30 YEARS OF RUAKURA – WHAT DOES IT MEAN TO SOUTHLAND?

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Summary

- Applied research is a partnership between farmers and scientists. This has been the key to New Zealand's dairying success over the last 50 years.
- Both groups share experiences, with scientists quantifying the effects of changes within the farm system, and farmers modifying recommendations to make them fit within the farm system.
- Short- and long-term experiments defined:
  - The effect of stocking rate on farm profitability
  - Grazing management techniques
  - Responses to nitrogen
  - Responses to supplements
  - The effect of cow body condition on reproduction and production
  - And many more
- The results of all of these experiments have been trialled on demonstration farms and commercial farms throughout the country, with biological principles verified, irrespective of region.

Introduction

New Zealand has a proud history of agricultural science, stretching back over 100 years. The names of McMeekan, Brumby, Hutton, Phillips, O'Connor, Edmeades, Bryant, Jury, Woolford, Macmillan, Clark, Penno, Kolver, and many more are synonymous nationally and internationally with high quality research. However, a criticism sometimes levelled is that the research has been too "Waikato-centric", having primarily been undertaken on the outskirts of Hamilton. Although most of the research has been undertaken at the Ruakura research station and its satellite farms, many of the principles have subsequently been proven on regional demonstration farms and commercial dairy farms. Non-Waikato farmers interviewed about the relevance of the research findings stated that the research principles were applicable to their operations, although, at times, response rates needed to be modified for the different regions.

It would be impossible to list all of the research projects that have been undertaken during the last 30 years in this paper, and certainly not do justice to all of them; therefore the paper focuses on the better known research projects, reporting the main results from these studies.

"***Equipped with his five senses, man explores the universe around him and calls the adventure Science***".

-Edwin Powell Hubble (1889-1953)

Research – the voyage of discovery

Research is generally recognised as a means of discovery. However, it is often assumed that these discoveries are spontaneous - "silver bullets". For example, people recognise Einstein's brilliance in discovering the relationship between energy and mass ($e=mc^2$) in 1905, but rarely understand that Einstein's discovery followed the significant effort of dozens of scientists over nearly 300 years. Lavoisier and Faraday outlined the constancy of matter and energy over the previous two centuries, while it was Galileo in the early 17th century that postulated that light had a finite speed. Similarly, Watson and Crick are rightly recognised for unlocking the "secret of life" in 1953, when they discovered the double helical structure of DNA. However, their "discovery" followed nearly 150 years of genetics research into understanding the inheritance of genetic traits; from Gregor Mendel in the early 19th century to Linus Pauling in the early 20th century, many people laid the groundwork for their discovery.

This should not detract from the brilliance of these scientists; they were the ones that pieced their respective jigsaws together. However, it should serve to highlight that ***science is an evolution, not a revolution***. All great discoveries come on the coat tails of smaller, seemingly less significant findings. As Isaac Newton said in his letter to Robert Hooke, "*if I have seen further than others, it is because I have stood on the shoulders of giants*".

Applied research

Applied agricultural research is no different; where successful, it has always been a partnership between farmers and scientists, building on the knowledge and discovery of previous farmers and scientists. There are continual discoveries on farm and in research centres; these are shared between the two groups, problems are solved, and opportunities are identified; most importantly though, they are discussed between scientists and farmers – both groups learn from one another.

What makes New Zealand so unique is the strength of this partnership; this has allowed the industry to achieve successes that make it the envy of every dairying nation on earth. We could argue that we live in an idyllic climate, nestled within the right latitudes, the perfect distance from our gigantic neighbour, and we could even argue our volcanic history provides soils that have given us an advantage. Although we have natural advantages, and we have used these natural advantages to our benefit, these advantages are not unique to New Zealand, and yet the industry is the greatest in the world. As the Wall Street Journal recently reported, New Zealand is the "Saudi Arabia of milk"! Not bad for a small pair of islands on the southern edge of the map of the world.

The reason for this "greatness" is the continued growth in productivity the industry has enjoyed through adopting beneficial technologies, while competitor dairy industries stood still, often because of a lack of "industry good" funded research. As Publilius Syrus said in ancient Rome, "***Many receive advice. Only the wise profit from it***". Many of these technologies have come out of the partnership that exists between farmers and research. Optimal stocking rate, grazing management, nitrogen fertiliser, profitable use of supplements, strategic use of altered milking frequencies, mastitis prevention and cure, and many others have been developed in applied research. The last 30 years is a fitting timescale to summarise.

Stocking rate

Dairy farm profitability depends on the efficiency of conversion of pasture into milksolids. Accordingly, stocking rate was recognised as one of the most powerful forces governing farm profitability as early as the 1950s, with McMeekan claiming that grazing management per se did little to affect farm productivity, when stocking rate was increased to near maximise utilisation of pasture.

Stocking rates had been incorporated in a number of trials since the 1970s, and stocking rate was investigated indirectly in some of the grazing management research undertaken at No. 2 dairy during the mid to late 1970s. However, despite recognising the importance of stocking rate over half a century ago, no attempt was made to define the optimum stocking rate. Stocking rates varied by as much as 2.0 cows/ha across farms, and there was no information on how breed could be accounted for under different stocking rates.

A trial undertaken in the late 1990s helped to define optimum stocking rate. It was recognised that cows/ha was a meaningless measure, because cows differed in their ability to eat and produce milk, there were breed differences in feed requirements, hectares differed in their ability to produce grass, and farms differed in the amount of supplements they bought. This experiment, therefore, set out with the objective of defining an optimum stocking rate that accounted for cow type, the ability of the farm to produce pasture, and the amount of supplement purchased annually. The outcome was ***comparative stocking rate*** (CSR), a means by which stocking rate could be compared across farms, districts, and regions. As with other stocking rate experiments, milk yield/ha increased with increasing stocking rate and milk yield/cow declined. This was similar when the results were expressed as comparative stocking rate. The programme also identified a comparative stocking rate at which farm profitability was maximised (all other things being equal). That comparative stocking rate was approximately 80 to 90 kg Lwt/tonne DM available. This stocking rate facilitated high utilisation of pasture (~80%) and efficient production of milksolids (73 g MS/kg DM). This was the first stocking rate experiment undertaken anywhere in the world to define a stocking rate that optimised the efficiency of converting feed into milksolids (g MS/kg feed DM) and profitability. The results have allowed farmers to reassess their stocking rate and make the necessary improvements to maximise farm profitability.

Grazing management

McMeekan believed that stocking rate was most important and that grazing management was relatively unimportant. Although this may have been the case in the 1950s, as people moved from low to moderate, and onto high stocking rates, an ability to manage pastures became more important, as the margin for error between pasture grown and pasture required became less. An example of this is presented in Figure 1, where data from top dairy farmers (Dairy Excellence Awards finalists) were used to determine the association between pasture eaten and operating profit. Importantly, the curve is sloping upwards; this means that there is a significant advantage to focussing on the top 10% of pasture that can be captured/ha. In fact, 68% of the variation in operating profit was explained by the amount of pasture eaten in this dataset.

There has been a considerable amount of research undertaken on grazing management over the last 30 to 40 years. Brougham's work is famous around the world as being ground-breaking in helping us understand the effect of grazing on pasture production. In that era, longer rotations were shown to grow more grass ("*grass grows more* grass"), with this knowledge facilitating even greater increases in stocking rate by allowing farmers to grow more grass. These recommendations have since been refined to ryegrass, cocksfoot, fescue, and prairie grass, with the optimal grazing stage for each of these species now known, and the best possible value from these grasses obtained. Recent research has proven that a consistent grazing residual of 7 to 8 clicks on a plate meter throughout the year produces the greatest amount of pasture of the highest possible quality, and that cows that consistently graze to 7 to 8 clicks produce at least as much milk as cows that do not graze as tight; in fact there is evidence that they produce even more milk! Results from these decades of work are employed successfully at a farm scale on the Lincoln University dairy farm and on many other New Zealand farms, and are the basis for the spring rotation planner, arguably the most important tool ever developed for farmers to aid in feed management.

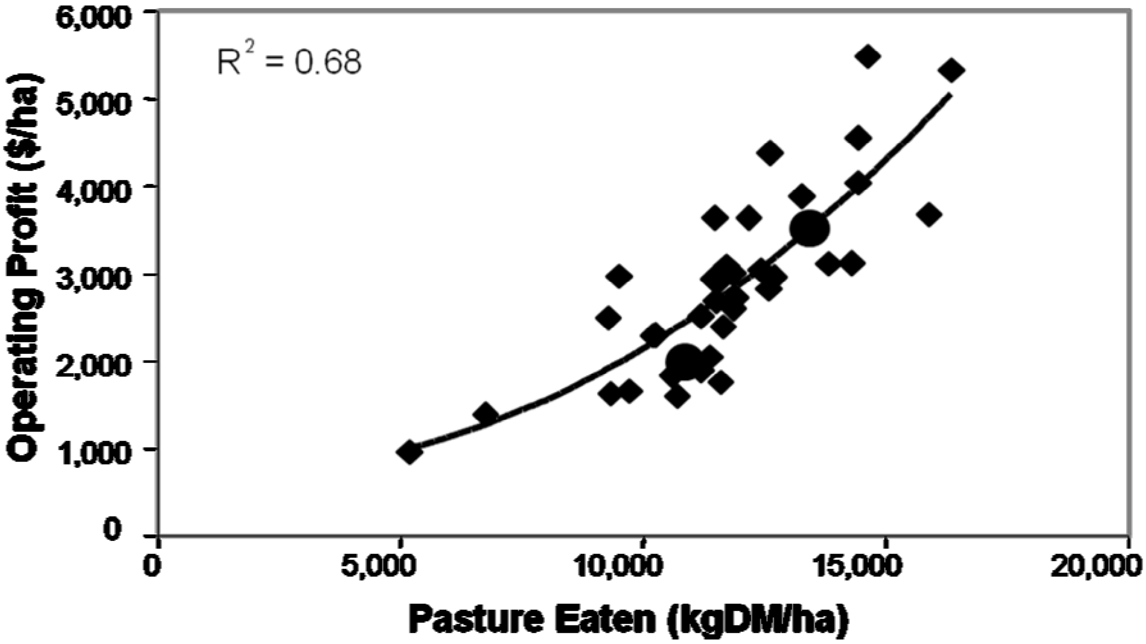

Figure 1. Relationship between pasture eaten/ha and operating profit/ha.

Nitrogen fertiliser

Nitrogen fertiliser was used for the first time in New Zealand during the 1970s. Professor Colin Holmes tested very high levels of N fertiliser (up to 435 kg N/ha/yr) in the early 1970s, finding a 34% increased in pasture growth, and responses of 12 kg of pasture DM/ kg N fertiliser applied; results were consistent with what had been observed in the UK. Milksolids responses, however, varied from year to year, depending on the need for the additional feed. Arnold Bryant and his team at Ruakura further refined the use of nitrogen fertiliser in the mid to late 1970s, testing 0 or 140 kg N/ha with low and high stocking rates and early and late calving. They found an increase in milksolids production when nitrogen was used to produce pasture for times of feed deficit, allowing earlier calving dates and facilitating further increases in stocking rate. However, at the time urea cost $470/tonne and the average milk price was $1.50/kg milksolids. The additional 0.2 kg MS/kg N fertiliser did not pay for the input. However, the fact that research had been undertaken meant that when the milk payout rose, responses to nitrogen fertiliser were known, and the technology could be introduced into the farm system where appropriate.

The use of nitrogen fertiliser was again evaluated in the 1.75 tonne milksolids trial at Ruakura in the mid-1990s. This trial reported a 12% increase in operating profit through strategic use of nitrogen at low stocking rates. These equated to 108 g MS/kg DM produced from additional nitrogen, compared with 78g MS/kg DM maize silage. Similarly, component research work at the same time indicated that tactical applications of N fertiliser in December/January would be beneficial to the growth of new perennial ryegrass tillers (after the older tillers have died in November), and increased pasture production by up to 15% during summer. Such timely applications result in profitable milk production responses, even when conditions are dry. As a result of these research studies, nitrogen fertiliser has become common place on the majority of New Zealand dairy farms.

Magnesium

In the 1970s grass staggers and milk fever were common problems on many farms. O'Connor and Young identified that supplementation with magnesium in the form of magnesium oxide was the easiest way to overcome the problem. Subsequently, other trials identified high pasture potash levels and high applications of lime in the autumn as triggers to Mg deficiency. The recommendations for magnesium supplementation have been further refined as a result of recent research, to better help prevent these metabolic conditions.

Supplementary feeding

There has been a considerable amount of research undertaken on the benefits of feeding cows different supplements, both in short term and in full farm systems experiments, where all inputs are accounted for. Research results are similar to those from all around the world; cows supplemented with an energy supplement, when they would otherwise be hungry, will produce approximately 8g MS/MJ ME eaten.

Research has also proven, on more than one occasion, that when sugars or starch replace pasture energy, there is no increase in milk production, there is a slight increase in milk protein, and a large decrease in milk fat. There is very little difference in the milk cheque.

These results provide the basis for advice on profitable use of supplements within a farm system. They also provide a note of caution, for anyone willing to listen, on the true profitability of incorporating supplements into farming systems, the need to source inexpensive energy supplements, and the need to feed them only when there is insufficient pasture (i.e., when pasture residuals are dropping below 7 to 8 clicks).

Fibre nutrition

The requirement of pasture-based dairy cows for supplementary fibre is arguably the most well researched nutritional topic in the last 20 years in New Zealand. A collaborative programme of work between research groups in New Zealand and Australia proved, beyond doubt, that there is no benefit to supplementing dairy cows grazing high quality pasture with fibre. This has since been confirmed on dairy farms in the South Island, through the research work of Dr. Jim Gibbs at Lincoln University.

Cows require fibre, protein, energy, minerals and vitamins. Grazing cows have a lower rumen pH than would be acceptable in other systems of farming; however, it does not adversely affect their health or production. Supplementing cows with fibre does nothing to rumen pH and reduces milk production. These results are directly applicable to the South Island, where many farmers have traditionally fed straw in the belief that cows need additional fibre in spring.

Transition cow nutrition

The transition period is often defined as the period beginning three weeks pre-calving and ending three weeks post-calving. It is the period during which a cow transitions from being dry and pregnant to lactating and losing weight. In overseas countries, it is also the time when the diet changes dramatically, from a largely fibre diet to one containing a large amount of concentrate feeds. Over the last 30 years there has been considerable research effort put into defining the needs of the transition cow under our pasture-based systems, and understanding the effects of nutrition and farm management on milk production and farm profitability.

Body condition at calving is still the most important factor during this period. Mature cows should calve at BCS 5, with 1st and 2nd calvers calving at BCS 5.5. This ensures maximum milk production and optimum fertility. Cows require 20% of their empty live weight (i.e. live weight without the calf) in metabolisable energy each day during the last month pre-calving. It doesn’t matter in what form this energy comes. The effect of pre-calving feeding on milk production is small under pasture-based systems.

Body condition score

Considerable research effort has gone into understanding the mechanisms behind condition score loss and gain, and the effect of farm management and nutrition on these processes. This research has allowed us to inform farmers on the importance of condition score from a milk production, fertility, and animal health perspective, and to provide firm guidelines on the effect their actions may have on condition score gain and loss.

Condition score loss in early lactation is a natural event over which a farmer has little control. This is defined in the cows’ genes, and is only partially controlled by nutrition. Feeding cows maize silage, concentrates, molasses, or bypass fat did not affect the rate of condition score loss in the first 5 to 6 weeks post-calving. Similarly, once-a-day milking did not affect condition score loss during this period either. After six weeks post-calving, nutrition and farm management has some control over when body condition score goes from a loss to a gain, but again the effect is small.

Reproduction

There have been some amazing advances in reproductive technologies over the last thirty years. Some of these discoveries have come directly out of applied research (e.g. CIDR, tail painting by Jock Macmillan), while more have been adapted for use in agriculture, although their origin was in human medicine (e.g. embryo transfer and sexed semen). Additional research has identified the link between calving and early lactation condition score and fertility, and has quantified the effect of condition score on reproduction.

Research results indicatie that feeding concentrates in early lactation reduces the length of the postpartum anoestrous interval. This may be important if CIDR use becomes restricted; however, this nutrition intervention does not appear to influence pregnancy. Similarly, a large experiment in Taranaki recently reported no effect of a short term negative energy balance (3 to 4 weeks) at the start of mating on conception rate to first service, providing farmers with relevant up to date information needed to plan their feed allocation in spring. Findings from these research programmes have been used to develop the ROMP and InCalf extension programmes to improve reproductive efficiency on New Zealand farms.

Genetics

Several research projects over the last 30 years have evaluated cows of different genetic merit in pasture-based systems. All projects, including those done in the 1970s, the 1990s, and in the early 2000s reported increased intake and milk production from high merit cows in pasture-based systems. On the advice of farmers that the increasing genetic merit for milk production appeared to be negatively affecting fertility, several research trials in the last 10 years examined the interaction between genetics and environment. A sister study between Ireland and New Zealand, arguably one of the largest of its kind ever undertaken across the world, showed that there were specific cows that suited specific systems, and that we need to include traits that are poorly heritable in our breeding index. This research programme is a perfect example of the success that can result from continued dialogue between farmers and scientists. Results from these studies have been used to refine the New Zealand Animal Evaluation Unit’s breeding index for profit.

Heifer rearing

One of the largest heifer rearing studies ever undertaken in the world took place in the early 1990s in New Zealand. Involving over 700 heifers, calves were reared at three different growth rates until puberty and two different growth rates until first calving. Body weight at calving and post-pubertal growth rate management are important in first lactation milk production, but did not affect milk production in subsequent lactations. Results defined the effect of heifer rearing on subsequent milk production, fertility and survival, providing farmers with the information to make feeding decisions based on the economics of the likely responses.

Sustainability research

Two of the treatments in the 1.75 tonne of milksolids trial were designed to investigate the sustainability of using up to 400 kg N/ha/yr. This was one of the first forays into understanding the impact of the dairy farm system on the environment. The current Resource Efficient Dairying (RED) trial is monitoring the impact of increasing feed inputs into a pastoral based dairy system on MS production, economic performance and environmental impact. These data are essential to make informed decisions regarding environmental sustainability in the future. Results indicate that applications of 170 kg N/ha/yr increased MS production by approximately 20%, but increased nitrate leaching per hectare at least 2-fold. The use of stand-off pads as a winter management practice or the use of maize silage reduced N leaching losses per kg MS on dairy farms. However, leaching losses were relatively high in the area of land used to produce supplementary feed, and therefore the whole-system efficiency (total kg N leached per kg MS produced) declined when supplementary feed increased.

Summary

This paper was not meant to cover all of the research areas undertaken over the last 30 years; it was merely to provide a small snapshot of research programmes and results that probably seem common place in New Zealand today. For example, mention is made of mastitis research, alternative forages, milking frequency, automation, or milk characteristics.

In addition, the focus has been entirely on the past and have not delved into how current research programmes in improving feed conversion efficiency, understanding the effects of early lactation nutrition and milking frequency on the lactation curve, extending lactations beyond 365 days, the interaction between immunity in early lactation and fertility, or a host of other research programmes currently being undertaken, will significantly influence the way we farm in the future.

New Zealand has the greatest dairy industry in the world. Alongside that industry is one of the most respected applied research teams in the world. There is little doubt that the industry will continue to prosper because of the partnership between farmers and scientists.

"Even if the open windows of science at first make us shiver after the cosy indoor warmth of traditional humanising myths, in the end the fresh air brings vigour, and the great spaces have a splendour of their own".

-Bertrand Russell, 1872-1970