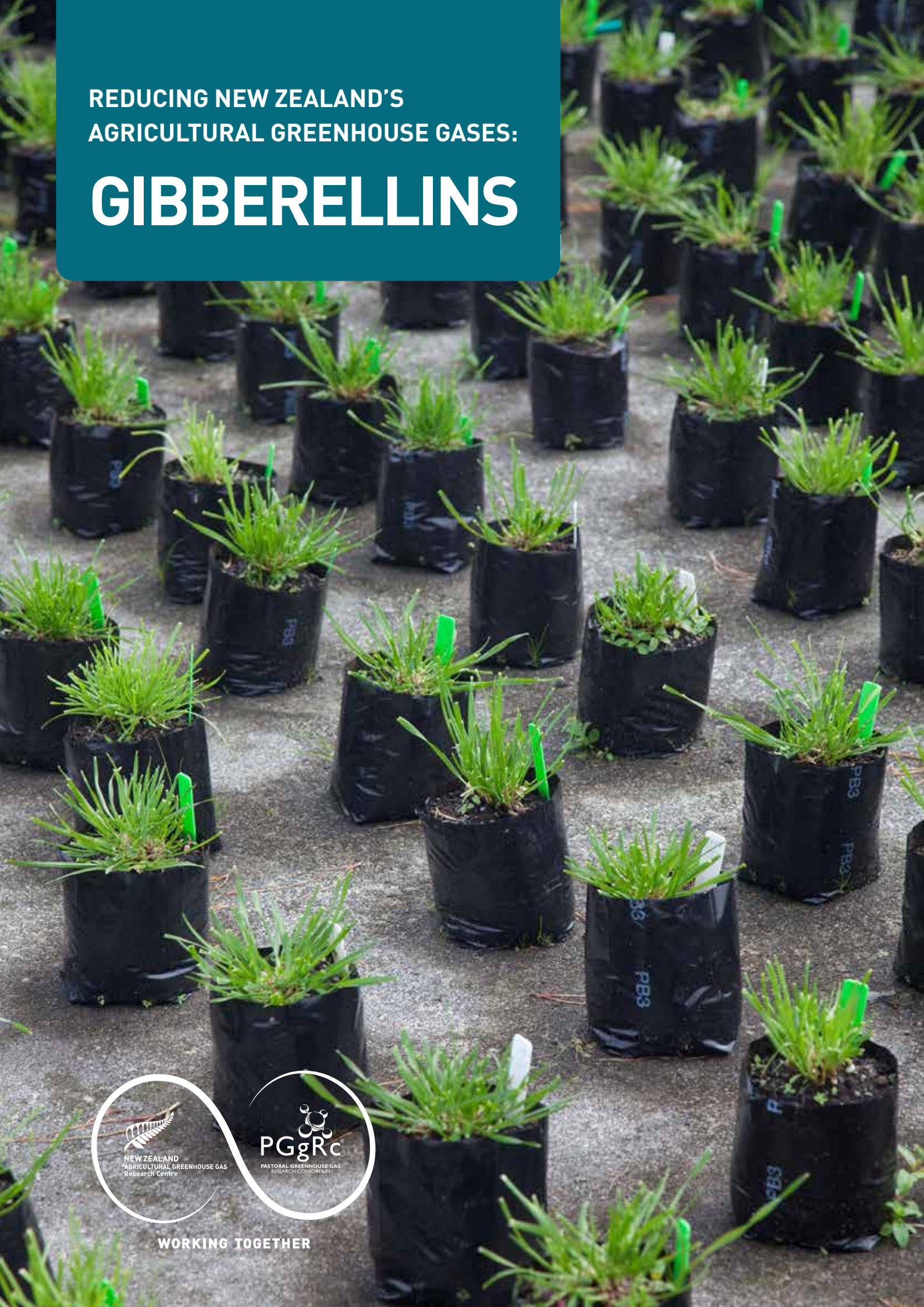
REDUCING NEW ZEALAND'S AGRICULTURAL GREENHOUSE GASES:

GIBBERELLINS



NEW ZEALAND AGRICULTURAL GREENHOUSE GAS Research Centre

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GIBBERELLINS

Gibberellins are natural hormones that stimulate plant growth. They were first discovered in fungi in the 1950s. Since then, about 50 different gibberellins have been identified, of which the most widely available is gibberellic acid GA3. There is increasing interest in using gibberellins to boost herbage growth in pasture, and whether gibberellins could be used instead of nitrogen fertiliser. This could have the effect of reducing emissions of nitrous oxide – a powerful, long-lived greenhouse gas.

KEY FINDINGS

Gibberellins promote dry matter production, especially when applied in early spring or late summer/early autumn.

Gibberellins reduce the nitrogen concentration of herbage with little effect on pasture quality.

On a typical New Zealand dairy farm, using gibberellins instead of nitrogen fertiliser once a year in late summer or early spring is estimated to reduce nitrous oxide emissions from the treated area by 5-6%.

WHY THE INTEREST IN GIBBERELLINS?

Nitrous oxide is one result of microbes breaking down nitrogen in soil. This happens naturally on ungrazed land. On farms, nitrous oxide emissions are generally higher because nitrogen goes onto the soil from the urine and dung of grazing animals and fertiliser.

Ruminant animals only need modest amounts of nitrogen in their food (estimated at around 2.5% of their diet). By contrast, it takes much more nitrogen to get the best pasture supply (most cool temperate grassland species need around 4.5% nitrogen concentration in their leaves to maximise productivity). When there is more nitrogen in pasture than the animals can use, they excrete the excess, primarily as urine. Urine patches from dairy cattle have especially high concentrations of nitrogen: the equivalent of 700-1,000 kilograms of nitrogen per hectare.

Table 1 illustrates the relatively high emissions of nitrous oxide from the nitrogen contained in dairy cattle urine, compared with the emissions from sheep urine and dung.

Table 1: Percentage of nitrogen emitted to air as nitrous oxide, based on measurements from 185 New Zealand sites

Source	Average (mean)
Dairy cattle urine	1.16%
Sheep urine	0.55%
Nitrogen fertiliser as Urea	0.48%
Dairy cattle dung	0.23%
Sheep dung	0.08%

Farmers use nitrogen fertiliser to stimulate herbage growth. If gibberellins can do the job without adding nitrogen, that could enable farmers to reduce nitrous oxide emissions as well as reduce nitrate leaching while still maintaining the productivity of their pasture. This is especially attractive in grassland farm systems with minimal use of supplementary feed.

EVIDENCE SO FAR

NZAGRC recently commissioned scientists from Landcare Research and Lincoln University to review the science on gibberellins. They identified relevant findings from well over 100 trials, and summarised the results. They also calculated the likely reduction in nitrous oxide emissions if gibberellins were applied on a typical New Zealand dairy farm.

EFFECTS OF GIBBERELLINS ON PASTURE

Dry Matter

Most studies have recorded an increase in dry matter production where gibberellins are applied compared to untreated pasture. One study from 2009, for example, found an average production

increase of 36% in 35 field trials across New Zealand. For these results, pasture had to be grazed within 40-50 days after the gibberellin was applied.

In another set of New Zealand studies published in 2013-14, gibberellins compared favourably with nitrogen fertiliser. Table 2 shows how much more dry matter was produced from perennial ryegrass and white clover mixed grassland compared with untreated pasture.

Table 2: Study comparing dry matter increases from gibberellins and nitrogen fertiliser

What	Average (mean) kg DM/ha	Range kg DM/ha
Gibberellins	427	212-1199
Nitrogen fertiliser	384	40-767

Application rates: gibberellins: 20 g active ingredient per hectare; fertiliser: 40 kg N urea fertiliser per hectare

Pasture composition

Nitrous oxide emissions from grazed pasture tend to be higher if the pasture has a high proportion of legumes (eg lucerne; white clover) compared with herbaceous plants (eg chicory; plantain) or grasses (eg ryegrass; tall fescue).

Based on a limited number of studies, it appears that gibberellins increase dry matter production for most pasture species, but may result in more legumes. Nitrogen fertiliser, by contrast, tends to reduce the proportion of legumes in pasture.

Pasture quality

Studies to date suggest that gibberellins reduce the nitrogen concentration of herbage with little effect on metabolisable energy (see Table 3).

Table 3: Gibberellins and feed quality

What	Effect of gibberellins	Why it matters
Herbage nitrogen concentration	Reduced nitrogen concentration	Less nitrogen in feed leads to lower excretion of nitrogen in urine and possible reduced nitrate leaching and reduced nitrous oxide emissions
Water soluble carbohydrate (WSC) concentration of herbage	No significant change	Changes in WSC could affect the proportion of dietary nitrogen excreted in urine
Metabolisable energy (ME) content per unit of dry matter	No significant change	Changes to ME content would affect animal productivity and could alter dietary nitrogen excreted in urine
Mineral content of herbage	Limited effect, except increased sodium uptake	Increased dietary mineral content is linked to increased urine volume, which may reduce the amount of nitrogen deposited in urine patches

EFFECTS OF GIBBERELLINS ON NITROUS OXIDE EMISSIONS

In the NZAGRC-commissioned review, the scientists investigated whether the use of gibberellins would be likely to reduce nitrous oxide emissions from a typical New Zealand dairy farm. They did this in two ways:

1. Estimate the impact of a change in herbage nitrogen concentration (from the use of gibberellins) on nitrogen losses for each urination by a dairy cow.

   Finding: application of gibberellins within a few days after grazing can decrease nitrous oxide emissions from a single urination by 14% compared with the emissions from untreated pasture.

2. Use the OVERSEER® farm systems model to estimate the effects of gibberellins on seasonal and annual nitrous oxide emissions.

   Findings: one application of gibberellins within a few days after grazing equates to 1-2% reduction in annual nitrous oxide emissions from the farm. If this single application of gibberellins is done instead of one application of nitrogen fertiliser in late summer or early spring, the farm's nitrous oxide emissions could reduce by an estimated 5-6%.

HOW MUCH WOULD WE HAVE TO USE?

Early studies of gibberellins applied very large amounts to pasture – up to 700 grams of active ingredient per hectare. Recent research has produced good results from application rates of as little as 5-10 grams of active ingredient per hectare. Combined with lower manufacturing costs, this makes gibberellins a more viable proposition.

WHEN IS THE BEST TIME TO USE GIBBERELLINS?

Studies consistently show that the time of year is crucial. The most marked responses to gibberellins are recorded in spring as temperatures warm up, and again from late summer through autumn. There is little benefit from applying gibberellins over summer. This includes studies specifically on cool temperate perennial ryegrass and white clover grassland.

COULD GIBBERELLINS TOTALLY REPLACE NITROGEN FERTILISER?

Consistent use of gibberellins without nitrogen inputs to the soil (either from fertiliser or from nitrogen-fixing plants) would gradually reduce the levels of nitrogen and carbon in the soil. We do not yet have a good understanding of the long-term consequences of enhanced use or multiple applications of gibberellins on soil carbon losses (which would offset benefits of reduced nitrous oxide emissions). If nitrogen and/or soil carbon become depleted, eventually pasture growth rates could slow down and affect other soil health characteristics. The interactions between all the factors involved require further study before the widespread increased use of gibberellins could be recommended.

ARE GIBBERELLINS COST EFFECTIVE?

The review did not include a cost:benefit analysis of using gibberellins. Such an assessment depends on the economics of a particular farm, including the cost of gibberellins and their application.

Full Paper:

David Whitehead and Grant R. Edwards. 2015.

Assessment of the application of gibberellins to increase productivity and reduce nitrous oxide emissions in grazed grassland.

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