo.

Forms of nitrogen

N occurs in water in several different forms, including nitrate (NO_3), nitrite (NO_2) and ammonium (NH_4) ions; dissolved inorganic N (DIN = $NO_3 + NO_2 + NH_4$); dissolved organic N (DON); particulate organic N (PON); and total N (TN = DIN + DON + PON). Some forms of N are bioavailable (notably DIN) and can induce excessive growths of algal slime and weeds in streams, and algal blooms in lakes. DON and PON are less bioavailable but can be broken down by bacteria, fungi and sunlight into bioavailable forms.

KEY POINTS

- A few studies indicate seepage wetlands remove between 75 and 98 percent of nitrate from water.
- Most N is removed via denitrification and uptake by wetland plants. Denitrification is reliant on shallow horizontal seepage (mixing between surface and upper wetland soils) and represents permanent N loss from water, whereas uptake by plants represents temporary storage until the plants die.
- Smooth, low-cover vegetation works best to promote filtration and prevent flow channels from forming. Channels reduce contact time between water and soil, reducing the effectiveness of denitrification.
- Livestock should be excluded from shallow (not just deep) wetlands, as they are more likely to enter these areas and cause damage to the soil. This may reduce wetland effectiveness (especially through soil compaction). Light grazing when the wetland soil is dry promotes smooth vegetative cover without degrading the soil.

Farm A seepage wetland at Taupo (see map page 16) – in pasture grazed by cattle[8]. Photo: Rob Collins, formerly NIWA.

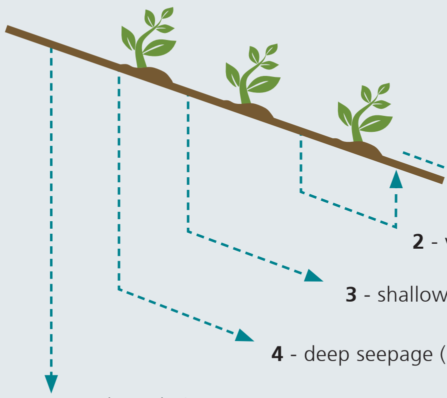
How do wetlands work?

Wetland soils are typically saturated, have a high organic content and are anaerobic. Such conditions favour denitrification – the reduction of nitrate (NO_3) to gaseous forms – which permanently removes nitrogen (N) from runoff. Several studies have measured high potential denitrification rates (quantified as the denitrification enzyme activity: DEA) in wetland soils. Two studies have measured high actual (*in situ*) denitrification rates from wetlands[4]. However, denitrification does not explain all NO_3 removal, implying that some is transformed to ammonium (NH_4), dissolved organic nitrogen (DON) and/or particulate organic nitrogen (PON).

Water travels through wetlands in a number of ways (*Figure 1*). Generally, more water travels across the top of a wetland than seeps through the microbially-active soils. High NO_3 removal (25 percent of added NO_3 removed over 1.5 metres) has been measured from surface flow during dry weather, although removal was less effective during rainfall[5].

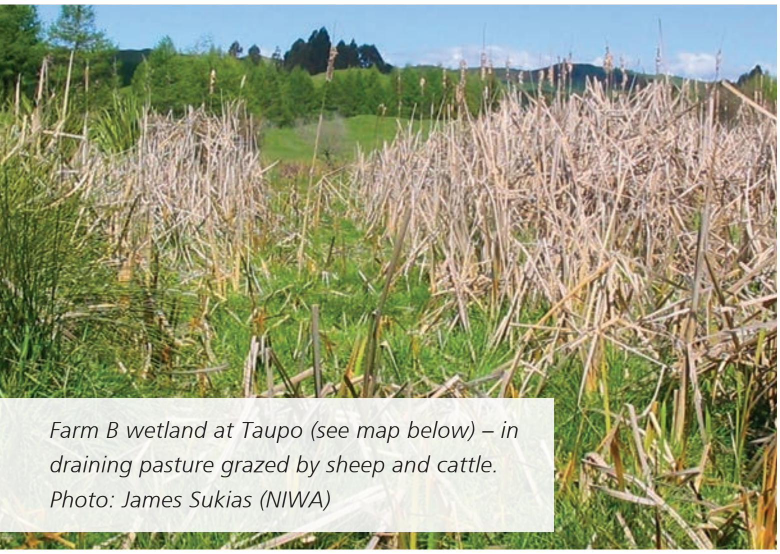
Surface water can also mix vertically into the top 5 to 10cm of the porous wetland soils, bringing NO_3 into contact with the denitrifying bacteria, which is where most NO_3 removal takes place (*Figure 1*). While soils 15 to 20 cm deep have high DEA (i.e. the potential to remove NO_3), porosity decreases with depth and reduces the vertical mixing. Consequently, NO_3 concentrations and removal rates decrease in soil depth below about 15 to 20cm[5].

Figure 1: Flow pathways in seepage wetlands.



Pathways:

1: Surface flow.
2: Vertical mixing, which is important for transporting nitrate to where denitrification occurs.
3: Shallow horizontal seepage flow in the top 5cm to 10cm, where most denitrification occurs.
4: Seepage flow in the bottom 15cm to 20cm, where NO_3 concentrations are depleted and little denitrification occurs.
5: Loss to deeper groundwater.

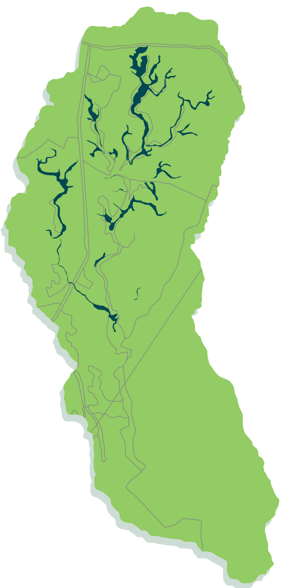


Farm B wetland at Taupo (see map below) – in draining pasture grazed by sheep and cattle. Photo: James Sukias (NIWA)

A close-up of soils and vegetation in Farm B wetland at Taupo (see map below) – in draining pasture grazed by sheep and cattle and studied by Collins et al. (2005). Photo: James Sukias, NIWA.

Seepage wetlands in the Tutaeuaua Stream catchment

This map shows seepage wetlands in the Tutaeuaua Stream catchment, Taupo (black). Also shown (grey) are fencelines and roads. The Farm A and Farm B wetlands are in this catchment. Seepage wetlands cover five percent of the catchment area[2].



NO_3 concentrations and denitrification rates also decrease as water moves from the top to the bottom of a wetland. NO_3 concentrations are high where water first enters and encounters soils with high DEA, but low near the outlet stream, reflecting that most NO_3 has been removed as the water passes through[4]. Regardless of where in the wetland most denitrification occurs, maximising the contact between inflowing water and wetland soils increases NO_3 removal rates through denitrification.

How effective are they at removing nitrogen?

So far, only a handful of reliable wetland studies have been undertaken in New Zealand. That is because seepage wetlands are challenging to study. Their water inputs are spread out, their soils are unconsolidated, and they are home to complex biogeochemical activities. Furthermore, key processes such as denitrification are difficult to measure.

However, a recent review of New Zealand seepage wetland studies found that, in comparisons of in-flow versus out-flow, all studies reduced NO_3 by 75 to 98 percent[4]. This was true regardless of the methods used and whether concentrations or loads were compared.

Studies of constructed wetlands are simpler to undertake because they have more defined in-flow and out-flow paths. The studies have quantified the uptake of nutrients (including N) by plants for growth, and the generation of organic carbon (which promote denitrification) when they deteriorate. In-flowing N removal from constructed wetlands in New Zealand has been found to range from 65 to 92 percent, and N removal increases linearly with plant biomass[6]. Plants almost certainly remove N from natural seepage wetlands, although rates attributable to plant uptake have not been quantified.

Wetlands are highly effective at removing N over the course of a year (i.e. on average). However, they perform best during low summer flows and are usually net sinks of all forms of nitrogen during this time. Conveniently, this occurs when nitrogen poses the highest risk, because it causes excessive plant and algal growth in receiving streams, rivers, lakes and estuaries. During other times of the year, wetlands may vary in performance. One study found wetlands can be net sources (putting out more than goes in) of some forms of N (NH_4, DON and/or PON) at times of higher flows[4]. But most other studies have found wetlands were sinks for total N (the sum of all organic and inorganic forms of N found in a water sample) even during times high flows[4,7].

How does a farmer assess wetlands' effectiveness?

The most common method for farmers to assess a wetland's effectiveness is by using Overseer, although this nutrient-modelling software does come with some limitations.

Overseer assumes an average rate of 250 milligrams per square metre per day ($mgm^{-2}d^{-1}$) (at 20°C), which is adjusted by wetland condition and temperature. Compared with four studies with measured removal rates[4,5], Overseer predicted only 36 to 67 percent of the measured NO_3 removal rates, indicating Overseer predictions were underestimated. It is not clear, however, whether Overseer is conservative for estimating the removal of all forms of bioavailable N. This is partly because we have an incomplete understanding of the bioavailability of organic nitrogen exports from wetlands. In addition, it is not clear what proportion of DON and PON losses from farmland is included in Overseer losses.

User inputs also affect the Overseer estimation. Users must enter data into Overseer, including inflows and the condition of wetland soils and vegetation. Although look-up tables are provided, users report difficulties providing input data objectively. NIWA is working with Overseer to make the process simpler and, consequently, more widely-accepted in nutrient budgets.

Even so, Overseer allows farmers to assess the potential of seepage wetlands to reduce N loss from farms, and to see how removal varies with wetland/catchment area ratio, flow channelisation, vegetation and stock damage.

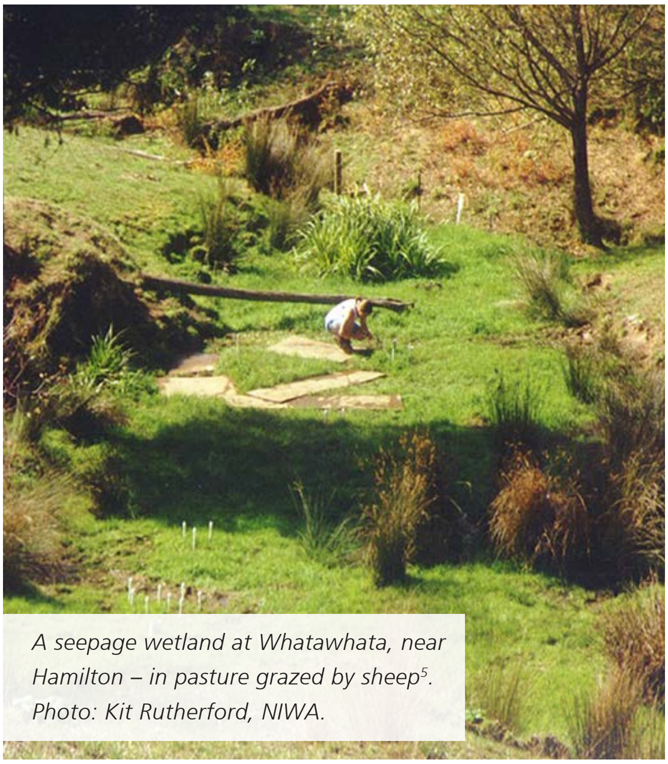
How are seepage wetlands best managed?

When cattle enter wetlands, they can degrade the water quality directly through faecal and urine inputs, and soil disturbance; and indirectly by altering soil physical properties (e.g. compaction) and damaging vegetation. High total and organic N exports[8] have been measured from small, shallow seepage wetlands after livestock incursions.

Currently, farmers use fencing to prevent cattle becoming trapped in deep wetland soils. However, cattle tend to avoid deeper wetlands[7], so shallow wetlands (standing water less than one metre deep) are likely to benefit more from livestock exclusion. Unlimited cattle access to unfenced wetlands deeper than two metres caused no observable impact on water quality. This was mainly due to the lack of wetland ingress by the cattle and the ability of the dense wetland grasses to capture and remove (attenuate) contaminants from the water. This deep wetland was also very effective at attenuating particulate matter and associated nutrients from the steep adjacent hillslopes[7].

Portable electric fences offer a flexible, effective way to exclude cattle from wetlands that could be grazed lightly during periods when the wetland soils have dried out. Light grazing is beneficial as it maintains smooth low cover vegetation, preventing channels from forming. We do not recommend bulldozing benches around wetlands for permanent fencing, because bare earth is vulnerable to erosion and benches may divert runoff away from wetlands.

Planting seepage wetlands with large vegetation (e.g. flax, shrubs, trees) is not advised as these are not as effective as smaller wetland plants, although some large plants may help protect wetlands from 'washout' during storms. Plants provide organic matter, promote denitrification and trapping solids, but larger plants encourage flow channels to form. Channels, like drains, reduce the contact time between water and the soils where denitrification and plant uptake occur.



A seepage wetland at Whatawhata, near Hamilton – in pasture grazed by sheep[5]. Photo: Kit Rutherford, NIWA.

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Does sowing rate affect persistence?

General advice on the best sowing rates for ryegrass pastures has remained unchanged for decades. So what happened when DairyNZ researchers tested different sowing rates in three parts of New Zealand? Was there a clear winner?

Seedlings were tagged seven weeks after emergence and checked for tiller number and survival over the next 12 months.

Recommended sowing rates for new perennial ryegrass pastures are around 20 kilograms of seed per hectare (kg seed/ha) for diploid cultivars and 28kg seed/ha for tetraploid cultivars (due to the tetraploid's larger seed size). Decades of research have shown little advantage of moving away from those standard rates. However, some schools of thought suggest sowing rates should be higher to ensure good establishment, or lower to prevent seedling competition that compromises their ability to survive in the first summer after sowing.

DairyNZ researchers compared the establishment and survival of seedlings from four perennial ryegrass cultivars sown in autumn 2011. The cultivars were sown at five sowing rates (equivalent to 6, 12, 18, 24 and 30kg diploid seed/ha) and three sites (Jordan Valley in Northland, Newstead in the Waikato, and Lincoln in Canterbury). Fifty seedlings of each sowing rate X cultivar combination were tagged seven weeks after emergence and checked for tiller number and survival over the following 12 months.

What were the results?

As expected, there was an inverse relationship between sowing rate and almost all aspects of plant size, such as the number of tillers and roots per plant, and total root and shoot biomass per plant. However, the weight of individual tillers was the same across all sowing rate treatments.

Thus, competition between plants pivots around a more-or-less constant tiller weight. Lower sowing rates result in plants with a relatively small number of multi-tillered plants, while higher sowing rates result in many plants with smaller tillers. Importantly, pastures grown from all sowing rates quickly reached the same total tiller density (although the lowest, 6kg/ha sowing rate, tended to lag).

Most seedling death occurred in the first two months after emergence, with higher death rates at high sowing rates. After that point, about 20 percent of plants died (mostly in summer/autumn) but there was no difference between sowing rates in mortality. Plants that accumulated 15 tillers or more by late winter/early spring had near 100 percent survival over the following summer/autumn. Generally, plants that did not reach this threshold died.

The message is clear: sowing rates of 18kg seed/ha for diploids and 25kg seed/ha for tetraploids are enough to ensure best possible establishment and survival into the second year of pasture life. However, success is still reliant on good management for seed bed preparation, weed control and care during establishment (until plants reach the 15-tiller threshold).

For more information about this research, please refer to the following publication: Lee, J. M., E. R. Thom, K. Wynn, D. Waugh, L. Rossi, and D. F. Chapman. 2017. High perennial ryegrass seeding rates reduce plant size and survival during the first year after sowing: Does this have implications for pasture sward persistence? Grass and Forage Science 72(3): 382-400.

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