Dr David Scott (1934-2017)

During the year before his death in October 2017, David summarised the results of the wide range of trials which he initiated at the Mt John Research Area near Lake Tekapo. From 1981 those long-term trials dominated his career pathway in Grasslands DSIR and AgResearch and then in to his retirement years.

In 2008, in recognition of his notable contributions to pasture science, David received the Ray Brougham Trophy which is the premier honour awarded annually by the New Zealand Grasslands Trust.

As the venue for the 2018 annual conference of the New Zealand Grassland Association is Twizel in the Mackenzie Country, near Lake Tekapo, it is appropriate for this summary to be published in the 2018 Journal of New Zealand Grasslands. Colleagues who contributed to the research programme are named as co-authors of the summary. The reference list (below) indicates the magnitude of David Scott's contribution. In particular, the series of 10 papers in the New Zealand Journal of Agricultural Research on the sustainability of New Zealand high-country pastures, presents in-depth results and discussion of the long-term grazing experiments. He regularly contributed papers to the annual New Zealand Grassland Association Conference, and contributions also came from studies by post-graduate students working at Mt John Research Station.

David was also lead author of the influential 1995 extension publication: "A guide to pastures and pasture species for the New Zealand high country". It is a valuable account of the David Scott approach to identifying and describing the characteristics and roles of pasture species options for Mt John-type country.

David's long-term grazing experiments have demonstrated:

1. The success of perennial lupin which was the dominant pasture legume at low fertiliser inputs
2. The success of the rhizomatous pasture legume, Caucasian clover, which over time, became the dominant legume at higher fertiliser inputs
3. Improved understanding of the need to match pasture species to possible fertiliser, stock management and environmental regimes
4. Improved understanding of many aspects of functional grassland ecology
5. Reducing the impact of Hieracium spp. with fertiliser and establishment of improved pasture
6. That perennial lupin seed-lines may be developed with reduced alkaloid level.

Thirty-six years (1981-2017) of Mt John pasture trials

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Introduction

The South Island high-country tussock grasslands have a great variability of sites at the margins of pastoral agriculture. Historically, there had been many small pasture trials scattered over this domain, but seldom large or accessible enough for controlled grazing treatments.

The 43 ha Mt John trial area (820 m a.s.l.) near Lake Tekapo was established in 1981 to overcome that limitation. The site is on undulating greywacke terminal moraine and lake-bottom material with ~650 mm rainfall, which in 1981, was hieracium (*Pilosella officinarum*)-infested degraded fescue tussock grassland.

In the ensuing studies of possible grazed pasture options for this class of country, use was made of the general concept of environmental gradients and species niche (Scott *et al.* 1995), and the experimental approach

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of initially sowing multi-species mixtures into a range of conditions (alternative land types, allowable fertiliser levels, animal type, possible grazing regimes, etc.) to find those correspondences. The four environmental gradients are: temperature in terms of latitude, attitude, aspect and slope; soil moisture in terms of rainfall, drainage, soil depth, and irrigation; soil fertility (either natural or applied), and the interaction of grazing and treading (or grazing management intensity and type) with the growing points of different species. Within these gradients, each forage species has a probable niche where it would be the most appropriate and productive to grow.

The following is a highly abbreviated version of the topics investigated, methods used, and principal outcomes.

Matching species to environmental, input and management conditions

The first trial, now in its 37th year (2017), was a 27 species seed mixture grazing experiment. Seed was rotary hoe-drilled in all combinations of five fertiliser levels S super (0, 50, 100, 250, 500 + irrigation) kg/ha/year, three sheep stocking rates (low, best, high), two stocking methods (mob, set), and two spatial replications. All plots were separately fenced. The fertiliser was applied for the first 20 years and the last 2 years. The main annual measurements were late-spring pre-grazing pasture species composition in each combination, and the annual sheep grazing days achieved.

There was early and rapid sorting out of pasture species in the first 2 years according to the fertiliser level used and a slower transition over decades from legume to grass dominance as nitrogen levels built up under the different fertiliser levels. Alsike and white clover dominated early stages at moderate fertiliser rates. The lupin was a highly successful pasture legume at low fertiliser inputs. There was low success of introduced species without fertiliser. Caucasian clover established slowly but became the dominant legume in the second decade at higher fertiliser rates. Chewings fescue was the second most successful grass across the whole fertility gradient, cocksfoot reached maximum prominence towards the end of first decade, and tall oat grass increased over time. Grazing management effects on pasture species selection was small relative to fertiliser effects.

The sheep grazing capacity increased from 0.8 stock units in the zero fertiliser treatments to 3.1, 2.6 and 2.7 SU/ha in the three successive dryland fertiliser treatments, to 8.0 SU/ha in the high fertiliser and irrigated treatments.

The important implications are the need to match pasture species to allowable fertiliser levels, stock management and environmental regimes.

S and P fertilisers

Another trial, established at the same time, with the same 27 species mixture under 31 S and P fertiliser combinations from 0/0 to 100/l00 kg/ha/year/element was applied as for above. The initial sorting out of species was according to the P fertiliser rates - in the early years alsike at high fertility and perennial lupin at low fertility were best. The few measurements of pasture yield showed a positive S by P interaction.

The grazing capacity, as measured by sheep grazing days, was determined almost totally by sulphur fertiliser rates, which in this trial was elemental S.

Fertiliser efficiency

These first two trials have been intensively monitored for other variables. They were soil sampled (40 cm depth) in the 10th year for macro-nutrients. Working from the above records, and considering fertiliser cost at depot, transport and spreading costs, it was estimated that the most efficient fertiliser regime, in terms of dollars spent versus grazing days gained would be 250 kg/ha of 2 mm sized elemental S every 5 years.

The results are a reminder that our concept of 'soil fertility' is plant oriented, not animal oriented, with a probable need to reassess the role of S in sheep nutrition.

Nutrient balance

A further aspect of the S x P trial (above) was that soils 'grow' with development (up to 4 cm by the 15th year) and that subsequent comparative soil sampling may not relate to the original soil strata.

Irrigation

Irrigation possibilities had been studied earlier in other parts of the region. It was only used as one treatment in the first Mt John trial, to establish a potential growth gradient for comparing different species. However, it does demonstrate the potential.

Establishing rhizomatous legumes

A trial investigated the establishment of Caucasian clover, zig-zag clover, and crown vetch from transplanted rhizome fragments under 3 fertiliser levels. Caucasian clover and zig-zag patches increased in diameter to ~2-3 m in 9 years, suggesting an alternative method for their introduction. Another trial of widely spaced tree planting, primarily for shelter, used the early stage until trees got above grazing height, to establish these legumes from stolon fragments.

Hill-country summer grasses

Mt John was one of several national sites evaluating 6 grass species (cocksfoot, perennial ryegrass, phalaris, tall fescue, prairie grass, and tall oat grass) for summer conditions, and for this site also late-autumn

or early-spring conditions. This was into a previously undeveloped site. Over the 7 years the sown grasses made only an occasional useful component to the feed of the different grazing treatments. The indication being that though sown with accompanying clovers there was insufficient build-up of soil N levels.

Grasses for *in situ* winter feed

While initial oversowings are generally legume dominant, the ultimate requirement is for grass dominant pastures. Quality and quantity of winter feed are the main restraints on high-country farming, for which legumes are not suitable.

Summer and autumn-saved grass, fed off in place, should be a most efficient form of winter feed. An 8 year trial compared cocksfoot, tall fescue, ryegrass and phalaris, spring sown with slow release nitrogen, then given 2 growing seasons to establish before winter sheep performance measurements were made for 6 years. There was good grass establishment using starter nitrogen, but a general subsequent decline of sown grasses and reversion to volunteer grasses within a decade.

Another similar trial compared cocksfoot (3 cultivars) tall fescue, ryegrass and phalaris, each with legumes, and different rates of additional N fertiliser over 6 years. There was a marked effect on browntop ingress depending on one month's difference of early summer grazing before closing for winter feed, but again a decline in the sown grass component.

Second stage grass development

A further attempt at grass introduction was made using a four legume/four grass mixture into the following treatment combinations: undeveloped versus 5 year partial previous legume phase; spring versus autumn sowing; nil versus 150 N kg/ha for first 2 years; discing versus partial cultivation drill; and high S versus normal superphosphate.

The new drillings were largely unsuccessful in the previously developed eastern plots due to continued competition from established vegetation. Grass establishment was largely unsuccessful as by the I2th year, there was some sown grass but only in the sub-plots receiving N, or in sheep camps adjacent to the central race.

A feature was the success and increasing dominance of lupin and the ingress of tall oat grass from distant plots into the previously undeveloped group of plots. Some of those plots were converted to tall oat grass dominance by heavy grazing out of the lupin.

Grasses

As a partial summary of the grasses, their introduction at modest fertiliser inputs has generally been a disappointment. Of the taller species, cocksfoot was still king. Tall oat grass could be a good contender, particularly from its self-seeding spreading ability. Smooth brome is also possible, and timothy remains an innocuous unsung hero.

It seems that at these lower inputs it was the domain of short grass species – browntop, self-spreading Kentucky blue grass and chewings fescue.

Perennial ryegrass was a standard component in most seed mixtures, but has remained a rare species. Tall fescue seems to be a better 'high fertility' species for these areas.

Hill slopes

There have been a number of trials established on the rocky hill slopes, but have been difficult to adequately manage, graze, and monitor. There are some features worth recording.

There was a 5-year trial that showed goats better controlled briar than sheep. There was another introducing grasses and again cocksfoot cultivars and resident old cocksfoot were best.

There were a number of introduction plots showing: success of tagasaste from seed in the higher thermal zone; the slow spread of the annual vetch species; and the greater success of tree lupin in the higher thermal belt of less acid conditions, compared with lupin on the low acid flats.

Spelling for reseeding

Spelling in some years to allow reseeding is advocated in many rangelands. A 27 year trial was sown with a six legume plus four grass mixture and subjected to: grazing every year versus every second year (but total balanced over time); in summer, autumn or both; and at high or low stocking rates. The trends have been for continued lupin dominance in all except the highest stocking rate plots; the greater persistence of cocksfoot when allowed to reach a tussock habit; increase in tall oat grass; and little indication of new seedlings of other species.

Low fertiliser options

If only low fertiliser rates could be contemplated on extensive tussock grassland, the question was which species mixtures, fertiliser method and frequency, grazing management, and stock transfer would suffice. An early 22 year trial varied treatments around a mean of 25 kg ha/year of sulphur superphosphate.

In the light of results arising from other trials, the sowing should have used perennial lupin as the main legume, and this was successfully introduced by surface seeding while the plots were continuing to be grazed.

Plant introduction and breeding

There is a continued need to screen species from other

parts of the world for their use in pastoral development of the high-country. This has been at different levels from new introduced species, comparison of available New Zealand material, to plant breeding within particular species.

Mt John was one of twelve high-country sites making initial evaluation of over 600 accessions of 180 different species under contrasting fertility and defoliation regimes for up to 6 years.

The species and number of accessions were for legumes: white clover (17), red clover (60), alsike (13), Caucasian (15), nine other clovers (66), lucerne (30), lotus (290), astragalus (36), eight other perennial legumes (22), and 25 annual species (56). For grasses and herbs: four cocksfoot spp. (29), tall oat grass (44), eight perennial bromes spp. (25), timothy (12), four secale/hordeum (11), 23 wheat and steppe grass spp. (68), 12 South American spp. (41), chewings/ovina (29) and seven herb species (10).

These were ranked according to their suitability, and have supported the wider use of lupin, tall oat grass, black mountain rye and sheep's fescue, while indicating that there were three new legumes and two brome species that warranted further evaluation.

Lupin agronomy

Lupin was a component in most of the seed mixtures evaluating different species suitabilities. In many cases its rise to dominance is better interpreted as lupin agronomy and two trials are described.

In one, lupin was drilled across a previous 3 year trial of sown strips of 24 grass and legume species and subsequently under four treatments contrasting grazing pressure (low, moderate and high set-stocking and mob-stocking). In the subsequent 27 years there was the establishment and continued dominance of lupin.

In a second trial into cultivated soil and starting with narrow strips of 14 legumes cross-sown with 14 grasses or herbs to determine the initial success of binary pairs. These were under two fertiliser treatments and hard-grazed once or twice a year. Over the years the lupin has spread from seeding, even under grazing, to become dominant over the whole plot, and only showing change to grass dominance after 20 years.

Sheep performance on red clover, alsike and lupin

Following the early indication of the success of lupin as a pasture species there was an initial 5 year trial of low density summer set-stocking on different new legume stands, with periodic sheep liveweight measurements. The weight gain on alsike and lupin were 70 and 53%, respectively, to that on red clover (the gold standard!).

Lupin selection

With the early trials showing the potential of lupin as a pasture species, a selection/breeding program was initiated. This started by collecting seed from 'good' looking plants and establishing an 8 year spaced plant trial from which seeds from 31 selected plants were saved.

That approach has been superseded by a general search for low alkaloid form of the species (hopefully more stock-palatable). At present this has involved field testing of ~30 000 plants, from which selection and partial multiplication of a hundred clones have been obtained qualifying as 'sweet' (less than 0.2% alkaloid).

Hieracium control

One of the secondary objectives in the establishment of the trial site was to see if hieracium could be controlled by pasture development. Most of the trials were drilled or only partially cultivated while retaining the hieracium presence. The short answer is yes, it has been generally reduced to a minor species where fertiliser and oversowing have been involved, even though hieracium is tolerant of low soil fertility and drought, it is better regarded as a moderate fertility species.

The site has been used for the determination of its population dynamics under different fertiliser and defoliation regimes and was one of the sites for the introduction of the rust biological control agent and the appearance of the powdery mildew.

Tussock fertilisation

A proportion of the hieracium-infested/short tussock plots have been ungrazed and unfertilised for 36 years. These have remained hieracium-dominant with some recovery of the tussocks.

There is a desire to retain fescue tussock cover. A 9 year trial compared fertiliser application at one, of either 3 N rates x 2 N types or 3 superphosphate rates and a single grazing in the 4th year. The tussocks did respond positively to fertiliser and a single grazing, but the response took several years to manifest itself. The largest response was the appearance in plots of species previously not perceived as present; legumes in plots receiving superphosphate and grasses in plots receiving N, and a short-term increase in hieracium.

A second similar trial compared various nitrogen and boron fertilisers. There was an effect of boron on suppression of hieracium and subsequent increase in grasses, but little long-term effect.

Re-seeding of tussocks

A 7 year trial compared seeding of six native grasses with six pasture grasses with and without initial N fertiliser, and with and without legumes. Only blue tussock and tall oat grass were reasonable, but were out-performed by some of the pasture grasses. A native grass seed orchard was also established.

Discussion

The Mt John trial site has investigated the pasture and development options for one type of high-country site under different levels of inputs from species, fertiliser, stocking-rates and stocking methods. This was within the concept of the need, within these large rangeland type holdings, for 'special purpose pastures' of smaller areas, and higher inputs to provide feed for particular periods e.g. hay paddocks, standing winter feed, lambing areas etc.

The need was to introduce N-fixing legumes. Such development will depend on fertiliser input, and probably more on sulphur inputs than phosphate. Also it is 'environment not species'; the choice of the pasture species for use has to be matched with the intended level of fertiliser use. A wide range of species is possible - with the suggestion that each has virtues in particular situations.

The first two trials described are probably the most important conceptual and practical trials on the site illustrating those points. They were started by sowing a common mixture containing many species over a large area and then superimposing many different fertiliser and grazing management regimes in individual fenced plots, and seeing how each species sorted themselves out and persisted.

The trial(s) have been studied for many aspects of functional grassland ecology as well as for the practical development of this particular class of site and have demonstrated that they cannot necessarily be extrapolated from experience elsewhere e.g. the unexpected high success of the horticultural perennial lupin as a forage legume at low fertiliser inputs, or the success of rhizome spreading Caucasian clover at high fertiliser inputs.

In summary, the site has demonstrated:

- there is a range of legume species available according to the fertiliser level used
- there is a need for grasses with better autumn production and winter standing feed quality, along with the difficulty of their establishment at modest fertiliser rates
- collectively S and P fertiliser can increase sheep grazing capacity by 3-4 fold, and the addition of irrigation 8-10 fold
- fertiliser and seeding of introduced species can overcome the weed hieracium.

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