
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

A review of recent research and extension on dryland lucerne in New Zealand

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Abstract

To maintain scientific integrity requires the publication of research articles in journals of high international standing. Results from such work are frequently discounted as irrelevant and of low value to practitioners wanting to interpret results for their farm situation. This creates a dilemma for funding bodies, scientists and industry good organizations. This paper outlines the strategy that has evolved to develop a dryland research programme based around lucerne. This aimed to satisfy the requirements of data integrity for excellent science output, yet maintain currency and relevance for wide-spread agricultural adoption. This utilized high quality science by a series of postgraduate students, and engaged industry good and Government organizations to provide funding support to demonstrate the key results, and for technology transfer. The successful adoption of information required the lead scientist to engage in all aspects of the science and extension. As the demands of each increased, digital technology in the form of a website, 'txt' alert service, and a blog were used to communicate to a wider audience and maintain accurate and timely advice. The development of a case study around 'Bonavaree' farm provided a focus for on-farm adoption and added currency and relevance to the scientific data. This allowed scientists, agribusiness professionals and on-farm practitioners to communicate with a farmer or scientist at a level that they felt most comfortable. The collective result has stimulated on-farm change to a greater extent than could be expected from a focus on any individual component of research, demonstration or technology transfer.

Keywords: alfalfa; *Medicago sativa;* technology transfer

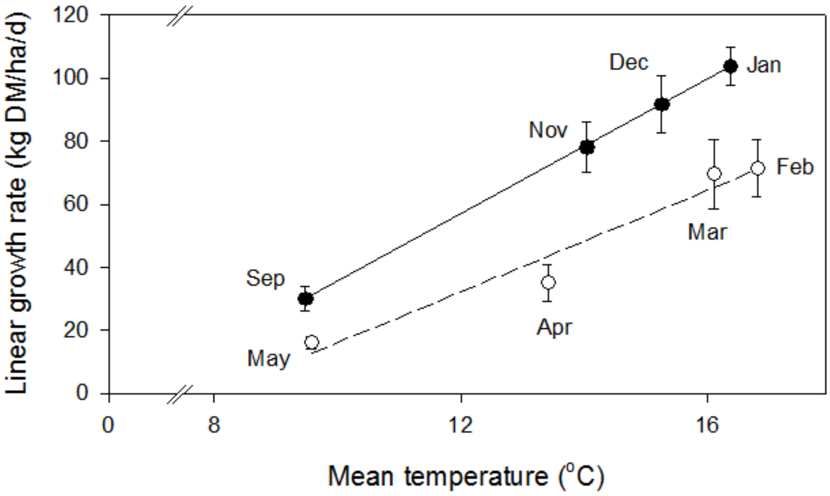
Introduction

For applied agricultural research, the challenge is to move scientific results from highly controlled laboratory or on-station experiments to adoption. The dilemma is to balance the data integrity required for peer review publication, with the need to be relevant to the intended audience of uptake (Bonoma 1985). To be successful, component research must have clearly defined aims and produce results that can be adopted into an applied context. The aim of this paper is to review recent research on lucerne (*Medicago sativa*), predominantly from the Dryland Pastures Research team at Lincoln University. The main research results are presented, followed by a description of how these underpinned an extension programme that has led to successful on-farm adoption (e.g. Avery et al 2008). This review offers my personal perspective of the key research results and extension methods that have led to a renewed interest in the use of lucerne in New Zealand farm systems. As such, it includes greater commentary and interpretation than is usually found in concise research papers and many of the experimental details and results have been published previously. This review aims to present the main results in a coherent chronology that explains the reasons for a renewed interest in lucerne as a forage plant. The underlying driver of the research and extension work has been acknowledgement that "*excellent science only becomes excellent agriculture in the field*".

Historically, most New Zealand agricultural students in the 1980s were introduced to the role of lucerne in dryland farming systems. The latest agronomic advice was collated in "Lucerne for the 80s" and in an excellent review by Douglas (1986). The intervening decades include a waxing and waning of lucerne use in New Zealand (Purves & Wynn-Williams 1989; Rolston 2003) and there is no guarantee that current enthusiasm will be sustained. A difference between the 1980s and now is greater awareness of the limitations of perennial ryegrass for dryland farms (Moot 2011) and the emergence of climate change as a potential issue for many farmers. In the early 1990s, climate change was an accepted phenomenon amongst the agricultural science community in Europe. Research was focused around modelling potential changes and their potential impacts for the major agricultural crops of the world, which offered opportunities for component research by antipodean postdoctoral fellows, such as myself (e.g. Moot et al. 1996). In New Zealand, similar work was underway and continues, focussed mainly on ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*), with an emphasis on the impacts of and for dairy farming. However, there was less focus on dryland grazing systems in the east coast of both islands. These areas are vulnerable to current and future climate variability (Salinger 2003) and offered a niche in which our applied research programme has developed.

The lack of lucerne being used in New Zealand in the 1990s prompted a survey of dryland farmers to identify why it had fallen from favour (Kirsopp 2001). This identified three main impediments to lucerne use on-farm; 1) lucerne had been tried but failed due to insect pressure; 2) confusion over which dryland species to use and 3) lucerne management criteria

Figure 1 Linear growth rates of irrigated lucerne in relation to mean temperature at Lincoln University, Canterbury, New Zealand. Each point represents mean from 5 years data and bars represent one standard error either side of the mean. Linear regressions fitted to data from September–January (●, y = -71.5 + 10.7x, R^2 = 0.99) and February–May (○, y = -64.7 + 8.0x, R^2 = 0.92) (Moot et al. 2003).



meant it was favoured for cut-and-carry but considered unsuitable for grazing. The first of these reasons has been largely overcome by the successful introduction of a parasitoid wasp to control *Sitona discoideus* (Goldson et al. 1990) and new genetic material that has conferred a degree of resistance to stem nematodes and several aphid species. Currently, there is an occasional isolated out-break of these and other insect pests, but they no longer appear to have as devastating or widespread impact as occurred in the 1980s.

The remainder of this review describes the experimental research used to address the second and third reasons. It then explains how the science information was packaged and disseminated for adoption. The review also describes the strategy used to allow the scientist to be involved in all aspects of the work from peer review publication to on-farm adoption. This has required deliberate targeting of different funding streams to deliver on different aspects of the programme and ensure each funder understood their role in the delivery process.

Science questions

Lucerne, chicory, or red clover?

The first experiment started in 1996/97 and compared lucerne with chicory (*Cichorium intybus*) and red clover (*T. pratense)* over five years in irrigated and dryland conditions (Brown et al. 2003). The dryland lucerne production averaged 20 t DM/ha/yr compared with 16 t DM/ha for chicory and red clover. The species were grown in a Wakanui silt loam soil, with a plant available water capacity of 150-200 mm/m of depth to at least 2.3 m. They had a similar maximum water use efficiency of 46 kg DM/mm/kpa, when normalized for vapour pressure deficit. The greater yields from lucerne were due to earlier spring growth and greater total water extraction. This enabled higher growth rates in summer and autumn than the other two species. The yield differences increased over time as red clover and chicory plants died through *Rhizoctonia* and *Sclerotinia* spp. infections. There was no red clover left after five years and 61% chicory compared with 94% lucerne. These results reinforced the decision to concentrate a research programme around lucerne.

A key result was the difference in daily growth rates of irrigated lucerne at the same temperature and radiation levels between spring and autumn (Figure 1) (Moot et al. 2003). This required an intensive investigation of underground reserves of lucerne and therefore roots were excavated from a grazed experiment. The seasonality of growth was explained by changes in above and below-ground partitioning (Teixeira et al. 2007). Specifically, lucerne remobilized nitrogen and carbon reserves in response to rising temperatures and day-length in spring and then restored these underground in autumn (Figure 2), independently of grazing

Figure 2 Root dry matter (t DM/ha, 0-0.3 m soil depth) of irrigated ‘Grasslands Kaituna’ lucerne crops defoliated at 28–day (○) or 42–day (●) intervals at Lincoln University, Canterbury, New Zealand (Moot et al. 2003).

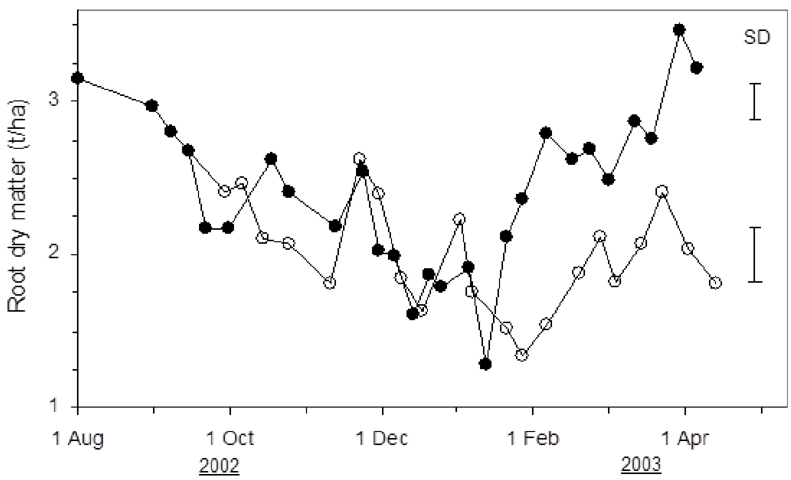
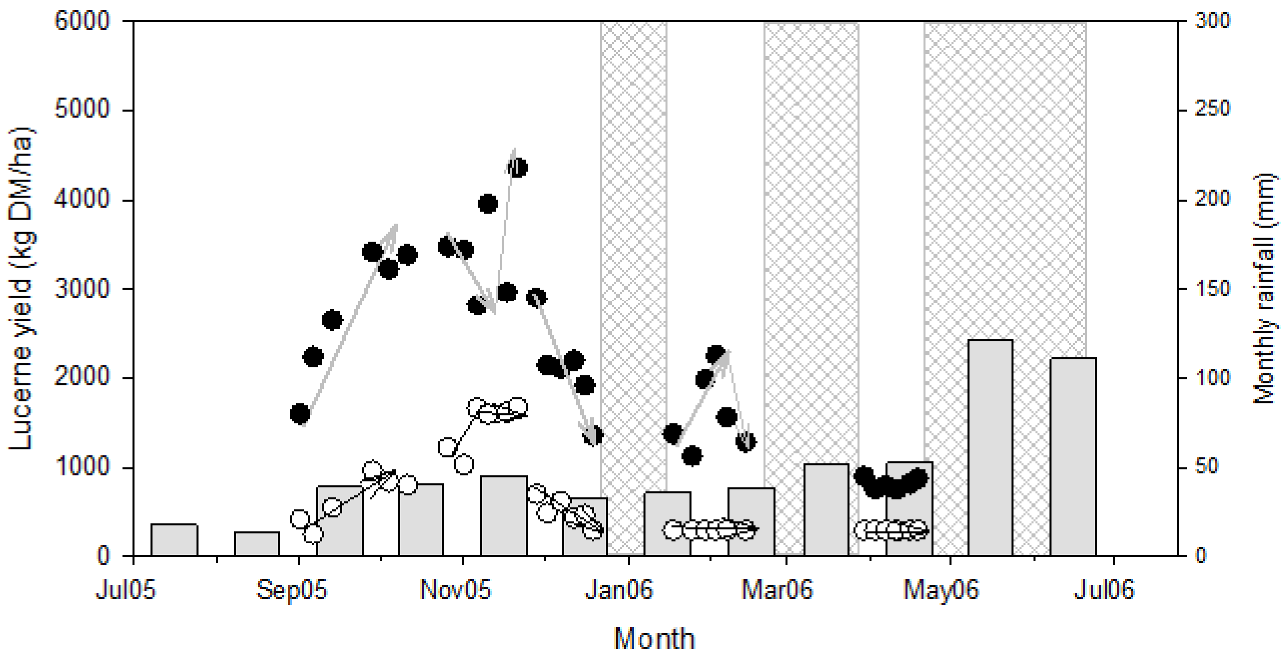


Figure 3 Pre- (●) and post-grazing (○) dry matter yields of a 4-year-old (2005/06) dryland 'Kaituna' lucerne monoculture in a direct-grazed six-paddock rotational system at the 'MaxClover' grazing experiment at Lincoln University, Canterbury, New Zealand. Arrows show the progression of grazing in each of the five rotations. Crosshatch grey shaded areas indicate periods when pastures were destocked due to drought and/or temperature restricted growth periods when feed supply was inadequate to support sheep grazing. Grey bars are monthly rainfall (mm) from the Broadfields Meteorological Station located about 2 km north of the experiment.



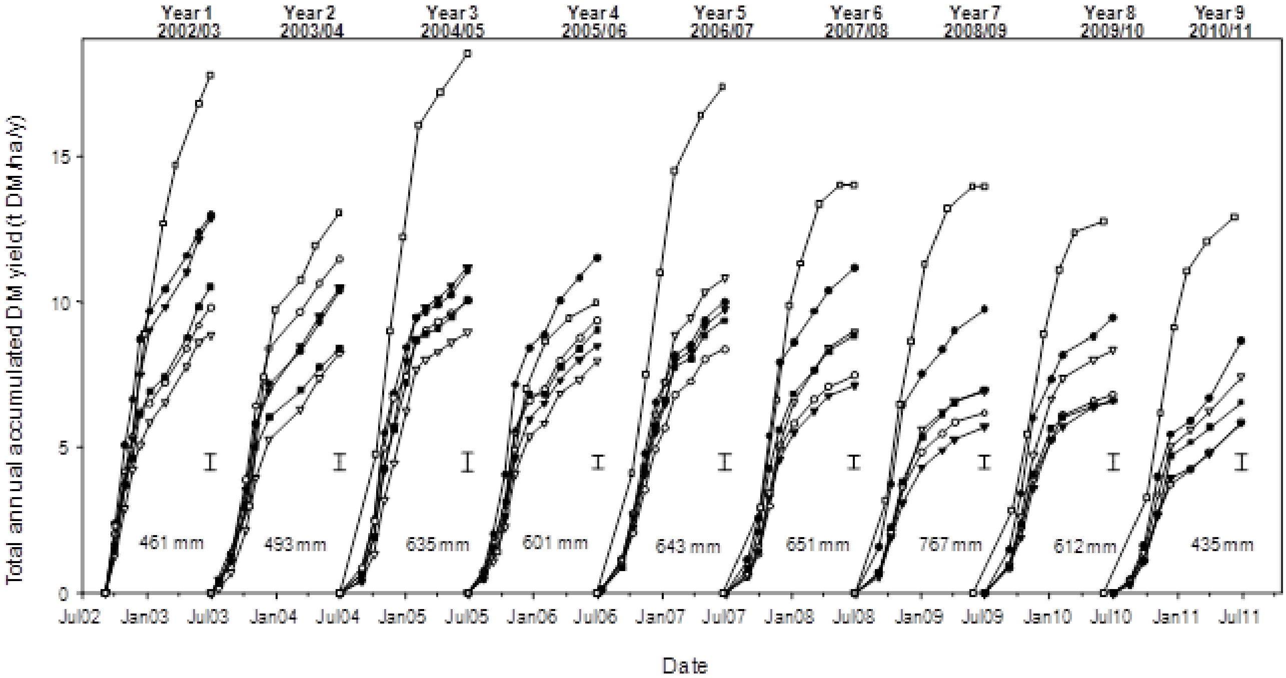
management (Teixeira et al. 2008). Validation of the understanding of the plant responses to the environment was necessary through additional modelling work with these and independent datasets (Teixeira et al. 2009). The main practical outcome from these new insights into the growth and development of the lucerne plant, was that it enabled definition of a new set of spring grazing management rules.

Can we increase the flexibility of grazing management of lucerne stands?

At the time of the initial survey, 67% of dryland farmers in the South Island grew lucerne but on less than 20% of their farm. This compared with recommendations for 40-60% of the farm to be in lucerne to maximize live-weight gain (White 1982). Effectively, integration of lucerne into sheep grazing systems had failed. Failure was due to conflicting objectives between plant and animal performance. A strong message had been delivered to farmers that lucerne should be left to at least 10% flowering before defoliation. This was based on North American literature that had an emphasis on cut and carry systems. It had made lucerne grazing management inflexible in New Zealand and marginalized the plant as a specialist conserved crop. Our greater understanding of crop growth and development meant guidelines were produced to encourage farmers to graze the crop in spring with ewes and lambs. Farmers are now advised to introduce ewes and lambs to lucerne stands (Moot et al. 2003) when the first lucerne paddock contains ~1500 kg DM/ha to create a feed wedge (Figure 3). Priority is to maximize lamb live-weight gain during lactation while maintaining ewe condition. Based on average lucerne growth rates, the stocking rate can be consistently estimated for the area of a six paddock rotation at 12±2 ewes plus twin lambs per hectare for intensive grazing. In autumn, management switches to restoration of these underground reserves (Teixeira et al. 2007), and early winter grazing to ensure feed is available at the earliest possible time again in spring (Moot et al. 2003).

These guidelines were first publically described in a series of eight commercially sponsored seminars around the South Island in 1998. The last of these, in Waipara in North Canterbury, was attended by Marlborough farmer Mr Doug Avery ('Bonavaree'). He has used this and subsequent knowledge from one-on-one discussions to induce transformational change on his dryland farm in Marlborough (Avery et al. 2008; Moot & Avery 2013). Having promoted the idea of lucerne grazing it became apparent that farmers and agribusiness professionals with previous experience with lucerne were in the minority. Those that had seen its use in the 1980s were often unwilling to explore its use again. Therefore, a complete re-education of the dryland sheep, beef and deer sectors on "how to use lucerne in a grazing system" was required. This

Figure 4 Total accumulated annual dry matter (DM) production of cocksfoot/sub clover (●), cocksfoot/balansa clover(○), cocksfoot/white clover (▼), cocksfoot/Caucasian clover (▽), ryegrass/white clover (■) and lucerne (□) pastures over nine growth seasons (2002—2011). Accumulation for Year 1 began on 4/9/2002. Total rainfall (mm) for each growth season is also shown. Error bars are SEM for total annual yields for each growth season (Moot 2012).



included introduction of the latest science to undergraduate students at Lincoln University.

Can we demonstrate these results on a larger scale?

The detailed physiology research into lucerne growth and development was largely achieved through postgraduate research, and provided the high data integrity required for peer review publications. However, to increase the relevance for farmers required demonstration of the new grazing principals in our 'MaxClover' experiment (Brown et al. 2006; Mills et al. 2008a, 2008b; Mills & Moot 2010; Mills et al. 2014). Importantly, Beef+LambNZ (BLNZ), and its predecessors, provided two funding cycles (six years) of financial support for a long term grazing experiment at Lincoln University. This added relevance for the dryland community on a time scale that was important to them. In this experiment, lucerne growth was compared with the industry standard (ryegrass and white clover), and four cocksfoot (*Dactylis glomerata*)/legume combinations. These pastures were grazed under best management guidelines for each species combination. This meant the lucerne was always rotationally grazed, but allowed an extended period to flower and increase below-ground reserves in autumn. Grasses were either set stocked or rotationally grazed as appropriate. For example, spring grazing aimed to maximize animal live-weight production, but allow subterranean clover (*T. subterraneum*) to reseed in different paddocks each year.

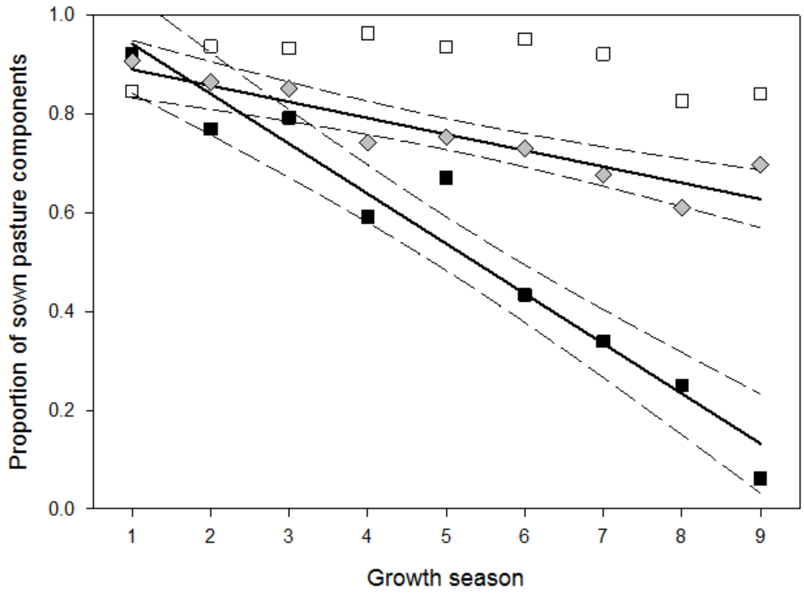
The results over nine years illustrated the superiority of lucerne for dry matter production (Figure 4) (Moot 2012), persistence (Figure 5) (Mills et al. 2014) and water use efficiency (Figure 6) (Moot et al. 2008). The latter proved to be most important to illustrate the advantages of lucerne to dryland farmers. Specifically, in spring, for each millimetre of water extracted from the soil, the lucerne produced ~30 kg DM/ha compared with ~20 kg DM/ha for the best of the grass-based pastures (grass and clover) and ~10 kg DM/ha for the poorer grass dominant pasture. Unexpectedly, neutron probe measurements showed that the total water extracted was not different between lucerne and the grass based pastures. This highlighted the fact that nitrogen deficient grass, which it nearly always is in a dryland system, was using water at the same rate as the lucerne but producing only a third as much dry matter. Mills et al. (2009) confirmed that nitrogen rather than water was the most limiting factor in a dryland system. To produce the same amount of feed from nitrogen-deficient grass as from a lucerne stand required the addition of 500-800 kg N/ha. These results challenged the previously widespread belief that superior lucerne growth was mainly due to deeper water extraction.

Extension processes

Demonstration to extension

The 'MaxClover' experiment provided a continuity of results that were able to be shown to students on campus, and reported at field days and conferences to maintain awareness of lucerne and cocksfoot (Brown et al. 2006) and highlight the continued failure of perennial ryegrass (Figure 5) in

Figure 5 Proportion of sown pasture components in dryland cocksfoot (◆) and ryegrass/white clover (■) pastures over nine growth seasons at the 'MaxClover' grazing experiment at Lincoln University, Canterbury, New Zealand. The first growth season was 2002/03 which started in 09/2002 following an 8 month establishment phase. Year 9 was the 2010/11 growth season. The regression for the four cocksfoot-based pastures was similar and thus bulked y=0.92±0.029 – 0.033±0.0052*x* (R^2 = 0.83). For RG/Wc y=1.04±0.050 – 0.101±0.009*x* (R^2 = 0.94). The change in the proportion of lucerne (□) was non-significant (P=0.380). Standard errors are reported for both intercepts and slopes. Dashed lines are 95% confidence intervals (Mills et al. 2014).

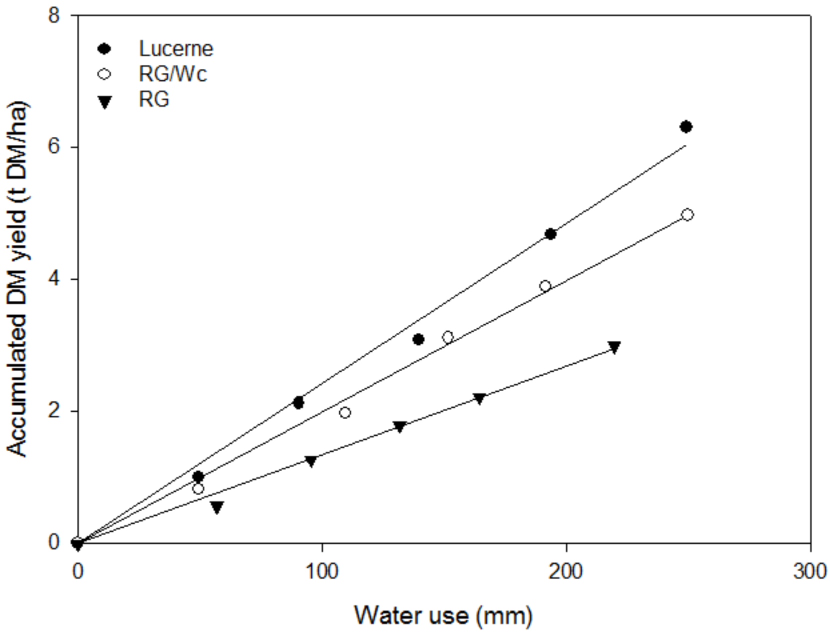


dryland conditions (Mills et al. 2014). In many cases, the lack of production and persistence of perennial ryegrass experienced in the 'MaxClover' experiment was mirrored on-farm. During this period, serendipity meant I had reconnected with Mr Doug Avery in 2002. He acknowledged the changes he had made on his farm were largely due to the 1998 presentation, but the system was yet to produce financial rewards. A consequent series of visits proved mutually beneficial to refine his lucerne grazing system. This interaction gave me, the scientist, confidence that the theory could be practiced on a commercial scale, and the farmer scientific knowledge to refine his management and believe in the repeatability and sustainability of results. These visits coincided with a separate MAF Sustainable Farming Fund (SSF) project on Soil Conservation that Doug Avery involved with. The final presentation from this group was at the "Beyond Reasonable Drought" field day in April 2008. By this time, the transformation on the Avery property had become well known in the district and practice change filled my field day and lecture presentations. Registrations for this field day exceeded 400, with most indicating the role of lucerne as the main reason for their attendance. This focal point gathered interested farmers from dryland districts in the South Island and some from the east coast North Island. It was followed in October that year by the New Zealand Grassland Association Conference field day, where a broader range of scientists and agribusiness professionals were shown the transformational change. A pivotal paper at that conference also provided the data required to convince farmers of the financial rewards produced from the change (Avery et al. 2008). These events occurred about a decade after my initial series of lucerne meetings. It also coincided with on-farm succession for some of the first students I had taught. They were now in charge of their own farm. They are enthusiastic to make changes to pay out siblings or parents, and ready to try something different from "what Dad had been doing".

Extension to adoption

For one group of Central Otago farmers and agribusiness professionals, the 'Bonavaree' messages were extremely pertinent and they created their own "Lucerne 4 Lambs" Sustainable Farming Fund group. This included flying in the "lucerne expert" to give the programme advice, but also working with local AgResearch scientists to gather on farm data to support a similar change to lucerne grazing in their region (Stevens et al. 2012). This proliferation of interest meant that between 2007 and 2010, I gave 60 field day and discussion group presentations and answered countless enquiries from the press and individual farmers, including many recent Lincoln alumni. Currency and relevance were high, due to the case study presented at 'Bonavaree'. It quickly became apparent that the role of 'lucerne champion' needed to be shared. From 2010 to 2013, I presented a further 90 field days with further funding assistance from Ministry for Primary Industries (MPI) SFF. The deliberate pitch for this project aim was to increase the network of people available to assist with lucerne advice by targeting the agribusiness community. This has given them the confidence to assist with lucerne extension and adoption. Field days targeted small discussion groups of interested parties, at their request, and return visits were used to encourage adoption. Farmer mentors were used to support those beginning the process of adoption and agribusiness professionals were educated about how to manage the agronomy and grazing of lucerne. Fortunately, Mr Avery continued to freely present information from his farm as a case study for other farmers. We hired a bus and took a group of young North Canterbury farmers to visit 'Bonavaree' and

Figure 6 Spring WUE (kg DM/ha/mm) of lucerne (24 kg DM/ha/mm), perennial ryegrass/white clover (RG/Wc, 20 kg DM/ha/mm) and perennial ryegrass (RG, 13 kg DM/ha/mm) pastures from Dataset 7 at Lincoln, Canterbury between 29/9-9/12/93 (Moot et al. 2008).



Each published post has an open window of two weeks where visitors have the opportunity to post comments or ask questions directly. Of particular interest has been the creation of a photo diary. A technician visited 'Bonavaree' on a regular basis to provide topical "on-farm" management advice based on several paddocks. This has been expanded to include results from Bog Roy Station at Otematata and other components of dryland pastures research at Lincoln University. At the same time, other pockets of expertise have developed on the east coast of New Zealand, again with support from BLNZ and MPI SFF. A further joint initiative with BLNZ involves the timely sending of 'txt' alerts on lucerne to interested parties. This system involved me sending an email to BLNZ on a weekly basis for a year with timely messages around

other Marlborough farms. This visit was designed to give them confidence and provide a catalyst for change on their farms. Each of the last three winters they have returned to our winter seminar series in Blenheim to learn the latest information and research results. The technical transfer activity aids successful adoption and encourages greater interest which then needs to be serviced.

Development of new extension tools

The extension messages were becoming clearer and frequently the same questions were asked at field days or directly via email. The range of questions also broadened with the newly- engaged farmers still requiring sound agronomic advice on issues such as establishment (Kearney et al. 2010). In contrast, those with several years' of lucerne experience sought more technical grazing advice as they pushed the boundaries of where and how lucerne could be utilized. A growing awareness and interest from the dairy support sector also occurred. To manage the increased demand for information, two internet-based initiatives were developed. SFF funding allowed the creation of a "Dryland Pastures" website (http://www.lincoln.ac.nz/dryland) which runs in conjunction with the "Dryland Pastures" blog (http://www.lincoln.ac.nz/conversation/drylandpastures/), both of which are hosted by Lincoln University. The blog went live in August 2012 and averages more than 900 individual page hits from about 400 individual visitors per month from New Zealand alone. There are also regular visits from Australia, U.S.A and Europe. The blog was created to discuss issues and developments around dryland pastures and disseminate information from the scientists and farmers involved.

lucerne management. These are now recycled on an annual basis and they maintain the contact list and deal with logistics. The scientists' role is now to answer questions that come back to them, via Twitter, in response to those alerts, and send out topical emails as issues change in any given year such as the North Island droughts of 2012 and 2013. This service now has 600+ subscribers and turnover of less than 1%. The answers to questions are also copied to our 'Frequently Asked Questions" page on the "Dryland Pastures" website to build up a library of responses that subscribers can then be directed to in future.

Current research opportunities

The last two decades of agronomic research have answered most of the questions associated with the growing and grazing of lucerne on dryland farms. The results have provided the physiological basis for the APSIM_Lucerne (Moot et al. 2001) and FAO Aquacrop models (Moot et al. 2012) and the research is well recognised internationally (Moot 2012). The challenge is now to support the integration of lucerne into a range of farm systems. The dairy industry is increasingly seeing lucerne as part of a supplementary feed programme and there is interest in direct grazing by dairy cows (Smith et al. 2013). Sheep farmers regularly use lucerne for grazing by dairy heifers and beef cattle, but there is a need to develop guidelines around animal health issues and expected live-weight gains for these classes of stock. The deer industry has shown successful integration of lucerne for dryland farms in the South Island. Work at Lincoln continues in relation to; 1) the development of even more flexible spring grazing guidelines, 2) the use of grain as a supplement to balance the high protein feed, 3) the role of lucerne grass mixes; 4) quantifying nitrogen fixation rates (Black & Moot 2013) and 5) rhizobia interactions (Khumalo et al. 2012; Wigley et al. 2012), and comparing water extraction patterns of established and seedling lucerne (Sim 2014). The agronomic recommendation to allow lucerne to flower in autumn suits plant requirements but the effect of this and other environmental stresses on phytoestrogen levels in plants and animals needs to be re-examined. The contribution of nitrogen fixation of lucerne to nitrate leaching is also being challenged and needs accurate scientific answers to inform policy. As a greater number of farmers utilise lucerne in a wider range of conditions, the research and extension needs will grow. The world's most important forage plant is unlikely to be number one in New Zealand, but with appropriate science research and parallel attention to agricultural extension, it has a major role to play in our farming regions.

Conclusions

To successfully integrate an applied science programme into agricultural adoption has required three distinct but complementary processes. First, a high degree of understanding of the science and the interpretation of that science by the researcher in an applied context. Second, validation of that science through peer-review publication coupled with testing of the principals with industry support and early adoption by progressive farmers. These provide the rigour and relevance for the third stage of widespread adoption on-farm. This process can be expressed as a linear progression from one phase to the next. However, it is more frequently a feedback system whereby new questions are asked by farmers that need to be well researched by scientists before the answer can be promoted. It becomes the scientists' role to remove all possible impediments to adoption, real and perceived. The long term nature of such a research programme does not always suit a short-term funding cycle. For lucerne, this has meant a deliberate strategy to source funds was used. High data integrity was maintained with postgraduate research, validation occurred through modelling, demonstration of the major results required industry support, while promulgation of results used MPI SFF programmes.

Acknowledgements

Beef+Lamb New Zealand through the Foundation for Research, Science and Technology, Pastoral 21 Feed programme and Ministry of Agriculture and Fisheries Sustainable Farming Fund (10/069). Dr Annamaria Mills for collation of experimental results and website publications. Mr Malcolm Smith for running all grazing experiments.
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