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Fertiliser use: responses to nitrogen and phosphorus

Developing a strategy at the start of the season can improve the return and reduce the wastage from your investment in fertiliser. Following below are some factors to consider.

Mark Shepherd and Gina Lucci, AgResearch Ruakura

Summary

- The economic benefit of both nitrogen (N) and phosphorus (P) fertilisers depends on being able to utilise the extra pasture growth generated. Nitrogen fertiliser is a tactical tool for meeting feed shortages
- Nitrogen fertiliser is a growth multiplier – it cannot make pasture grow if the environmental conditions are not right
- Growing conditions drive the response of dry matter production to fertiliser N. This means a large rapid response in spring; and a low, slow response in autumn/winter
- The rate of N application greatly influences N fertiliser use efficiency. Efficiency begins to decrease at rates above about 60 kg N/ha (depending on conditions)
- A farm's P fertiliser strategy should be related to the target soil P level and whether it needs to be built up, maintained or run-down.

Matching stocking rate and animal productivity to the farm pasture production potential and additional supplementary feed is a strategic decision, i.e. planned at the start of the season. However, as well as a strategy, a farm needs tactics to achieve its goals[1].

The day-to-day management of feed and nitrogen (N) fertiliser is a tactical decision, reacting to situations and developing a plan for the short and medium-term. N fertiliser is used to boost pasture covers to fill expected feed shortages; a tactical approach to N fertiliser usage for supporting the overall feed strategy.

Likelihood of response to N fertiliser

N fertiliser is a growth multiplier – it cannot make pasture grow if the environmental conditions are not right for growth. Therefore, the likelihood of N response is closely linked with pasture growth.

If conditions are unfavourable for growth, N fertiliser response will be small. In addition, pastures respond best to N when all other nutrient levels are satisfactory.

Soil N supply

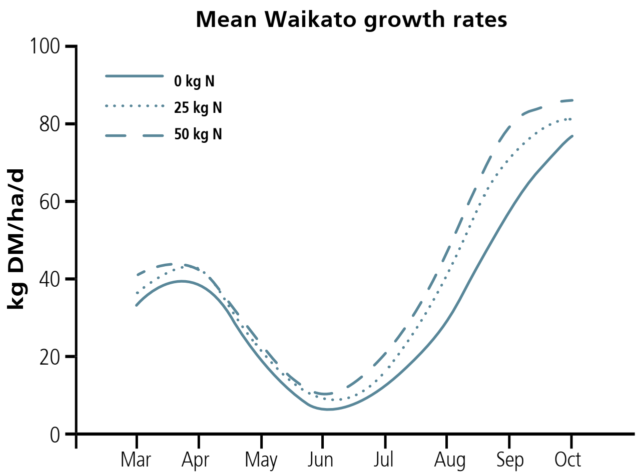
Pastures will respond to N fertiliser when plant demand for N exceeds supply from the soil. Where soils are severely deficient in N, the response to N fertilisers will be greatest[2]. The native soil N supply (without the addition of fertiliser) originates largely from the mineralisation of organic matter and from clover.

Soils with high levels of organic matter have been found to have a higher soil N supply[3], which means the pastures they support do not require as much N fertiliser, once soil temperatures rise and mineralisation rates increase.

Season

Data collected from New Zealand's national N trials database[4] show that the greatest growth rates and the greatest responses to N fertiliser are in the spring (Figure 1). These responses are generally associated with lower soil N supply post-winter. In contrast, growth rates and N responses in the autumn and winter are smaller. In the example in Figure 1, this is shown by the response to 50 kg N/ha being similar to the response to 25 kg/ha.

Figure 1. Average ryegrass/white clover pasture growth rates in the Waikato measured from March to October with 0, 25 or 50 kg N/ha applied. Data aggregated from a wide range of experiments, sites and years.



Temperature

Soil temperature is the main limiting factor for winter growth in many regions of New Zealand. Between 5-10°C, every 1°C increase results in an increase in pasture production of 5-10 kg DM/ha per day[5]. Above 10°C, the response is less with 3-5 kg DM/ha per day, with every degree increase in soil temperature up to 14°C.

This finding is supported by data from the N fertiliser trials database which, for temperatures > 5°C, showed a linear increase in production of 4 kg DM/ha per day with every degree increase in soil temperature. A commonly accepted rule of thumb is not to apply N when the temperature is < 6°C. At soil temperatures above 16°C, responses are reduced because of greater N mineralisation of soil organic N[2].

Soil moisture

Even small changes in water availability can have a large effect on yield[6]. Water stress has been found to limit N uptake by pasture, as well as dry matter (DM) production[7]. Unless irrigation is provided, high evapotranspiration rates in the summer and autumn, and low reserves of soil moisture, mean that lack of rainfall can limit growth at this time.

The summer period is subject to the most uncertain yield response to N, and is the most difficult period for decisions on use of N fertiliser; particularly as this may well be when feed is in short supply.

Clover content

Research shows, for every 3 kg fertiliser N applied, N fixation by clover is reduced by about 1 kg N/ha/year[2]. Clearly, if clovers or other leguminous plants make up a large proportion of pasture, then use of N fertiliser needs to be carefully considered. However, it has been reported that application rates in the order of 20-50 kg N/ha are unlikely to have a major effect on the yield of clover.

Size of response to N fertiliser

The size of the response to N fertiliser will depend on all of the factors listed above, particularly soil N/clover supply and growing conditions, along with rate of N fertiliser and spelling period (time between fertiliser application and grazing).

The rate of N application greatly influences N fertiliser use efficiency (NFUE), with higher rates generally resulting in lower efficiencies[9]. Figure 2 shows the typical shape of an N fertiliser response curve from yields measured in spring in the Waikato. Fertiliser efficiency (kg DM/kg N applied) begins to decrease at rates above about 60 kg N/ha (depending on conditions), which supports the 50 kg N/ha upper limit per application recommended by many[2,8].

Some of the 'unused' fertiliser after the first harvest (cutting or grazing) is potentially available for the regrowth (Figure 3). The additional response will depend on rate of N originally applied, spelling period and growing conditions during this period, as well as the other processes that are competing for the N (e.g. leaching, immobilisation in the soil).

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Figure 2. Typical shape of the yield response (over two three-week harvests) to N fertiliser applied to ryegrass/white clover in spring. The vertical bars around each point show the experimental variation around each measurement.

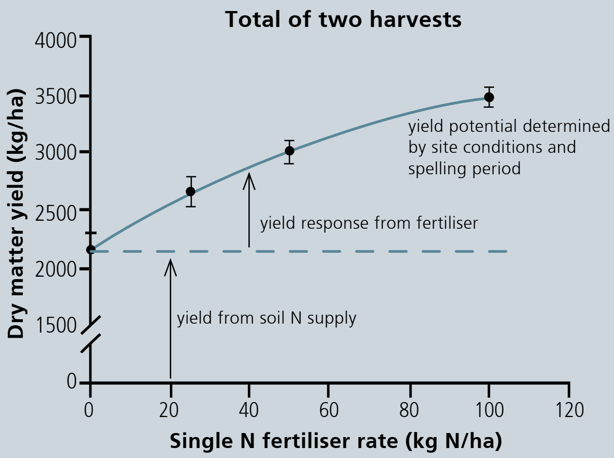
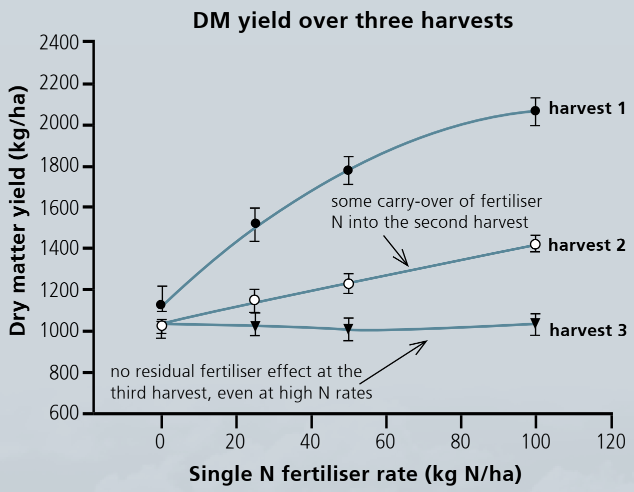


Figure 3. Demonstration of residual effects of fertiliser N over three three-week harvests in spring after a single N fertiliser application to a ryegrass/white clover sward. The vertical bars around each point show the experimental variation around each measurement.



Typical response rates

Growing conditions affect (a) the overall response of DM production to fertiliser N and (b) the time that it takes the pasture to express this response fully. Guidelines are shown in Table 1, but actual responses will depend on many factors. Building up a bank of knowledge on the individual farm over time is a useful management tool to refine these guidelines.

Fertiliser N losses can be reduced at times by matching the appropriate fertiliser to the prevailing soil moisture and weather conditions. Ammonium nitrate or sulphate of ammonia are less susceptible to volatilisation when applied during hot, dry conditions than are urea and diammonium phosphate (DAP). Urease inhibitors can also decrease losses from urea in such circumstances[10].

Response to phosphorus fertiliser

The pasture response to phosphorus (P) from fertiliser is underpinned by the soil P supply; the same principle as N fertiliser and soil N supply. This is where the similarity ends; with P (unlike N) it is possible to build up soil P reserves by fertiliser additions, so that pasture production is not limited by P shortage and is unlikely to give an economic response to fresh additions[11].

The standard Olsen P test is an estimate of the plant-available fraction of soil P. Target levels of Olsen P differ with soil type (Table 2) because some soils have a large capacity to adsorb P, leaving less available for pasture. However, the principles are the same across all soil types: soil P levels below target suggest a response to fresh P is likely, while levels at or above target suggest a response is unlikely.

The economic benefit depends on being able to utilise the extra growth. Thus, in some high producing situations, there might be justification for increasing soil Olsen P above target levels[11].

Managing soil P status

Increasing and maintaining target soil P levels costs money. Once target P levels have been reached, maintaining these levels requires topping up to replace the P removed in produce and that immobilised in the soil (Table 2). To obtain more farm specific recommendations, the nutrient balance model Overseer is a great tool for calculating nutrient (fertility) transfers around the farm and calculating the maintenance fertiliser requirements.

Raising soil P status, of course, means applying more than is removed. This capital investment should be tailored to meet farming and business objectives. Extra P inputs to increase soil test levels by one unit are shown in Table 2. Fertiliser P levels required to build up or maintain soil P levels will also depend on the soil's Anion Storage Capacity (ASC).

The ASC is a standard soil test, used to inform fertiliser recommendations, that measures the soil's ability to 'retain' P and this phosphate 'retention' varies with soil parent material and degree of weathering[12]. Also, the average soil P retention for each soil is included in the Soil Series Fact Sheets, available from Landcare Research (**http://smap.landcareresearch.co.nz**).

Temporarily stopping fertiliser P applications can be a good practice where levels are above optimum. This will run soil P levels down and decrease the farm's P loss in surface run-off.

The recommended procedure for this run-down phase is to monitor soil P status regularly and not forget that other nutrients such as sulphur and potassium may still be needed[13]. Applying half P maintenance dressings is one strategy for running soil P levels down over time.

Table 1. Typical pasture N response rates according to season[2]

Season	Months	Time for full response (weeks)	Typical response (kg DM/kg N applied)
Late winter/early spring	July-Sept	5-8	10-15
Mid-spring	Oct-Nov	3-4	20
Summer	Dec-Feb	unpredictable	unpredictable
Autumn	Mar-Apr	6-10	5-10
Early winter	May-Jun	10-14	4-8

Table 2. Soil Olsen P target levels, average P maintenance levels and extra P fertiliser required to raise Olsen P by 1 unit, as affected by soil-type[11, 13]

Soil-type	Target Olsen P levels	Maintenance P (kg P/100 kg MS)	Extra P required to raise Olsen P by 1 unit (kg/ha)*
Volcanic – ash	20-30	6	11
Volcanic – pumice	35-45	6	7
Sedimentary	20-30	5	5
Peat	35-45	**	**

**i.e. extra above maintenance rate; ** Difficult to generalise: depends on the soil's Anion Storage Capacity.*

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Peer reviewed publications

Bryant, R.H., P. Gregorini, G.R. Edwards. 2012. Effects of N fertilisation, leaf appearance and time of day on N fractionation and chemical composition of *Lolium perenne* cultivars in spring. *Animal Feed Science and Technology* http://dx.doi:.org/10.1016/j.anifeedsci.2012.02.003

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Storing carbon in soil

Can we slow a revolving door?

Louis Schipper, Faculty of Science and Engineering, University of Waikato. www.waiber.com

There are several important reasons for maintaining or increasing the carbon content of soils.

Organic matter is critical for supporting many important soil functions that contribute to production and protect the environment. These include improving soil structure, nutrient and water retention, and providing a food source for soil microorganisms.

Carbon makes up about 50% of soil organic matter and in New Zealand soils there is on average about 100 t of soil carbon in the top metre of each hectare of grazing land[1].

The transfer of carbon dioxide to soil organic matter through photosynthesis is an important buffer for managing the total production of greenhouse gases that contribute to global climate change. There is more carbon held in soil than in plants and the carbon dioxide in the atmosphere above.

Most of the carbon dioxide released to the atmosphere from human activity has come from the burning of fossil fuels with about 10 to 15% coming from land use change in recent years[2].

Where does soil carbon come from?

Plants convert carbon dioxide from the atmosphere into sugars through photosynthesis. These sugars are converted into leaves and roots and are converted back to carbon dioxide when needed to produce energy for the plant.

Carbon enters the soil when leaves and roots die, or are eaten and excreted, or when carbon leaks from roots into the surrounding soil. It is thought that roots contribute the majority of carbon to soil, whereas much of the vegetation and excreta on the soil surface are converted to carbon dioxide[3].

The plant carbon that enters the soil is used by microorganisms as a food source, with the majority being respired back to the atmosphere as carbon dioxide. The remainder is converted into microbial biomass and microbial by-products that are transferred into the surrounding soil. Some of this transferred carbon can be bound by clay particles to form soil aggregates and is protected from further decomposition.

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As a result of this cycling, there are several carbon pools in soil, including plant litter (fragments that are recognisable or partially decomposed), microbial biomass and various stabilised carbon pools in aggregates that have been processed by microbes.

While litter and the microbial biomass turn over relatively quickly (months to years), the stabilised pools can last for a very long time – 10 to >1000 years. To increase carbon content of soil in the long-term, it is important that newly sequestered carbon is stored in these stabilised pools and not just as plant litter that could decompose very rapidly to carbon dioxide.

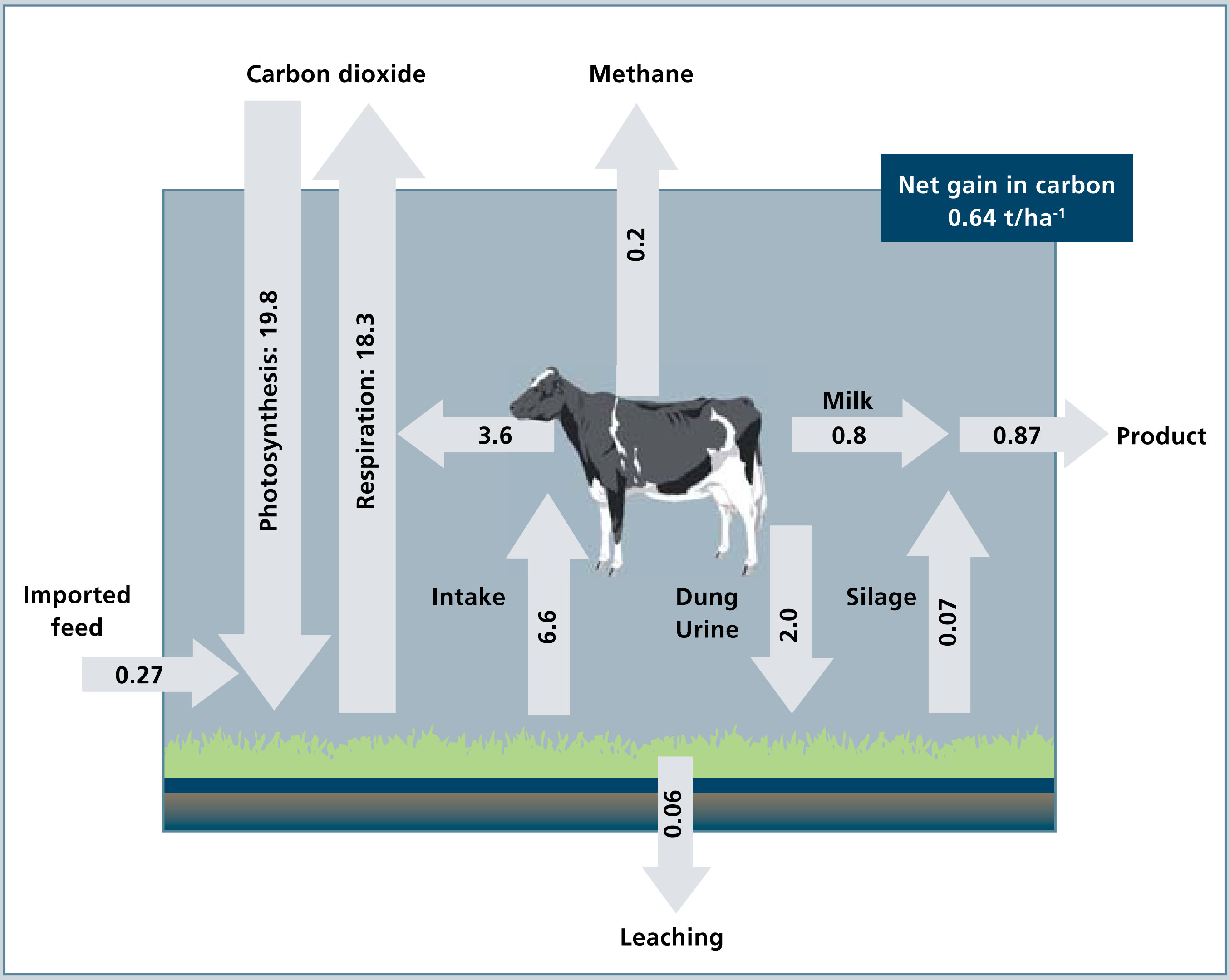
So while there can be very large inputs of carbon to soil every year, this is usually matched by exports of carbon in the same year. This is a major reason why increasing carbon storage in soil is a slow process. As an example, all the flows of carbon into and out of an example dairy farm in the Waikato have been measured (Figure 1)[4].

In this study, nearly 20 t of carbon were fixed per hectare, by pasture during the year. Other inputs of carbon included imported feed (0.27 t). Of this incoming carbon, the majority was cycled back to the atmosphere through plant respiration but also respiration by cows after feeding on grass.

A small fraction was released as methane (0.2 t) and 0.87 t was exported in product (milk and silage). Leaching losses were estimated at 0.06 t per hectare but this number is a very rough estimate. When accounting for all the inputs and outputs, this dairy farm gained about 0.64 t of carbon per hectare.

These carbon balances are site specific and vary from year to year but serve as an example of the size of the fluxes that contribute to changes in soil carbon.

Figure 1. The flows of carbon into and out of Scott Farm (DairyNZ, Newstead) grazed by dairy cows in 2008[4], with all values in tonnes of carbon ha^{-1} yr^{-1}. Internal cycling (pasture uptake, dung/urine and cow respiration) were estimated using published data[5]. Uncertainties are not shown to maintain clarity but estimated uncertainty for net carbon gain was 0.55 t carbon ha^{-1}. Uncertainties for other fluxes were estimated at 0.08 (imported feed), 0.1 (product), 0.05 (methane), and 0.2 (leaching).



Soil carbon differs between land uses

The amount of carbon held in soil depends on the balance of carbon inputs from photosynthesis and losses from respiration. But imports and exports of carbon from the ecosystem also need to be taken into account.

The amount of soil carbon differs between common New Zealand land uses (Table 1)[1].

Using pasture soils grazed by drystock (100 t c/ha) as a point of comparison Table 1 shows differences due to other land use. For example, if pasture was converted to exotic forest, on average the soil would contain about 16 t carbon ha^{-1} less.

Table 1. Land use effects on the stock of carbon in the top 30 cm of soil comparing pasture to listed land use[1] .

New land use	Difference in soil carbon stock compared to pasture (t carbon per hectare)
Exotic forest	-16 (7)
Natural shrub	-12 (5)
Natural forest	-1 (5)
Cropland	-11 (8)
Horticulture	-9 (7)

Recent changes in soil carbon in pastures?

While conversion from one land use to another can result in large changes in soil carbon stocks[1], less is known about the influence of different pasture management practices, such as different grazing intensities.

Soil profiles were sampled from pastures around New Zealand, and compared to previous samplings[6]. This study found that the amount of carbon in dairy pastures had declined by about 0.73 t ha^{-1} y^{-1} in the previous 27 years, while there was no change in the carbon content of drystock grazing flat land.

The carbon content of hill country grazed by drystock had increased by about 0.52 t ha^{-1} y^{-1}. Lastly, the carbon content of tussock grasslands had not changed. It is not known whether these changes are ongoing or these soils have now reached a new steady state.

The reasons for losses under dairying are not entirely understood and are being investigated by a number of research groups. One thought is that dairy cow urine patches can extract organic matter from soil, making it more vulnerable to decomposition by microorganisms[7] or that there are lower inputs of carbon into soil under dairying pastures.

The reasons for gains in hill country are also not entirely clear but may be due to the slow re-accumulation of carbon following sheet erosion that occurred when land was first cleared from forest to be converted to pasture (Parfitt et al., submitted). For example, New Zealand's rivers currently export about 14 t km^{-2} y^{-1} in dissolved and particulate carbon from erosion processes[8].

Efforts to increase soil carbon in New Zealand?

There is a maximum amount of carbon that a particular soil can protect, for a given level of plant inputs. For example, clay-rich soils can protect more carbon than sandy soils.

Because carbon in soils under dairy grazed pastures has declined, they are below their maximum storage capacity, so provide an opportunity to increase carbon again. There are many approaches for increasing carbon content in agricultural soils, including altering cropland management and restoring organic and degraded soils[9].

In New Zealand, studies are examining if increasing the mix of pasture species with deeper/more roots, e.g. chicory and plantain, can increase carbon content. An advantage of increasing the carbon content of soils through root inputs, is that the carbon is deposited next to clay particles, encouraging formation of aggregates which stabilise this new carbon.

Studies are also examining if earthworms can incorporate leaf litter from the surface into the soil and if the addition of biochar can be stabilised in soil. This is not a simple challenge because, in general, soils lose carbon fast and recover it only slowly.

Conclusion

There is no doubt that soils are a vast store of carbon and partially control the carbon dioxide content of the atmosphere. Maintaining soil organic matter is also crucial for production and environmental protection.

Land-use change and management practices are central to maintaining soil carbon, because these can both increase and decrease soil carbon. Pasture systems can store large amounts of soil carbon and there may be an opportunity to store more in New Zealand dairy systems with multiple benefits.

Active research is investigating approaches to achieve this goal through the New Zealand Agricultural Greenhouse Gas Research Centre.

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Forage Value Index – the science

Jeremy Bryant, David Chapman, Bruce Thorrold, DairyNZ; Graham Kerr, New Zealand Agriseeds; Glenn Judson, Agricom Ltd; Tim Cookson, Cropmark Ltd; Grant Edwards, Lincoln University; William McMillan, W McMillan Consultancy Ltd.

Summary

- The Forage Value Index (FVI), currently based on seasonal dry matter (DM) yields, provides a comparative estimate of profit ($/ha) for perennial ryegrass cultivars and endophyte combinations
- FVI is calculated by multiplying seasonal DM yield performance with economic values for these traits
- Performance values (PV), or the expected increase in DM yield during a period (e.g. winter) compared to a genetic base, are currently estimated from individual, small plot trials run under the auspices of the New Zealand Plant Breeding & Research Association (NZPBRA)
- The FVI is similar to the production worth of dairy cows
- FVI is calculated for four regional zones (Upper North Island, Lower North Island, Upper South Island and Lower South Island)
- Currently, FVI ratings are only available for a limited combination of cultivars and endophytes, availability will increase in late 2012
- Information on nutritive value and persistence will be added to the FVI when this information becomes available, significantly strengthening the applicability of the FVI.

DairyNZ, in collaboration with NZPBRA (the organisation representing the majority of commercial plant breeding companies), has developed an economic Forage Value Index (FVI; $/ha).

This allows farmers and advisors to compare perennial ryegrass cultivars in overall economic terms for seasonal dry matter (DM) production.

FVI ratings are presently only available for a limited combination of cultivars and endophytes, but this will increase later in 2012 as another dataset becomes available. The FVI is currently a combination of seasonal DM production traits and regionalised economic values.

Over time, information on nutritive value (within two years) and persistence (within three to five years), which is currently being collected, will be available and combined into the FVI. It is worth noting that, first and foremost, farmers should choose cultivars that have the characteristics (e.g. particular endophytes, diploid or tetraploids) that suit their system and environment. This is especially so in the Upper North Island (north of Taupo) where AR37, NEA2 and Endo5 endophytes are recommended. Help with these decisions is provided at **dairynzfvi.co.nz.**

The FVI calculation

The FVI is most similar to the production worth (PW) of dairy cows[1]. Both FVI and PW give an estimate of profit; $/ha for a perennial ryegrass cultivar and endophyte combination for FVI and $/4.5 t DM eaten for a dairy cow for PW.

The current FVI is made up of seasonal DM production traits corresponding to winter, early spring, late spring, summer and autumn. These combine with economic values (EV) (see pg 13) to make the overall FVI.

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Performance values

In the FVI system, each trait is expressed as a performance value (PV), relative to the average performance of a genetic base. The genetic base is "all perennial ryegrass cultivars first tested in National Forage Variety Trials (NFVT)[2] administered by NZPBRA before 1996".

The genetic base includes cultivars with familiar names such as Nui, Yatsyn and Bronsyn. PVs for the five seasonal dry periods have been estimated. These are expressed as the expected total change in DM production over that period (e.g. +300 kg DM/ha over the months of June and July for a winter DM PV) relative to the genetic base.

In some instances, cultivar performance for DM yield re-ranks when comparing performance in sites north of Taupo (Upper North Island) as opposed to sites south of Taupo. This is commonly referred to as a genotype by environment interaction, where genotype refers to a particular cultivar/endophyte combination.

The term environment relates to the set of climatic, soil, pest, disease and management conditions for a particular region[3]. This means the best cultivar and endophyte combination for Southland is not necessarily the best for Northland.

Consequently, a separate FVI exists for the four regions: Upper North Island, Lower North Island, Upper South Island and Lower South Island that use different EV and, in some cases, different PV. For instance, Upper North Island uses EV and PV specific to that region, whereas regions further south use an EV estimated specifically for the region, multiplied by PV for Lower North Island, Upper South Island and Lower South Island combined.

Only a limited number of trial results exist for the Upper North Island, but the cultivar x endophyte results from the Upper North Island and the rest of New Zealand are not totally unrelated. This allows "out of region" information to be used when estimating PV. For instance, there is a strong relationship between summer DM production in the Upper North Island and the rest of New Zealand, whereas for early spring it is weak. These seasonal relationships were used to merge "out of region" data back into a PV.

This ensures valuable data is not lost and provides a more robust estimate for the Upper North Island, that otherwise may have been based on single trial results. It does, however, mean that FVI and PV in the Upper North Island are more subject to change than for other regions.

National Forage Variety Trials (NFVT)

PVs are derived from NFVT[2] data. The NFVT system was set up in 1991 by NZPBRA, encompassing the plant breeding companies Agricom, Agriseeds, Cropmark Seed Ltd, DLF Seeds Ltd, Grasslanz, PGG Wrightson Seeds and Seed Force Ltd. It is a means of independently testing new cultivars of ryegrass.

More than 110 individual, replicated, small plot yield trials have been completed under the NFVT system, including 44 perennial ryegrass trials that provided data on the potential DM yield and seasonal growth pattern for a range of cultivars.

NFVT trialling of a new cultivar is one of the final steps in a breeding programme before release for commercial use. This process also involves crossing and individual plant selection (from hundreds or thousands of breeding lines) and plot

Table 1. Economic values ($/kg additional dry matter, DM) for seasonal DM yields in dairy systems in four regions of New Zealand

	Upper Nth. Island	Lower Nth. Island	Upper Sth. Island	Lower Sth. Island
Winter DM*	0.30	0.37	0.45	0.40
Early spring DM	0.48	0.47	0.42	0.46
Late spring DM	0.21	0.17	0.29	0.23
Summer DM	0.40	0.33	0.17	0.12
Autumn DM	0.41	0.32	0.29	0.27

*Winter = May and June (North Island) and June and July (South Island).
Early Spring = July and August (North Island) and August and September (South Island)
Late Spring = September and October (North Island) and October and November (South Island)
Summer = November to January (North Island) and December to January (South Island)
Autumn = February to April (North Island) and March to May (South Island).

screening trials using phenotypic or genotypic recurrent selection approaches. From the initial plant crosses to cultivar release, it may take 14 years. Crosses and individual plants may be rejected because they have poor disease or drought tolerance, are susceptible to pest attack, or show average or poor yields. Only the very best cultivars reach NFVT, and thereafter may still be rejected for commercial use.

In 2011, the NFVT system was reviewed to see how it could provide better information to support the calculation of FVI, namely providing information on persistence and nutritive value (e.g. metabolisable energy concentration).

New initiatives in 2012 include the sowing of specific perennial ryegrass persistence NFVT on commercial dairy farms under 'normal' grazing management, to provide more realistic rankings of cultivar persistence. Secondly, specific trials will be set up to collect information on the nutritive value of perennial ryegrass cultivars. Information from these persistence and nutritive value initiatives will be built into the FVI over time.

Economic values

PV derived from NFVT are then combined with EV to give an FVI. An EV is the expected change in profit per unit change in a trait value[4].

For FVI, EV have been estimated by simulation modelling using Farmax Dairy Pro[5] for traits such as winter DM production e.g. the expected increase in profit from each additional kg DM/ha increase in pasture production over this period. These EV are updated annually and use current and historical market values for specific farm expenses, milk price and supplement costs.

EVs differ by region (Table 1). The EVs essentially mirror the seasonal balance of feed supply and demand on farms in the different regions. The value of additional feed in a particular season, in a specific area, reflects how well the extra feed can be used, for example, to substitute for purchased feed (save costs) or to extend lactation (increase milk income).

In summer in the Upper North Island, additional pasture can replace expensive supplements, allow for higher intakes and/or extend the dry off date. Whereas in summer in the Lower South Island, additional pasture may create a larger pasture surplus that has to be conserved.

Inclusion in the FVI

To be included in the FVI, new cultivar and endophyte combinations must have progressed through individual company forage breeding processes and demonstrated high DM yield performance over three years. They must also have participated in at least three separate NFVT (one must be north of Taupo) and no more than 50% of a NFVT, related to a specific cultivar, can be managed by a particular company.

These tests are carried out using comprehensive and scientifically based protocols. All results are subjected to a rigorous peer review before publication is considered.

(cont'd p14)

Practical example

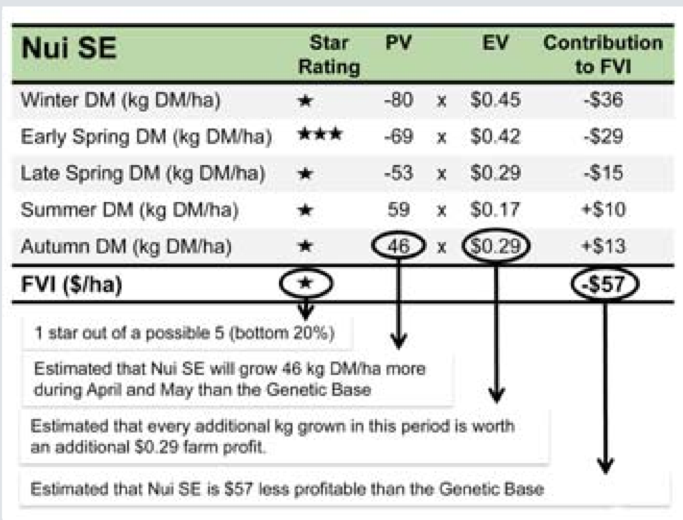
Nui with Standard Endophyte (Nui SE) in the Upper South Island region is used to illustrate how a FVI is calculated (Figure 1).

First, it is given a star rating for its individual PVs. If in the top 20% it is given five stars and one star if in the bottom 20% of FVI eligible cultivar x endophyte combinations.

Nui SE receives one star for all traits, with the exception of Early Spring DM production where it receives three stars. PV is then multiplied by EV and summed to calculate the FVI. Note: the FVI of Nui SE is penalised as it performs poorer than the genetic base from winter to late spring.

Over time, as persistence and nutritive value information is added to the FVI, its FVI could increase or decrease, but this information is not yet available. Presently, its estimated FVI means it has a one star FVI.

Figure 1. Illustration of how the FVI is calculated and what it means in practical terms for the Upper South Island



Nui SE	Star Rating	PV		EV	Contribution to FVI
Winter DM (kg DM/ha)	★	-80	x	$0.45	-$36
Early Spring DM (kg DM/ha)	★★★	-69	x	$0.42	-$29
Late Spring DM (kg DM/ha)	★	-53	x	$0.29	-$15
Summer DM (kg DM/ha)	★	59	x	$0.17	+$10
Autumn DM (kg DM/ha)	★	46	x	$0.29	+$13
FVI ($/ha)	★				-$57

1 star out of a possible 5 (bottom 20%)

Estimated that Nui SE will grow 46 kg DM/ha more during April and May than the Genetic Base

Estimated that every additional kg grown in this period is worth an additional $0.29 farm profit.

Estimated that Nui SE is $57 less profitable than the Genetic Base

(cont'd from p13)

DairyNZ research initiatives

Careful consideration should be given to the expression of the trait under real-world sward conditions in the target sowing region[6]. To understand this better, new pastures have been sown at four sites (Newstead, Waikato; Massey University, Manawatu; Lincoln University, Canterbury; Woodlands, Southland). There, eight cultivars of perennial ryegrass are being grown with or without white clover, and at two levels of N fertiliser input to investigate:

a. If the rankings seen in NFVT trials (where only the ryegrass component is measured) are the same as the rankings calculated when grass and clover are grown as a mixture (where total pasture yield is measured)

b. If the rankings differ, what are the factors responsible for re-ranking?

c. How to adjust NFVT data to produce a robust estimate of relative rankings for total pasture yield including clover.

Alongside each experiment, the same eight ryegrass cultivars are compared using the standard NFVT management protocols, enabling direct comparisons of rankings from NFVT versus the four treatment environments (clover or no clover, moderate or high nitrogen).

The experiment will continue for five years, and provide comprehensive information on DM yields (total annual and seasonal), clover and grass content, and nutritive value. In addition, a pilot cultivar proving scheme has been started where three to five perennial ryegrass cultivars are sown in a mixture with two standard white clovers, in strips lengthwise, in paddocks on six commercial dairy farms.

Paddocks are subject to normal farm management, with the farmer carrying out regular farm walks to determine growth of individual cultivar strips. At regular intervals, nutritive value is assessed by sending pluck samples away for analysis or taking visual scores of persistence.

Information from these farm trials will be used to test that cultivar rankings in a commercial farm environment match those derived from small plot trials. Over time, information from commercial farms may be used to estimate trait values (seasonal dry matter production, metabolisable energy and persistence) and FVI.

Within the next 12-24 months, further research will start to: estimate the rate of genetic gain currently being achieved in whole pasture performance from perennial ryegrass breeding, that will allow identification of future genetic gain targets. It will also compare the efficiency with which dry matter produced by different cultivars can be utilised by dairy cows and converted to milk.

Further out still, a full-scale grazing trial is being planned using cultivars with highly contrasting FVI and PV to confirm that differences in profit predicted by FVI are achieved on farm.

This will be akin to the animal strain trials carried out in the 1980s and 1990s. It will be a major milestone in the life of the FVI, and could well have a significant influence on the future direction of plant breeding for New Zealand dairy pastures.

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Keeping your cows cool

Anthony Clark, Chris Burke, Jeremy Bryant, Nita Harding, DairyNZ

Summary

- New Zealand dairy cows, on average become heat stressed when temperatures exceed 24°C, with moderate humidity (relative humidity: 75%)
- Signs of heat stress include a reduction in milk production, increased breathing rates, seeking shade and crowding around the water trough
- Friesian dairy cows are more susceptible to heat stress than Jersey dairy cows
- Cooler night time temperatures allow cows to dissipate heat accumulated during the day and this lowers the risk of heat stress
- Cows in the Waikato, Bay of Plenty and Northland are most at risk of heat stress
- To limit heat stress on hot days, graze paddocks without shade and further from the shed after the evening milking, use water sprinklers in the shed and supplement with fans if humidity is high
- Provide cows with access to shade and plenty of drinking water (at least 120 l/cow/day during hot conditions).

New Zealand's temperate climate means that environmental temperatures rarely approach body temperature, so severe heat stress is uncommon. Nevertheless, summer heat does affect cows throughout New Zealand. By ensuring farm infrastructure and stock management practices assist cows to reduce heat load, appetites can be sustained and summer milk production increased.

What are the signs of heat stress in cows?

The first observable change as heat stress develops is reduced milk production. Examination of herd testing records in New Zealand showed that hot conditions were associated with reduced milk and milksolid yields[1].

Production fell by 10g MS/d for each unit increase in the temperature-humidity index (THI). This index combines air temperature and relative humidity (RH) in an approximately linear relationship, although air temperature makes the larger contribution.

The production by Friesian cows was reduced when THI increased above 68 (approximately equivalent to 21°C at 75% humidity)[1]. This is a lower threshold than is reported for cows in overseas dairying systems, and it has been speculated that greater exposure to solar radiation and longer walking distances in pasture systems influence the appearance of signs of heat stress[1].

Scientists postulate that the decline in milk production is most strongly associated with loss of appetite, but heat-stressed cows also divert blood circulation to the skin to aid cooling, rather than to the mammary gland[2].

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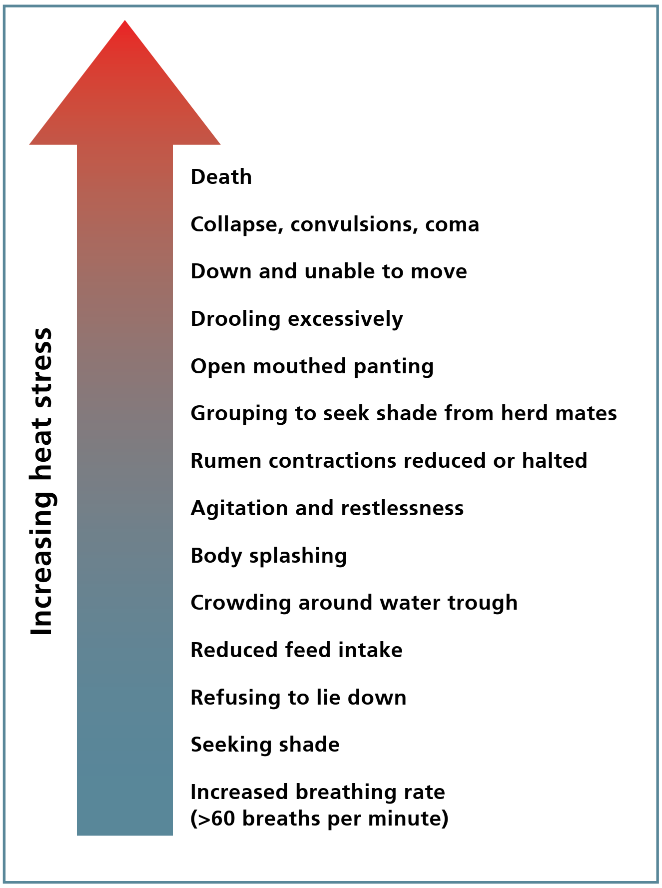
Figure 1 outlines the common signs of heat stress which become increasingly severe as heat load increases[3]. Behaviour changes at herd level, such as shade seeking, restlessness, not lying down, crowding around water troughs and crowding together for shade, are signs that heat load is causing stress and discomfort.

Abnormal herd behaviours observed in summer are often attributed to flies rather than heat stress. Nuisance flies contribute to cow discomfort and cows' response to fly attacks (restlessness and crowding together) adds to heat load.

It is important to differentiate between these two causes of abnormal grouping behaviour by checking cows closely. High respiration rates mean heat stress is more likely to be the cause, and this requires management in addition to fly control.

Figure 1. Observable signs of excessive heat load *(Image from Dairy Australia's Cool Cows website, courtesy of Dairy Australia)*[3]



Prolonged periods of increased breathing rate alter the acid-base balance of the blood. More carbon dioxide is cleared through the lungs, reducing bicarbonate levels in the blood.

This puts the cow into a state of alkalosis and bicarbonate secretion in saliva is reduced, lowering her capacity to buffer changes in rumen pH.

This is important where grain is fed to maintain summer production as it may precipitate bouts of rumen acidosis[2,3]. During prolonged hot conditions, feeding of buffering agents such as bicarbonate may be beneficial to maintain rumen health where grain is fed. Prolonged sweating also contributes to metabolic imbalance with a net loss of potassium in sweat. Supplementing potassium and sodium may improve cows' ability to cope with heat stress[4].

The individual cow's ability to tolerate heat load is influenced by:

Breed
Jerseys and Brown Swiss are less vulnerable to heat stress than Ayrshires, and Holstein-Friesians (HF) are most vulnerable. This was confirmed in a New Zealand study[1] where a drop in milk production was observed in HF cows at THI 68, but not in Jersey cattle until THI was 75.

Age
Young cows are more tolerant because their surface area to liveweight ratio is greater, so they can lose more heat through the skin[2, 3]. Older cows, especially with heart or lung disease, are more easily stressed than healthy cows.

Production level
High-producing cows show signs of heat stress at a lower threshold than low-producing cows, due to greater metabolic heat production arising from higher intakes and higher milk production. No consistent effect of genetic merit on production during hot weather occurs across breeds, but within the HF and HF x Jersey breeds, the decline in milk yield during hot conditions tends to be greater in animals of higher genetic merit[1].

Coat colour
Dark hair increases the inward flow of heat. Black steers transfer 58% more heat through the skin than white steers, and had a higher mean body temperature[5]. Coat colour has a greater impact where cows are exposed to solar radiation. New Zealand dairy cows with predominantly black coats tend to have higher respiration rates than cows with black and white coats[6].

Assessing the risk of heat stress for an individual farm

The risk of heat stress occurring on an individual farm depends on prevailing climate, herd composition and farm-specific infrastructure and management practices.

Climate risk
Estimates of environmental heat load traditionally use THI as the environmental indicator. Heat-stress warning systems for cattle generally suggest that a THI >72 is the threshold for signs of heat stress in lactating dairy cows[2, 7,] but there is some evidence of a lower threshold being more appropriate for grazing cattle under New Zealand conditions[6].

Climate risk for pasture-based dairy cows is not fully described by THI[1], and a New Zealand-specific Heat Load Index (HLI_{NZ}) has been developed recently[8]. This incorporates a wider range of factors and the thresholds for heat stress were determined by direct measurements of cows' physiological and behavioural responses to heat load[8].

Combining historical weather data with the HLI_{NZ} model has allowed regional mapping of the seasonal risk of heat stress (Figure 2). This is a general guide to climate only, and many local, cow and management factors will govern the stress felt by your herd. It's important to not only rely on heat stress predictions, but recognise the physiological signs in cows early (Figure 1) and be prepared to undertake the mitigation options outlined here.

Herd susceptibility

Differences in individual susceptibility to heat stress translate to herd level differences. A herd of Jerseys producing less than 400 kg MS/cow/year is much less susceptible than a HF herd producing 600 kg MS/cow/year[3].

Farm level factors

Both farm infrastructure and management practices affect the risk of heat stress; fortunately they also offer opportunities to manage higher risk situations. Components of farm infrastructure that influence risk include distances from the dairy to pasture, whether shade is available in pastures or at the dairy, use of sprinklers and fans at the dairy and the adequacy of the water supply.

Heat risk scores for paddocks

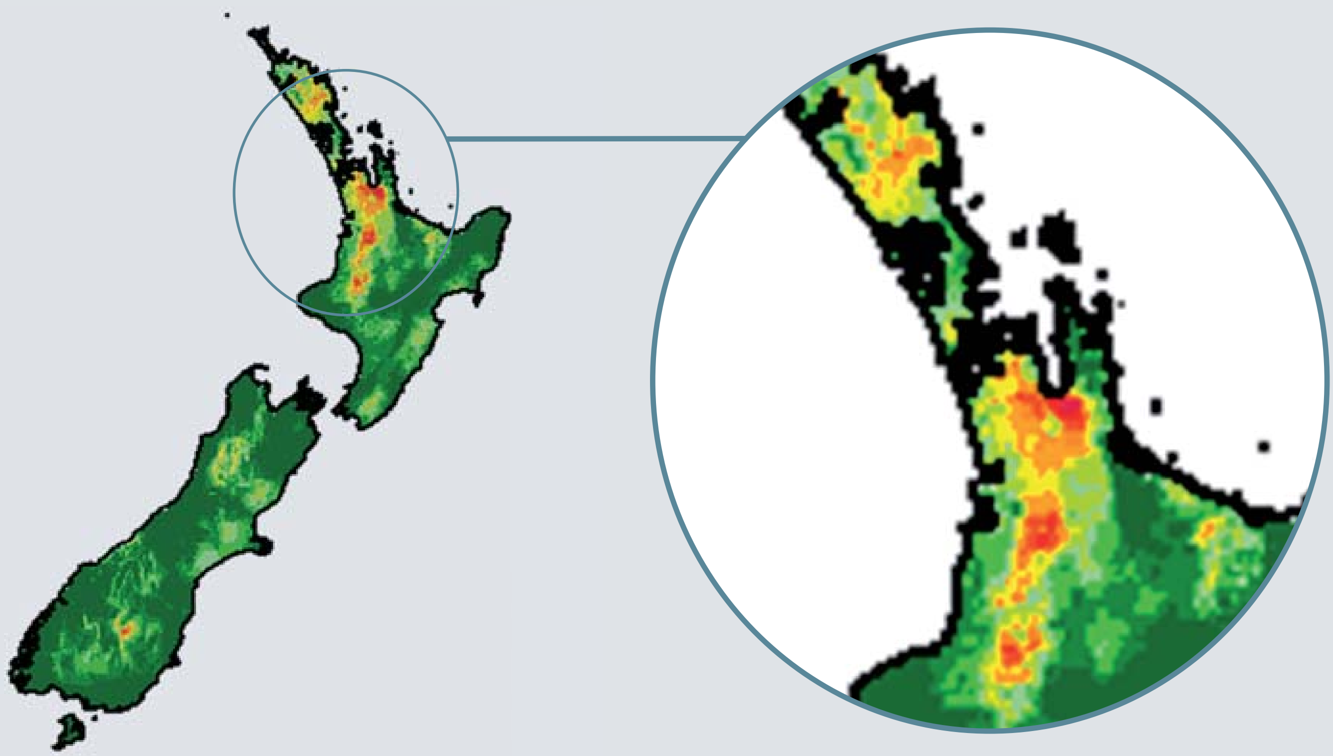
Individual paddocks can be scored for their contribution to heat load. The system described on the Australian Cool Cows website[3] can be used to estimate this risk:

1. Give each paddock a score from 1 to 10 based on the amount of shade provided in the middle of the day (1= no shade; 10 = each cow has 4 m^2 shade available)
2. Give each paddock a score from 1 to 5 based on distance from the dairy (1= more than 2 km; 3= 1-2 km; 5= less than 1km)
3. Combine the scores for each paddock and rank paddocks according to their risk. Paddocks with the highest scores are the "coolest paddocks".

Use this information when planning summer grazing rotations e.g. reserve paddocks with high scores for hotter days or day-time grazing, and use paddocks with low scores for the "once-a-day herd" or night grazing.

(cont'd p18)

Figure 2. General regional guide to summer heat stress occurrence across New Zealand. Estimates for a 450 kg Friesian dairy cow based on New Zealand Heat Load Index (HLI_{NZ}) model outputs. Farm estimates will vary depending upon cow, management and local factors.



Crimson	threshold exceeded for 18-19 days
Orange	threshold exceeded for 12-13 days
Green-yellow	threshold exceeded for 8-9 days
Dark green	threshold exceeded for <2 days

- *On days above the HLI_{NZ} threshold, the minimum production loss is less than 0.05 kg MS/cow/day*
- *The HLI_{NZ} threshold of your herd can be changed using the mitigation options described in this article*
- *DairyNZ is building a thermal stress early warning system where you can get detailed estimates for your farm. Available for the 2013 summer.*

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Fungal endophyte in pasture can contribute to heat load and could be included when assessing individual paddock risk. While endophyte produces chemicals that protect plants from insect damage, many are tremogens that cause nervous signs and ryegrass staggers. Pastures containing novel endophyte (e.g., AR1 and AR37) are less likely to contribute to heat load[9, 10].

Drinking water

The availability of drinking water (free water intake) should be assessed, both in terms of access to troughs and if the reticulation system can provide sufficient water during peak demand periods.

The volume of a cow's free water intake is primarily determined by feed intake, milk yield and the dry matter content of feed, but ambient temperature also contributes[11]. Water intake increases by around 1.2 l for every 1°C increase in ambient temperature[2].

Free water intake more than doubled between November and January for lactating Friesian cows grazing ryegrass pasture in the Waikato (18 vs. 51 l/cow/d, respectively) and the respiration rate was 27% higher in January[12]. Cows in late lactation fed pasture drank less than similar cows fed a total mixed ration (54 vs. 73 l/cow/day)[13].

Water consumption is synchronised to feeding and milking events, especially during dry weather. Cows generally have two or three drinks each day, and drinking activity peaks after milking, especially in the afternoon[13]. It is important to provide a source of good drinking water as cows leave the dairy, particularly on hot days.

Allowance should be made for water demand to double during heat stress conditions[2] and at least 120 l drinking water/cow/day should be available. Water reticulation systems need to be capable of delivering sufficient water during the peak demand period, i.e. at least 20 l/cow in the two hours immediately following afternoon milking.

The space available at drinking troughs (dependent on the number and size of troughs) during peak demand periods is also important. More submissive animals, such as younger cows, may not push in to drink when cows gather around the trough.

Cooler drinking water will assist cows coping with heat load, since some heat energy is absorbed as the water is raised to body temperature[14]. While there is some evidence that providing cooled drinking water may improve milk production[14], having very cold water may be counterproductive, since cows may drink less[3].

Having adequate water available is more important than the water's temperature, but water should be kept as cool as possible by burying reticulation pipes (water temperature readily rises to 50°C inside black polythene pipes in direct sunshine) and by using large volume concrete troughs (e.g. >1000 l)[3].

Cows have a well-developed sense of taste, so water palatability is also important to ensure they drink sufficiently for their needs. Water containing iron compounds and dissolved CO_2 is acidic and may be unpalatable to cows. Reduced water palatability is further aggravated in summer, when zinc sulphate is added to water for facial eczema management.

Flavour enhancers increased water consumption and feed intake of calves, but adult cattle did not show the same response[15]. Where water consumption is limited by poor palatability, the better strategy may be to install a filter system that removes the contaminants.

Feeding during hot weather

Cows alter daily grazing activity during hot conditions, e.g. cows with access to shade grazed more during the night[16]. They may also eat faster to maximise their opportunity during the cooler hours[2].

Cows can be offered the main part of their daily ration during cooler times of the day. This also allows them to maximise time in available shade during peak temperatures[15].

Other options for heat mitigation

If the risk of summer heat stress is high on your farm, then additional management options to enhance shade and evaporative cooling should be considered.

A recent New Zealand study suggests that cows prefer shade to sprinklers. Cows were offered a choice between ambient conditions, shade or sprinklers after walking either 0.3 or 2 km before afternoon milking in summer[17].

Two thirds of the cows chose shade over either sprinklers or ambient conditions, and this choice was expressed more on hotter days, even though sprinklers were more effective at reducing respiration rate and core body temperature as well as reducing fly avoidance behaviours.

While planting trees to provide shade is a good approach, it takes some years before they provide effective shade, and trees may not be the answer for all situations. Where natural shade is insufficient, temporary shade structures may be considered, e.g. a portable shelter can provide shade for growing calves, but these have limitations in terms of flexibility and ease of management.

It may be more beneficial to assess if permanent facilities such as the feed pad, dairy yard or wintering pad could be covered with shade cloth. Artificial shade and permanent roof structures can lead to increased relative humidity and should be designed so that adequate ventilation is maintained. This is particularly important if cows are also sprinkled with water. Fans can be used to increase air movement and reduce relative humidity.

Sprinkling is the most common way to apply water for evaporative cooling. It is very effective and will quickly reduce body temperature, provided the hair is wet down to skin level[6]. Droplet size should be medium-to-large and cows must have space for air to circulate between them.

If water availability is restricted, installing a 15 minute adjustable timer and running sprinklers on an on/off cycle will enable sufficient water to be applied to cows to wet them effectively, while minimising wastage[3].

Fog and misting systems are available and are often used in more extreme conditions found overseas, or within cow barns[18]. These use a smaller droplet size and rely on cooling the environment, rather than the cow.

Allowing stock to stand in natural waterways to cool themselves is not an environmentally acceptable option for New Zealand. In most New Zealand contexts, sprinkling is the most feasible, effective and cheapest way to enhance cows' evaporative cooling mechanisms.

Conclusion

New Zealand's temperate climate protects cows from heat stress for much of the year, nevertheless summer heat has a detrimental effect on milk production in many parts of the country.

The risk of heat stress occurring on an individual farm can be assessed based on historical weather information, herd characteristics and farm infrastructure.

This information can be used to design both long and short-term management strategies to protect cows and maintain milk production as heat loads increase from summer weather.

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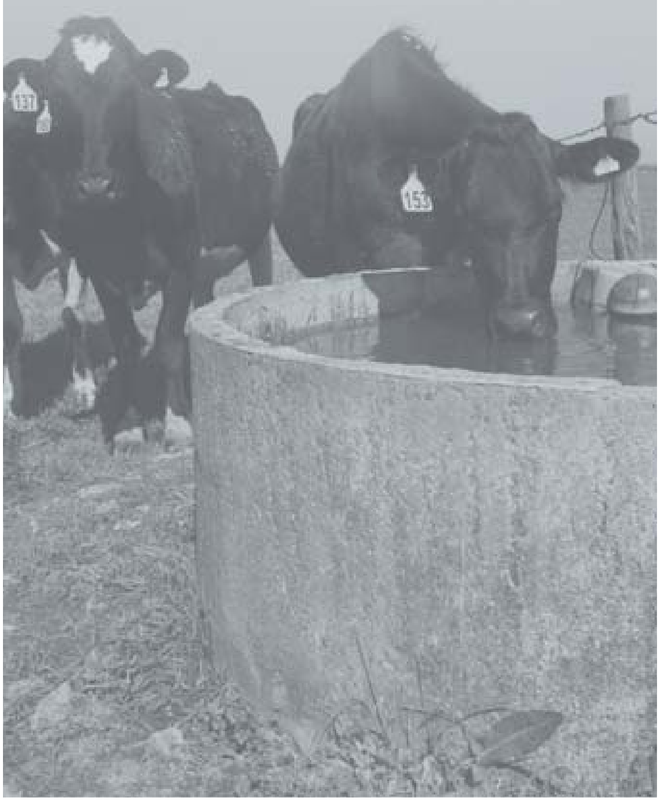

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Focus on international research

The following is a brief summary of some key science papers recently published.

Huzzey, J. and others (2012). The effects of overstocking Holstein dairy cattle during the dry period on cortisol secretion and energy metabolism.

Journal of Dairy Science 95: 4421-4433.

In this US study, researchers used over-crowding of a housing barn during the dry period as a stress model to determine the impact of stress on cow physiology. Although stressed cows ate more and had greater amounts of glucose in blood, the fat content of blood was also higher, indicating greater body condition score loss in the stressed cows. In addition, stressed cows produced less insulin in response to a glucose challenge; this indicates that a stress, such as over-crowding, is enough to alter cow physiology sufficiently to cause increased body condition loss during the dry period.

DairyNZ comment: The results indicate a relatively large effect of stress on cow physiology. The impact of common stressors on New Zealand farms (e.g. nutrition, weather) needs to be evaluated, as does the effect of likely management strategies that might lessen the effect. How the concept applies to wintering barns and stand-off/feed pads needs to be considered.

Whelan, S. and others (2012). Effect of supplementary concentrate type on nitrogen partitioning in early lactation dairy cows offered perennial ryegrass-based pasture.

Journal of Dairy Science 95: 4468-4477.

Cows grazing low crude protein (CP: 17% DM) pasture were supplemented with either a barley-based high CP (19% DM) concentrate containing soybean meal, a barley-based low CP (15 % DM) concentrate, a barley-based low CP concentrate containing protected methionine (an amino acid), or a maize-based low CP concentrate. Concentrate ration did not affect the yield of milk protein or fat, although the study design was not sufficiently powerful to detect realistic differences if they existed. Cows fed the high protein ration had lower nitrogen use efficiency than the low CP concentrate treatment groups, primarily because of lower urinary nitrogen output. However, the corn-based low CP group also captured a greater proportion of consumed nitrogen in milk.

DairyNZ comment: The data are consistent with New Zealand research results that indicate an improvement in nitrogen use efficiency per cow when low nitrogen concentrates are included in the daily diet. However, as with New Zealand experimental results, this effect is primarily because less protein is being consumed, with very little of the benefit being the greater capture of dietary nitrogen. Future research must find ways to capture more nitrogen in milk, so that less nitrogen is being excreted in urine.

Gao, F. and others (2012). Effect of prepartum maternal energy density on the growth performance, immunity, and antioxidation capability of neonatal calves.

Journal of Dairy Science 95: 4510-4518.

It has become increasingly evident that a slight feed restriction during the two weeks before calving can improve cow health and energy metabolism and reduce the risk of metabolic diseases in early lactation. However, little is known about the effect of maternal nutrition so late in pregnancy on the calf. In this Chinese study, cows were fed a low energy, medium energy or high energy-density ration pre-calving and its impact on the calf immune system assessed. A criticism of this study is that cow intake was not reported, making the degree of over-feeding and restriction impossible to determine. Differences in blood fat content in the low group, however, indicate that they were mobilising body condition. Calves from cows fed the low energy-density ration were smaller and lighter and there were indications that their immune system was not as well developed at birth.

DairyNZ comment: There is no information on the effect of transition cow management on the health of the calf in pasture-based systems and almost no information globally. With the increased interest in transition cow nutrition and how it affects cow health and productivity post-calving, more measurements must be undertaken on the calf to determine the impact of transition cow management on immune function and subsequent productivity.