The Rough Guide to Herbal Leys

Introduction

Herbal leys (or multi-species swards) have become increasingly popular as farmers and policy makers look to integrate them into farm systems. There is strong evidence that they can deliver multiple benefits in grazing production systems, such as climate resilience, high levels of livestock production, reduced input use and biodiversity support. But there are challenges in managing them, with much yet to understand about the mechanisms surrounding what makes a herbal ley successful.

Herbal leys are not new. Robert Elliot from the Scottish Borders wrote about his Clifton Park system of farming at the turn of the last century. He developed a low input system using a mix of grasses, legumes and herbs to help build soil health and fertility ahead of the cereal part of his rotation. He also noted how animal performance benefited from grazing these leys.

Well implemented and in the right context, herbal leys deliver benefits for the wider environment and food production on improved or arable land. It's important to note that they are not the same as, nor should they replace existing species rich or semi-natural pastures.

This publication is divided into three sections - an overview, information on the key species and two case studies. It seeks to bring together key knowledge and insight to help inform and guide farmers and growers towards successfully fitting them into their own farm system.

1

OVERVIEW

Key 'need to know' information on herbal leys and the potential benefits they can deliver

2

KEY SPECIES

Guide to the main species commonly used in herbal leys and their needs

3

CASE STUDIES

Examples of how farmers are using herbal leys in their systems

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Key Principles

"Start with the end in mind"

As with establishing any pasture or forage crop, its important to consider what your key objectives are. Herbal leys can serve many beneficial functions depending on the species chosen - they each have strengths and weaknesses.

Potential objectives include:

- To increase total dry matter production
- To reduce N usage, optimise N efficiency or reduce N losses
- To provide high quality feed during periods of production - lactation and growth
- To offer higher levels of micronutrients
- To offer dietary choice
- To increase animal output per hectare
- To reduce anthelmintic use
- To maintain production during dry periods
- To improve nutrient cycling
- To build fertility ahead of an arable crop
- To improve soil function
- To improve soil health/function
- To support biodiversity
- To reduce carbon footprint

Whilst this is an impressive list, herbal leys can be challenging to manage, particularly if we are expecting multiple benefits from them. Some of the species available may be unfamiliar and require new management knowledge or skills to fit into existing livestock systems.

For success, it's important to find the 'right' species combination, not only to match your main objectives but for compatibility in terms of plant productivity and persistence.

Design of the mix should be based around what you hope to achieve alongside knowledge of the species available and their characteristics. You need plants that will perform well in your soils and climate, suit your grazing needs and stock classes available. As noted by Younie (2008) *'the management system employed, including during establishment has an over-riding effect on botanical composition'*

THE FUNCTIONAL GROUPS

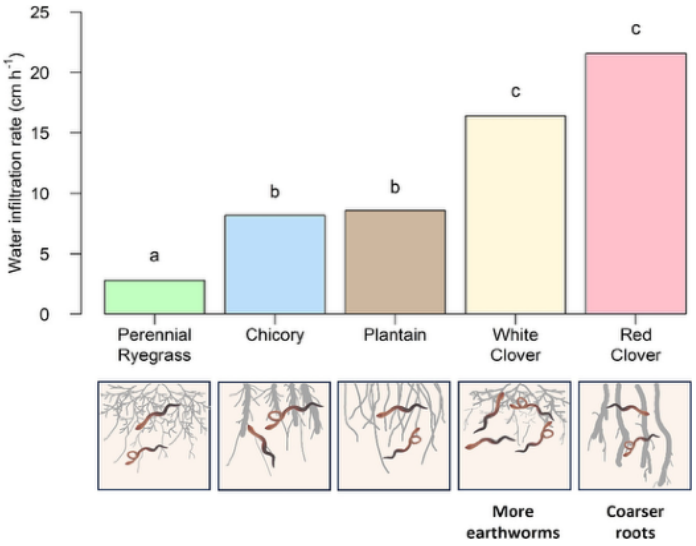
The plant species included in herbal leys are grouped into three functional groups, or plant families that share similar characteristics or roles within an ecosystem ie what the plants do.

1. **The grasses** - provide biomass (yield). They typically have narrow, upright leaves which grow from the base, close to the soil surface, making them well suited to continual growth when grazed. They are nitrogen users.
2. **The legumes** - fix atmospheric nitrogen and provide high quality forage with good protein levels. They have broad leaves, most of the grazing legumes have three leaflets joined to form a single trifoliate leaf. Most are upright in growth, though white clover is prostrate and can better tolerate grazing.
3. **The herbs** (also known as forbs) - are made up of a diverse range of plant families that typically have good nutritional value, including key micro minerals, along with secondary or bioactive compounds which can support livestock health.

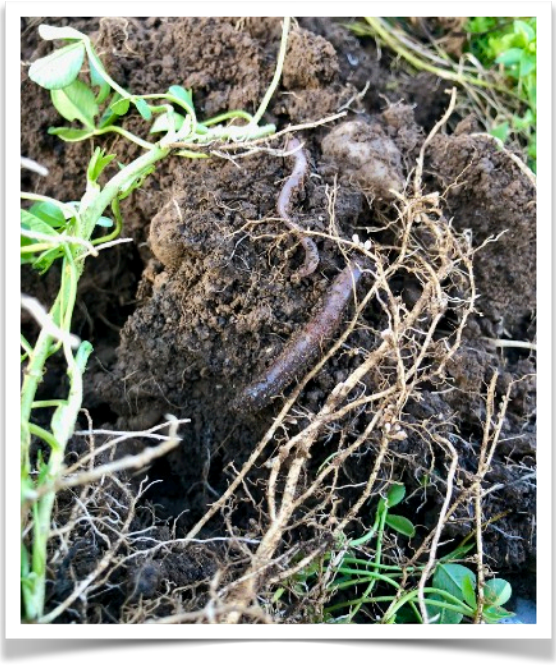
Wider ecosystem service benefits

One of the most widely known benefits of mixing different species with complementary traits is the increased production seen when mixing grasses with legumes. The Nitrogen (N) fixation by legumes compliments well with the N-use efficiency of grasses, offering a yield benefit when growing both together. Legumes offer the opportunity to reduce or remove the need for bagged nitrogen and aiming to establish at least 30% legume content in the sward will drive animal production and make best use of N-fixation.

Research into the wider ecosystem service benefits of herbal leys is ongoing, however there are already some useful insights. Marley et al (2024) found higher water infiltration rates and higher earthworm biomass under red and white clover versus plantain, chicory and ryegrass. They also found that soil bulk density was lower under both chicory and plantain.



Source: Marley et al (2024)



Van Eekeren et al (2009) also found higher earthworm abundance associated with white clover than in ryegrass only swards, as did Crotty et al (2015). Their work looked at the effect of different forage species (ryegrass, red clover, white clover and chicory) on soil faunal diversity and abundance. The lowest diversity was in ryegrass soil, the highest in the soils of the two clovers, with chicory in-between. The soil species associated with the clovers and chicory have also been identified as those which help increase decomposition, promote the N and C cycle and nutrient redistribution..

Work in Ireland on herbal leys (Ryan et al. 2023) found greater soil microbial activity - particularly relating to carbon cycling - deeper in the soil profile when deep rooting plants were present.

KEY RESEARCH SNIPPETS

There is also evidence that suggests diverse swards are better at suppressing weeds. Research across the EU by Finn et al (2013) showed that compared with monocultures, mixtures maintained a resistance to weed invasion over at least 3 years. 'In mixtures, median values indicate <4% of weed biomass in total yield, whereas the median percentage of weeds in monocultures increased from 15% in year 1 to 32% in year 3'. In their literature review TOMS (2021) also found evidence that mixed species showed weed suppression effects.

Nutritional benefits

There is much published research on the performance benefits of livestock grazing herbal leys - in terms of growth and lactation in both cattle and sheep.

It's the higher levels of legumes and herbs in herbal leys, each with their higher nutritional value *and* intake levels that helps drive production.

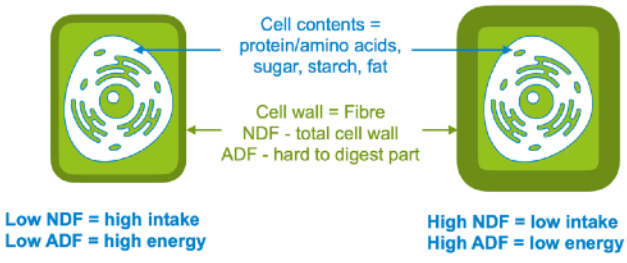
Different feeds vary in their quality, often according to the part being eaten - leaf, stem or root - and the age or stage of plant maturity. More mature forages are generally more fibrous and therefore of lower quality.

For livestock, energy comes from carbohydrates, proteins and fats. For ruminants, carbohydrates are the major energy source and they make up approximately 75% of plant dry matter.

There are two types of carbohydrates found in forage plants;

1) Non-structural carbs - soluble sugars and starches found within the plant cell - these are highly digestible

2) Structural carbs (or fibre) - the plant cell wall, which includes cellulose and hemicellulose. Most of these structural carbs are digestible and contribute most of the metabolisable energy (ME) for ruminants at pasture. On forage analysis, you'll see these are shown as NDF (neutral detergent fibre). Other structural carbs, such as lignin, which provides most of upright support strength to the plant, are the least digestible parts of the plant and are shown as ADF (acid detergent fibre) on forage analyses.



As a general rule;

The lower the NDF, the higher the intake potential
The lower the ADF, the higher the energy content

Pasture quality (or digestibility) is the main driver of pasture intake and animal performance. The higher the digestibility, the less an animal has to eat to meet it's nutritional needs. High digestible feed is therefore really important for animals with smaller rumens, such as growing lambs, or at key production stages with high nutrient demand such as early lactation.

Plant palatability also plays a role. Given choice, livestock - particularly sheep - will preferentially graze legumes and herbs. This is important when considering grazing management systems for herbal leys. Clovers and herbs can be subject to heavier grazing pressure than grasses.

As plants mature towards flowering and setting seed their fibre content increases, particularly in the grasses as stems develop. Thus both the NDF increases (reducing intake) and the ADF (reducing digestible energy content). Even though stock may be full, they won't necessarily be receiving sufficient nutrition. Due to physiological differences, both the legumes and herbs tend to see less of a decline in quality as they mature offering more consistency in diet quality, particularly during the summer, than the grasses.

A certain amount of fibre is required in ruminant diets and ADF levels of <20% and NDF levels <28% can cause metabolic issues. Although it is unlikely that levels will be this low in any of the pasture species.

Bioactive compounds - protein, worms, bloat & methane (CH_4)

Not only are legumes and herbs highly digestible, they also contain good levels of some key minerals along with plant secondary metabolites such as condensed tannins, which can support nutrient use efficiency, provide anthelmintic effects, reduce bloat risk and methane production.

Condensed tannins (CT) can have a big effect on the digestion and absorption of protein. In the rumen they bind to and protect plant proteins from microbial breakdown, allowing more amino acids to reach the small intestine. They effectively increase the 'bypass' or undegradable protein in the diet.

However, high levels of CT can also interfere with the absorption of amino acids in the small intestine, so are considered anti-nutritional when at levels of >5% dry matter. At these high levels, they reduce both the palatability (so intake is lower) and digestibility of the plant (Waghorn et al 1998).

Although research is ongoing, levels of around 2-4% are thought to bring the most benefit; but not just nutritionally. These levels can also reduce the risk of bloat (birdsfoot trefoil and Sainfoin are known for not causing bloat), have an anthelmintic effect and reduce levels of methane emitted.

The protein protection effect also shifts some nitrogen excretion from urine to faeces where it is more stable, thus helping to reduce the risk of N losses via leaching.

Table 1 Potential benefits[#] of condensed tannins in temperate forages for ruminants.

- Prevent bloat in cattle
- Reduces dags in sheep and flystrike
- Can increase rate and efficiency of liveweight gain
- Can increase wool growth (11% with BT[a])
- 15% increase in milk production from sheep (with BT)
- High protein, low fat milk
- Can increase ovulation rate in sheep (with BT)
- Improved tolerance of nematode burdens in sheep and deer
- Reduces worm numbers in sheep fed sulla

[#] Benefits do not apply to all types of condensed tannin
[a] Birdsfoot trefoil

Source: Waghorn et al (1998)

Research is ongoing to fully understand how plant secondary metabolites, not only condensed tannins, can help enhance production and deliver wider ecosystem services.

KEY RESEARCH SNIPPETS

Although white clover leaves are low in condensed tannins, their flowers and seed contain higher levels - highlighting that CT levels vary across species at different maturities. Whilst birdsfoot trefoil offers ideal levels of CT, the challenges of yield, competitiveness and persistency makes it a challenging plant to grow. There is work currently underway in New Zealand to develop white clovers with higher condensed tannins levels.

Legume species	CT level (% DM)
Lucerne	<0.05%
White clover (leaves)	<0.2%
White clover (flowers)	~3%
Red clover	0.3-1%
Birdsfoot trefoil	1-4%
Sainfoin	2-5%

Mineral content

Livestock mineral deficiencies can be highly location and soil specific. Although able to supply some of the main macro-minerals - Calcium (Ca), Phosphorous (P) and Magnesium (Mg), grasses are not a major source of some of the key micro-minerals such as Cobalt (Co), Copper (Cu), Selenium (Se), Iodine (I) and Zinc (Zn).

However, both legumes and herbs do contain some of these micro-minerals that can be production limiting.

It's important to note that the mineral profile of plants is affected by several factors, including plant species and maturity, location, weather conditions, soil pH and fertility. Season also plays a role and some forages at certain times of the year may be able to fully supply the trace mineral requirement of the animal, but not at other times.

With the caveat that plant mineral content can vary, research in the UK by Darch et al (2020) found the the following:

- Herbs were highest in Iodine (I) and Selenium (Se)
- Legumes were highest in Copper (Cu), Cobalt (Co), Zinc (Zn) and Iron (F)
- Grasses were highest in Manganese (Mn) and lowest in Copper (Cu), Cobalt (Co) and Iron (Fe)

Although some species have high levels of certain minerals, it's important to consider what proportion of the available pasture they make up. There may not be sufficient dry matter of species available, or intake to meet the animal's mineral needs.

However, the work by Darch et al (2022) highlights that if seeking to improve mineral uptake, selecting species which suit and yield well on your specific soils is important.

When considering addressing mineral needs it's important to undertake this in consultation with a vet or mineral nutrition specialist.

Plantain is also notably high in Calcium (Ca), along with most of the legumes. Care needs to be taken if removing early to peak lactation livestock from pastures containing high levels of plantain and red clover. Work from NZ suggests that hypocalcaemia is a risk if the pasture they move to a pasture which has lower calcium levels.

KEY RESEARCH SNIPPETS

Its not just the condensed tannins that support the anthelmintic effect of the herb species. When compared with perennial ryegrass, Marley et al (2006) found that there were fewer infective larvae (58% and 63% fewer for birdsfoot trefoil and chicory respectively) 14 and 35 days following application of sheep faeces to trial plots. Their findings suggest that the structure of the plants, compared to ryegrass, reduce the ability of infective larvae to develop, survive or migrate into the grazing zone.

Is what you sow, what you get?

In his publication on ley farming in 1941, George Stapleton notes *"even to this day there are adherents to the idea that the more species which are included in the seeds mixture, the better the resultant sward"* however, he notes…."*that only a few of the main species settle down and become real contributors to the sward, no matter how complex the mixture". George Stapledon (1941)*

Sow the same mix on five different farms and you'll see five different looking leys. Soil type, fertility, pH, sowing date, method and depth can all have an impact on which species establish successfully. Add in weather variables and different management regimes and it's unsurprising that individual species that establish and thrive will vary across farms.

There will always be trade-offs between sward composition and management, but it is possible to factor out some of the 'failure' risks by choosing mixtures based on:

- Soil type and fertility - your soil texture, pH, high or low fertility
- Climate and weather - species suited to drought or heat tolerance
- Intended use - the stock classes you have, your planned grazing system or suitability for cutting
- Species compatibility - plants that suit similar grazing timing, pressure or rest periods.

Most of the species available are suitable for a range of soil types, however some are **particularly** well suited to certain soil types:

Light land:

grasses: cocksfoot and tall fescue

legumes: sainfoin and lucerne

herbs: yarrow

Medium land:

grasses: festuloliums

legumes: white clover and birds foot trefoil

herbs: plantain

Heavy land:

grasses: timothy, meadow fescue, ryegrass

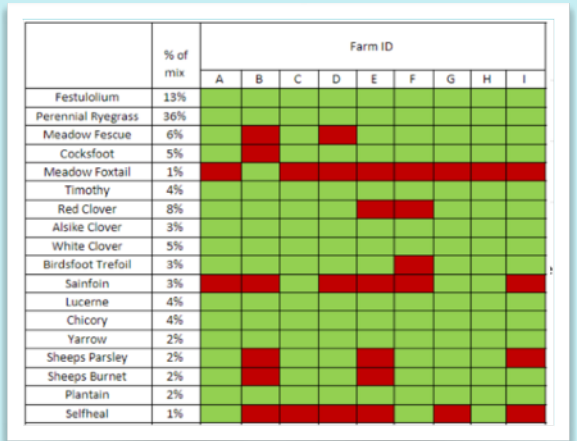
legumes: red clover and alsike clover

herbs: burnet

KEY RESEARCH SNIPPETS

In their investigation into the performance of mixed species swards across a number of farms in Cornwall, the TOMS team found some species didn't establish well at all - particularly Selfheal, Meadow foxtail & Sainfoin. With other species establishing well on some farms, but not others.

Farmers also anecdotally report sheep's parsley and burnet having low competitiveness and persistency.



https://www.multispeciessward.co.uk/our-farm-research/

Competition between species and persistence

When several plant species share the same space, they compete for resources. There is competition for light, for nutrients and for water.

Grasses tend to be dominant species. Part of the reason is physiological. Grasses are monocots, that is they have a single seed leaf with fibrous root systems. Legumes and herbs are dicots, they have two seed leaves and generally, though not always, have taproot systems. Having to invest in establishing large root systems means these dicot species take longer to establish their aboveground biomass, making them susceptible competition from the more dominant species.

Being slower to establish and to build above ground biomass results in some of the herb and legume species need a longer period to their first graze following germination. Table 1 overleaf shows germination times and suggested date to first graze. It also explains why autumn sown leys tend to become grass dominated, but legumes and herbs tend to establish better in spring sown leys.

Herbs and legumes generally require higher soil temperatures to grow than the grasses and show lower winter and shoulder season growth. This also

gives the grasses a competitive advantage, although the herbs and legumes tend to show higher late spring early summer growth. The herbs and legumes are also highly palatable and tend to be preferentially grazed. Grasses again retain a competitive advantage by being able to recover and regrow more quickly from defoliation throughout most of the season.

These are core reasons why persistence is an issue with many herbal ley species. There's a constant trade off between each species needs - the challenge of not grazing the dominant species too late, nor the less competitive species too early. Being able to control and manage the grazing is important to support the persistence of different species.

GRAZING MANAGEMENT

The herbs and legumes are particularly sensitive to grazing frequency and continuous grazing can very quickly result in loss of these species. They need sufficient time (rest period) to replenish root reserves following defoliation. This is often longer than for the grasses. They are therefore best suited to rotational or strip grazing (with a back fence).

Many of the herb and legume species also have a crown, or growing points at or just above soil level; the grazing residual or cutting height is also important. Recommendations are to cut or graze to around 6-8cm. Although both are important, much of the research into plantain and chicory suggests that grazing frequency (having sufficient rest period) is more important for persistency than grazing intensity (residual height). Rest periods will depend on pasture growth rates, a rough rule of thumb is to add at least 6-10 days to an intensive ryegrass/white clover rotation rest period.

TABLE 1 – ESTABLISHMENT TIMES

Please note that values are an indicative range based ideal conditions. Soil fertility, type, temperature, moisture and sowing depth can all impact.

Forage type	Days to germination	Seed depth	Weeks to first graze	Comments
Perennial Ryegrass	7-10	10-20mm	6-8	Pluck test
Festulolium	10-14	10mm	8-10	Pluck test
Timothy	14-21	Max 10mm	8-10	Pluck test
Cocksfoot	14-21	10mm	10-12	Pluck test
Meadow Fescue	10-14	10mm	8-10	Pluck test
Tall Fescue	14-21	Max 10mm	10-12	15-20cm
White clover	7-14	5-10mm	6-8	
Red clover	7-10	5-10mm	8-10	7-8 true leaves
Birdsfoot trefoil	10-21	5-10mm	10-12	
Alsike	7-14	10-15mm	8-10	
Lucerne	7-14	5-10mm	12-14	
Sainfoin	10-14	10-20mm	10-14	
Chicory	7-14	Max 10mm	8-12	When have 7 full leaves
Plantain	7-14	Max 10mm	8-12	When have 6 full leaves
Yarrow	14-21	Max 10mm	10-12	
Sheep's Burnet	7-14	10mm	10-12	
Sheep's parsley	14-21	10mm	8-10	

KEY INFO

Soil temperature plays a key role in seed germination and early root development. Spring temperatures of between 8°C and 18°C are ideal for the germination of most of the grasses herbs and legumes. In NZ, they suggest 12°C is ideal temperature for Chicory, and 10-12°C for plantain https://www.dairynz.co.nz/feed/crops/

Autumn sowing with falling soil temperatures and shortening day length can slow germination, but in particular make it harder for young plants to establish strong root systems and reserves before winter. Spring sowing, with rising soil temperatures is more likely to benefit herb and clover establishment.

Faster germinating and establishing species can outcompete or out-shade the slower species and it can be challenging to manage the ideal time to first graze to control the competitive species, whilst not limiting the slower species. So the mix choice is important for ensuring species persistence.

A mix of between 4 to 6 species is thought to give a optimum balance between diversity and managing competition.

TABLE 2 – NUTRITIONAL VALUE OF DIFFERENT SPECIES

Please note that values are an indicative range. All measures can vary depending on a variety of factors such as soil fertility, environmental conditions, plant age and stage of growth.

Forage type	D-value	ME MJ/kg DM)	CP (% DM)	NDF (%DM)
Perennial Ryegrass	70-80	10.5–12.5	14–20	40–50
Festulolium	68–78	10.2–12.3	13-19	48-53
Timothy	65-75	9.8-11.8	12-18	50–55
Cocksfoot	60-70	9.6-11.2	10-16	50–60
Meadow Fescue	66-76	10.0-12.0	13-19	50–55
Tall Fescue	62-72	9.7-11.5	11-17	53–58
White clover	70-80	11.5-12.5	20-26	30-40
Red clover	65-75	10.5-12.5	18-24	40-50
Birdsfoot trefoil	60-70	9.5-11.5	16-20	40-50
Alsike	65-75	10.5-12.0	17-22	35-35
Lucerne	65-75	10.5-12.5	18-24	40-50
Sainfoin	60-70	9.5-11.5	15-20	45-55
Chicory	70-80	10.3-12.5	18-26	23-28
Plantain	65-75	10.0-12.0	18-25	33-40
Yarrow	No data	No data	No data	No data
Sheep's Burnet	No data	No data	No data	No data
Sheep's parsley	No data	No data	No data	No data

DESIGNING MIXES AROUND STOCK CLASS NEEDS

Breeding/Dry Stock - mature cows, ewes and replacement stock

Pastures for this class need to support the farm's breeding stock numbers through a range of environmental conditions and through winter. They need to be robust and in sheep systems have autumn quality to support tupping.

Lactating Stock - ewes with lambs, suckler cows with calves

Particularly for sheep systems, early lactation is the period of a ewe's highest demand and she needs high digestibility and palatability feed to maximise intake. Pastures need to supply high quality feed, ideally with good clover content as early as possible and not lose quality over the summer. Suckler cows have lower feed demands during lactation than ewes, but may still benefit from quality late spring pasture to ensure ready for bulling

Growing Stock - post weaning lambs and calves, replacement stock

Pastures need to supply high quality feed to maximise growth rates to finish or ahead of first winter. Autumn supply is important, and for units with yearling cattle, quality and supply spring onwards is key.

Perennial Ryegrass

Well suited to temperate, maritime climate where have summer moisture, moderate temperatures and good soil fertility.

Suitable for a range of soil types.

Grows best at 5-18C.

High palatability and digestibility.

Quick to establish, with good persistency.

Reasonable spring and autumn growth.

Yield potential 12-15T DM/ha.

Like all grasses, difficult to maintain quality when enters reproductive phase

Well suited to rotational grazing and cutting for silage or hay.

Growing point is at base of the stem, so can tolerate tight grazing.

Each plant is made up of a number of tillers. Tillers only last for up to a year, so new tillers are required to allow the plant to survive. If insufficient new (daughter) tillers survive to replace the existing (parent) tillers, then will lose plants.

Spring and autumn are key for tillering. Autumn tillers will give winter and spring growth, that will then go onto develop flowering stems. Spring tillers will give late spring, summer and autumn growth. Lax grazing in late spring can shade out new daughter tillers.

Diploid and Tetraploid Ryegrasses

Diploids have two chromosomes. They have smaller cells and leaves, with lower moisture content. They tend to produce more tillers, provide denser swards, more prostrate growth, and sustain production in lower fertility and water soils. They are more persistent than tetraploids and well suited to grazing.

Tetraploids have four chromosomes. They have larger cell size and wider leaves with higher levels of soluble carbohydrates and less fibre giving higher palatability. They have a slower recovery after grazing. Tetraploids have a more upright growth habit and don't tiller as vigorously. They are more suited to drier conditions.

Italian Ryegrass is a short lived species, lasting only two years. It will grow at the lowest temperature of all the grasses at 3°C, offering useful shoulder season growth. It's quick to establish, has an open upright growth habit. Yield potential 16-18T DM/ha with good palatability and digestibility levels. Also available as diploid or tetraploid.

Hybrid Ryegrass is a cross between Italian and perennial ryegrass. It has a lifespan of around 4 years. Brings benefits of both species.

KEY REASONS TO GROW

- Well suited to most conditions across the UK with good persistence
- Tolerant of a range of management and grazing regimes
- Quick to establish with good yields of high digestibilty feed
- Wide choice of varieties and types to match management needs

Festuloliums

These grasses are a hybrid between ryegrass and fescue. Their parent can be either Italian or perennial ryegrass (the former being shorter-lived) and either tall or meadow fescue (the latter being higher quality).

Quick to germinate, albeit slightly slower than ryegrasses.

Can grow on more variable soils than ryegrasses, and have a deeper root structure.

The fescue genes offer good resilience to stress conditions such as drought, heat or cold - the ryegrass genes offer rapid establishment, good nutritional value and palatability.

Most festuloliums have Italian ryegrass breeding - so only have a short lifespan of 2-3 years.

Varieties that are more ryegrass in type will show good early and late spring growth.

For those varieties that are more fescue in type, their summer growth will be better than ryegrass and they will have a slightly slower post grazing regrowth rate than ryegrass.

KEY REASONS TO GROW

- Combines the best attributes of ryegrass and fescues - offering a more robust species
- Palatable grass with good dry matter production and nutritional content

The Fescues - Tall & Meadow

Tall Fescue

Drought and heat tolerant - better hot/dry summer growth than other grasses.

Slow to germinate and establish with low seedling vigour. Best sown when soil temp >12C.

Can tolerate low pH.

Useful in lower fertility soils.

Yield potential 12-15T DM/ha.

Needs time to establish before first graze. First graze should be when plants are 15-20cm tall.

Don't graze below 7cm during establishment year.

Once established, graze before reaches 3000kg DM/ha ~18cm.

Best suited to rotational grazing.

Upright growth habit, lax grazing can leave tussocks - which can provide a useful habitat

Once feed quality is lost, it's difficult to graze well.

Ryegrass can dominate and outcompete it

Can defer in late summer to early autumn, but best grazed in first half of winter.

Credit: Rob Still/WildGuides

Meadow Fescue

Suits a range soil types, but useful in heavier clay type soils

Thrives in slightly acidic to neutral soils

Excellent cold tolerance/winter hardiness.

Once established, more drought tolerant than ryegrass.

Moderate establishment time, butquicker than tall fescue

Growth rate drops when temperature <5C and in colder environments will be semi-dormant over winter. In milder winter climates will have low growth rate. Less winter active than tall fescue

Good early spring growth

Higher feed quality than tall fescue (lower fibre content).

Lower yielding than tall fescue - potential 7-10tDM/ha. In fertile soils will yield at 80-90% of ryegrass

Best suited to rotational grazing - benefits from a rest period.

KEY REASONS TO GROW

- Once established, good tolerance to a range of environmental conditions
- Meadow fescue is of higher feed quality than tall fescue. Research from the US showed steers had a higher ADG on meadow fescue vs. tall fescue (0.84Kg/day vs. 0.98Kg/day). But higher yield of tall fescue gave similar gains per hectare (728 vs. 735Kg/ha) Schaefer et al 2014. [NB these swards included white clover].

Timothy

Hardy, persistence species well suited to Northern temperate climate - widely grown in Scandinavia.

Shallow, but wider rooting structure.

Very tolerant of acid conditions - suited to pH5.5-7

Suitable for medium to heavier soils. Will tolerate periods of water logging and ice encasement.

Low drought tolerance.

Slow to establish - best sown earlier in year, low competitiveness in first few months

Small seed - Needs a fine seedbed for establishment - low competitiveness means not ideal for oversowing into existing swards

Reasonable palatability and digestibility - feed quality depends on flowering stage, but particularly palatable in spring, with good early growth in cold, late springs

Well suited to rotational grazing. Grows best if leaving 3-5cm residual.

Slower to recover from grazing than ryegrass

Widely used for cutting, but has a lower sugar content than ryegrass

Upright habit, forms reasonably open sward - mixes well with clovers and other species

Credit: Rob Still/WildGuides

KEY REASONS TO GROW

- Good persistence
- Good early spring growth, particularly in cold, late springs
- Upright habit with low competitiveness, mixes well with legumes and herbs
- Useful where have lower soil pH, or poor soil fertility

Cocksfoot

Persistent, resilient species with good drought tolerance. Well suited to and thrives on light free draining soils.

Extensive, fibrous root system ~15% longer than ryegrass

Good production in low fertility soils

Lower digestibility than ryegrass, (lower water soluble carbohydrates) particularly from mid-summer onwards

Slow to establish, poor competitor during first few months. Best sown earlier in season

Needs intensive grazing to maintain quality. Lax grazing will allow plants to become tall and lose palatability.

Upright habit Tussock forming under lax grazing

Resilient - good winter hardiness with good early spring growth

Despite anecdotal evidence of soil benefits, no peer reviewed evidence of soil health benefits,

Can become dominant in some pastures, particularly against clovers under lax grazing.

Some evidence that it has allelopathic properties It is concluded that cocksfoot roots may have produced metabolites that inhibit the seed germination and plant growth of companion or volunteer species. This could be a contributor to the superior persistence of the species and have significant practical implications on weed control. (Li et al 2016)

KEY REASONS TO GROW

- Good for free draining soils, particularly in drought prone/summer dry areas
- Deep, fibrous roots
- Useful where have poor soil fertility
- Tussocky form provides a good habitat

White clover

Low growing, adaptable, persistent plant that copes well with grazing - unlike other legumes it spreads via stolons

Range of small through to large leaved varieties available. Larger leaved ones tend to be higher yielding but less persistent. Small leaved varieties, lower yielding but provide good ground cover and grazing tolerance, including continuous grazing - especially if maintained at 3-5cm.

Also suits rotational grazing on a short rotation.

Fixes 50-200Kg N/annum.

Pairs well with ryegrass due to it's nitrogen demand and use efficiency.

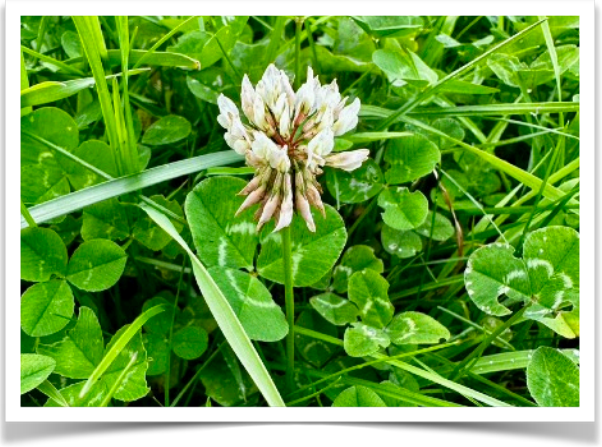
Very low to no winter activity.

Has a higher growing temperature (when soil 8C vs. 5C) than ryegrass, but summer active.

Shallow root depth - low drought tolerance.

Persistence and productivity depend on its stolon (creeping stem) which acts as a carbohydrate store and the site of new leaves, roots and flowers. It needs light at at the stolon (soil) level, particularly in mid to late spring - high pasture covers will shade plants making them susceptible to overgrazing. Repeated shading will reduce clover content in sward.

High quality, highly digestible feed - will be preferentially grazed, but valuable for livestock performance, particularly from mid-summer when grasses lose quality and productivity.



It's higher nutritional value is due to a lower proportion of structural fibre, higher protein content, and higher levels of some key minerals, such as cobalt.

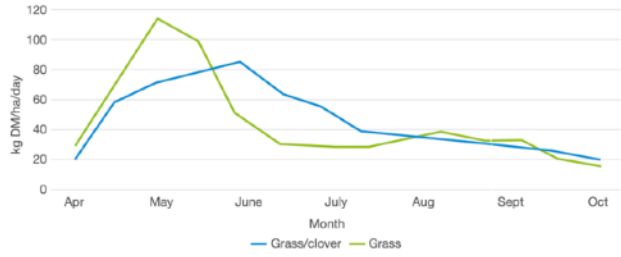


Figure 1. Grass growth curve pattern

Source: AHDB (2021) Establishing and growing clover

The flowering plants also attract pollinators, particularly bees.

Research has shown that white clover can improve soil structure, showing a higher proportion of soil macropores compared to ryegrass (Holtham et al 2007) .

Work by van Eekeren (2010) also showed higher earthworm abundance under clover swards, with evidence that earthworms show a preference for clover litter (Marley et al, 2024)

KEY REASONS TO GROW

- Adaptable in a range of management situations - can persist well in longer term pastures
- High palatability and intake levels, supports high levels of animal performance
- Removes or reduces the need for bagged N
- Maintains its digestibility at a later stage of maturity than the grasses - fills the summer 'grass gap'
- Good for soil structure, earthworms and pollinators

Red clover

Tall upright growing, with strong deep tap root - can tolerate dry periods

Grows from a 'crown' where energy is stored, just above ground level, which is prone to damage from trampling or cutting, particularly in wet conditions.

Reasonably short-lived, usually lasting 3-4 years.

Fixes 150-250KgN/ha/year - highest of all the legumes

Not winter active - recommendation is not to graze over winter , allowing the plant to maintain its stored energy reserves for next season.

Highly palatable with good intake levels and livestock performance. But not tolerant of high grazing frequency or continuous grazing. Best suited to rotational grazing, ideally with at least 30 day rest period.

Summer growth profile complements grass quality and productivity declines.

Quick to establish.

First graze at ~6 leaf stage.

Graze to approx 6cm, cut to 7-8cm.

High yield potential ~12-14T DM/ha and tall growth habit, it can compete reasonably with grasses.

Useful for silage - well suited to cutting.

Some varieties contain high levels of oestrogen which has been implicated with reducing fertility in

ewes tupped on red clover swards. Low oestrogen varieties are available, or avoid grazing with ewes six weeks pre and post tupping.

Can cause bloat in cattle (low in condensed tannins) if sward has high content carefully introduce stock that aren't hungry.

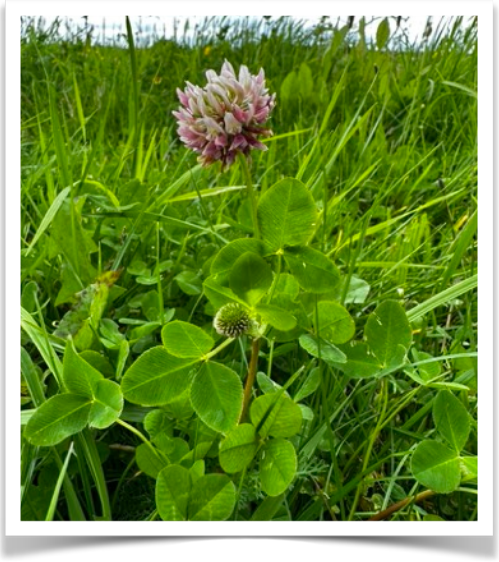
The flowering plants also attract pollinators, particularly bees.

Work is underway to breed longer lasting and stoloniferous versions.

KEY REASONS TO GROW

- High yielding legume, with good palatability and intake levels supporting high levels of animal performance
- Maintains its digestibility at a later stage of maturity than the grasses
- Removes or reduces the need for bagged N
- Suitable for cutting and making high quality silage with good protein levels
- Attractive to pollinators

Alsike



Upright growth habit, similar to red clover.

Believed to have originated in Sweden, grows well in northern latitudes with relatively cool summers.

Good winter hardiness, low winter activity

Tolerant of acidic conditions, wetter, heavier type soils and lower soil fertility

Poor heat and drought tolerance

Short lived legume (2-3 years)

Lower yielding (4-5T DM/ha) and lower N fixation than red clover at 65-150Kgs N/ha/year

Low competitiveness at establishment so not ideal for over-sowing existing pastures, or with the more competitive grasses.

Best grown with grasses such as Timothy.

Shallow root depth.

Graze lightly in first season.

Best suited to rotational grazing. Can be cut for silage.

Can cause bloat in cattle.

No reported issues with phyto-oestrogens.

Some reports of photosensitivity, particularly to horses and when grazed wet.

The flowering plants also attract pollinators, particularly bees.

KEY REASONS TO GROW

- Useful legume for wet, acidic soils
- Good winter hardiness

Sainfoin

Tall, upright habit with deep taproot - suitable for dry conditions - drought tolerant

Prefers deep, free draining soil

Best suited to alkaline soils pH 6.5-7.5

Usually lasts 3-6 years

Cold tolerant, but not winter active

Not tolerant of wet soils

Fixes 130-160Kgs N/ha/year

High yield potential of 10-15t DM/ha

Sow in spring when soils warm

Large seeded- unlike other legumes - sowing depth 2cm. High seed rate required

Slow to establish - long period to first graze (10-14 weeks)

Best sown in the late spring, avoid grazing until the following year.

High palatability with good intake levels and livestock performance.

Best suited to rotational grazing. Continual or frequent grazing will reduce persistency.

Traditionally cut as a hay crop. Regrowth after cutting can be slow - best suited to a single cut

Grows from a crown - cut to 7-10cm height.

Contains beneficial levels of condensed tannins - offering good dietary protein protection, non-bloating and anthelmintic properties. Desrues et al (2015) found a 40% reduction in FEC and 50% reduction of adult *Ostertagia Ostertagi* in jersey dairy calves fed sainfoin pellets against control of ryegrass hay and starter pellets (the diets were balanced for crude protein and net energy)

Credit: Rob Still/WildGuides

The flowering plants also attract pollinators, particularly honey bees - the nectar has a high sugar content and offers good yields of high quality honey.

KEY REASONS TO GROW

- High yielding drought tolerant legume, suitable for free draining/thin alkaline soils
- Non-bloating due to high condensed tannin levels. Also good anthelmintic properties.
- High quality forage, which makes good silage or hay

Lucerne

Tall, upright habit with deep taproot - suitable for dry conditions - drought tolerant

Prefers deep, free draining soil

Best suited to alkaline soils pH 6.5-7.5

Usually lasts 5-8 years

Cold tolerant, but not winter active

Not tolerant of waterlogged soils

Fixes ~250Kgs N/ha/year

High yield potential of 10-15t DM/ha

Sow in spring when soils are warm

Slow to establish - long period to first graze (12-14 weeks). Graze lightly, but quickly in establishment year. Cutting is usually recommended for first harvest.

Good palatability with high intake levels and livestock performance.

Best suited to rotational grazing. Continual or frequent grazing will reduce persistency. Allow a rest period of 35-45 days.

Graze or cut to a minimum of 7cm.

Allow a late summer rest period of 6-8 weeks, or allowing up to 50% of stems to develop flowers to build root reserves for the following spring, improving persistence

Makes high quality silage - needs making with care to avoid leaf shatter

It is not necessary to allow lucerne to flower before each cutting/grazing. The only exceptions to this are the first grazing after establishment and once every autumn.

Needs seed inoculation

Can cause bloat in cattle or red gut in sheep. If sward has high lucernecontent, carefully introduce stock that aren't hungry.

The flowering plants also attract pollinators, particularly bees.

KEY REASONS TO GROW

- Good drought tolerance on free-draining alkaline soils
- Highly yielding, highly palatable, high quality forage supporting good livestock production

Birdsfoot Trefoil

Low to moderate height, upright growth, with small tap root.

Suitable for low fertility, low pH (acidic) soils

Good tolerance to both drought and water logging

Slow to germinate and establish - vulnerable to competition from other plant species, particularly during establishment phase. Best grown with non-aggressive grasses.

Yield potential 3-4TDM/ha

Fixes 100-150KgsN/ha/year

Regrows from buds on the stem rather than from the crown, so it's important to not to graze too low 6-10cm residual.

Best suited to rotational grazing, with at least 30 days rest. Ideally allow 6-7 leaves to fully develop (25-10cm) before next graze.

Highly palatable with good intake levels and livestock performance.

Avoid late autumn grazing to encourage root reserves and new shoot development

Not winter active - recommendation is not to graze over winter , allowing the plant to maintain its stored energy reserves for next season.

Continual or frequent grazing will reduce persistency.

Persistence can be improved by allowing seed set. Rest for ~70-80 days from early June. However, this has the challenge of losing pasture quality, and

requirement for careful grazing to support seedling survival

Contains beneficial levels of condensed tannins - offering good dietary protein protection, non-bloating and anthelmintic properties.

The flowering plants also attract pollinators, particularly bees.

KEY REASONS TO GROW

- Wide tolerance to range of environmental conditions; useful where have low soil fertility and low pH
- High palatability
- Non-bloating due to high condensed tannin levels. Also good anthelmintic properties.

Plantain

Upright plant of moderate height with coarse fibrous root.

Suitable for a range of soil types.

Tolerant of a range of soil pH -optimum of ~5.8

Good summer dry tolerance, but not as drought tolerant as chicory

Usually lasts 3-4 years

Later spring sowing is best, once soils have warmed.

Moderately slow to establish, does not compete well with species with high seedling vigour.

Yield potential 8-12T DM/ha.

Highly palatable with good intake levels and livestock performance.

Low winter activity - recommendation is not to graze over winter , allowing the plant to maintain its stored energy reserves for next season.

Highly palatable, will often be preferentially grazed.

First graze important for persistence. Ideally when 6-8 fully developed leaves (around 20-30cm in height).

Graze to 5-8cm.

Best suited to rotational grazing. Continual or frequent grazing will reduce persistency.

Length of rest period more important than residual height - though low residual height risks crown damage

Once established, can withstand more intensive grazing frequency than other herb species

Becomes less palatable and digestible in later stages of seed development - once seed head has hardened.

Good levels of key minerals, notably calcium.

Good feed for supporting lactation, particularly in ewes with triplets or lambed hoggs. But use with care if moving breeding stock from pastures containing high to low levels of plantain from pre-lambing to peak lactation to avoid sudden drop in calcium levels.

Actively forms strong relationship with mycorrhizal fungi.

KEY REASONS TO GROW

- Suited to a range of soil and environment types
- High palatability
- Contains up to four times more calcium level than young ryegrass - can help support high levels of animal performance - particularly lactation
- Maintains its digestibility at a later stage of maturity than the grasses
- Actively forms relationship with mycorrhizal fungi

Chicory

Upright plant with deep taproot that is well adapted to a range of soil types, with fertile free draining soils best.

Can tolerate acid soils (optimal pH 5.6-6.2).

Reliable in hot/summer dry conditions offering good summer production.

Later spring sowing best once soils have warmed.

Low competitiveness at establishment.

Usually lasts 2-4 years.

Yield potential 12-15T DM/ha.

First graze important for persistence. Ideally when 6-8 fully developed leaves (around 25-30cm high).

Best suited to rotational grazing. Continual or frequent grazing will reduce persistency.

Next grazings when approx 20cm high, likely a 25-40 day rotation.

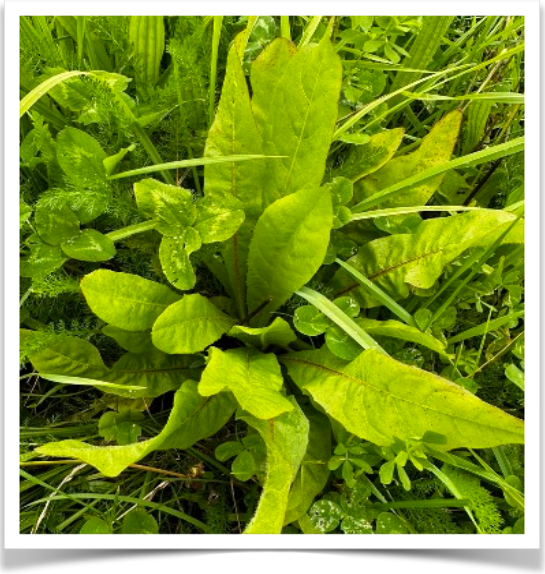
Graze or cut to 5-10 cm.

Grows from crown - need to avoid crown damage from grazing during prolonged wet weather, overgrazing or grazing during winter.

Not winter active - recommendation is not to graze over winter , allowing the plant to maintain its stored energy reserves for next season.

Highly palatable, will often be preferentially grazed.

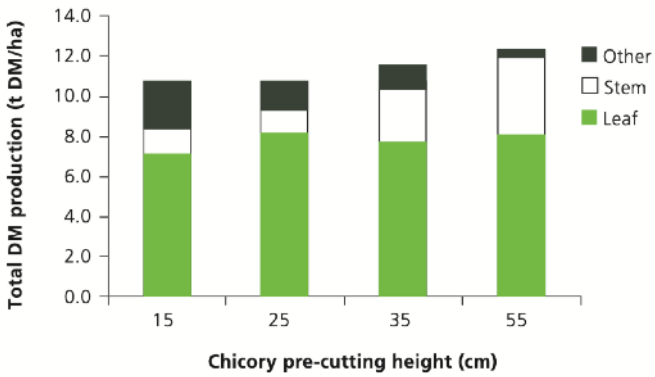
In it's second spring, chicory will develop a flowering stem. Ideally this should be grazed off, stem is still small <10cm and soft. A second



grazing 2 weeks later should reduce stem regrowth for the rest of season. Don't let entry height exceed 25cm in second year and onwards

High digestibility, low fibre.

Plant has an anthelmintic effect, with research showing reduced FECs in lambs grazing pure swards.



Source : Dairy NZ https://www.dairynz.co.nz/media/cxejzxyg/management-of-choice-chicory-crops.pdf

KEY REASONS TO GROW

- Deep taproot, tolerant of hot/summer dry weather
- Productive plant, high palatability with good intake and animal performance levels.
- Could help reduce reliance on anthelmintics
- Maintains its digestibility at a later stage of maturity than the grasses

Yarrow, Burnet and Sheep's Parsley

None of these species are usually grown as a single species, so information on growing and management is sparse.

Yarrow

Yarrow

Prefers well drained, low fertility acidic soils.

Drought tolerant .

Low growing, upright plant with feathery leaves.

Shallow fibrous roots, with a stoloniferous creeping base.

Can withstand heavy grazing/set stocking. Care needs to be taken to avoid lax grazing as it can become dominant.

Burnet

Upright plant, with tap root.

Prefers deep, free draining, alkaline soils pH 6.5-7.5.

Slow to establish with low competitiveness

Recommendation is to not graze until year following establishment.

Research in NZ 'The content of sown species often declined over the study period with that of sheep's burnet declining 20-60% in one year' Douglas & Foote (1993).

Best suited to rotational grazing.

Sheep's Parsley

Prefers light, sandy soils.

Usually biennial

Best suited to rotational grazing

Susceptible to heavy trampling

KEY REASONS TO GROW

- Add further diversity to mix
- Useful sources of minerals and vitamins

Dusty and Michael Rhodes, Low Moorhead Farm, Lancaster

Dusty, Fiona and son, Michael farm in partnership 130ha of mostly SDA land within the Forest of Bowland. Annual rainfall is around1700mm. They have approximately 11.3ha (28ac) of herbal leys across two fields. They run 23 head of stabiliser cross cows, with progeny sold as forward stores at 16-20 months. Alongside around 400 head of Aberfield cross ewes, with lambs sold fat or store, aiming to have all lambs off farm by the end of November.

Dusty and Michael started using herbal leys when they signed up to the SFI Pilot scheme in 2022. Soil health was a key driver of that decision, alongside the wider benefits of high quality pasture to help finish lambs, plus the potential for reduced reliance on anthelmintics and fertiliser.

Their mix included ryegrass, timothy, cocksfoot, sheep's fescue, yellow blossom clover, red and white clover, chicory, plantain, sheep's parsley and burnet. All the species sown did establish, but moving into it's fourth season, as expected, the sward is now predominantly ryegrass and white clover.

Establishment was by spraying off the existing sward then scratched in using a Guttler drill. A small amount prilled lime was applied along with a light dose of slurry. No bagged fertiliser was used. Ground lime was applied the year before, with a target pH of 6.

The sward was grazed lightly during establishment year, then in 2023 they had a high quality pasture for turning ewes and twin lambs onto. Good lamb growth rates are achieved, with twins on the herbal ley showing similar growth rates to singles. The fields are divided into nine 1.2 ha (3 acre)

Credit: Michael Rhodes

paddocks and rotationally grazed on three day moves, giving a 24 day rest period. Silage is made when pasture supply exceeds demand. The paddocks are then shut off in October/November and may be re-grazed in January, depending on the weather. Despite living in a wet part of the country, Dusty and Michael haven't reported any issues with damage to the herbal ley.

Although it has been difficult to quantify soil health benefits, Dusty and Michael do see the value in the high quality feed, that allows them to increase output by finishing lambs quickly, coupled with the reduction in fertiliser use. They note that herbal leys have been a benefit to the system, and would likely still use them to some degree even if funding support was not available.

KEY BENEFITS

- Production of high quality feed to help drive ewe lactation and lamb growth from a limited area of improved ground
- Reduced reliance on bagged fertiliser

James Drummond, Lemmington Hillhead, Alnwick

James farms 380ha near Alnwick, Northumberland. The farm includes approximately 200ha of herbal leys. An Innovis breeding partner, James runs approximately 1,500 mostly stud ewes, with 350-400 ram lambs grown on for sale as shearlings. Any lambs not making the grade for breeding are sold fat, finished on herbal leys. The farm also runs 115 head of mostly spring calving Angus type suckler cows, with calves sold either store or finished.

Just over ten years ago James undertook a Nuffield Scholarship looking at improving economic efficiency in sheep systems. Having seen herbal leys in New Zealand improving the performance of lambed ewe hoggs and ewes rearing triplets, he has been using them on his own farm since 2014.

With this strong forage focus, James has clear objectives for each of his pastures according to the stock class he needs to support through the season and he tailors his mixes accordingly. These are:

- wintering cattle - youngstock
- ewe lactation and lamb finishing
- growing on ram lambs

To achieve this, he uses a short term winter mix which includes brassicas, short term grasses - such as Italian ryegrass and Festulolium, with annual clovers, perennial white clover, chicory and plantain. This mix will last two winters before being reseeded as a longer term herbal ley. It is grown in blocks alongside fodder beet allowing cattle to strip graze both crops at the same time. Including the chicory and plantain is with the intention of increasing the seed bank of these two species, allowing seed set over the deferred summer to autumn period before being grazed over the winter. Early spring regrowth is then grazed by sheep, followed by silage, then deferred for next winter.

For the other stock classes, the growing rams are on an all grass wintering system where James is targeting early spring growth. He includes tetraploid perennial and hybrid ryegrass and festulolium along with legumes and herbs. His longer term mixes where early season growth is less important will include grasses such as timothy and cocksfoot alongside tetraploid ryegrasses. Having tried various herb and legume species, he has settled on plantain, chicory, yarrow, birdsfoot trefoil, red and white clover. He aims for 60% grass, 20% legumes, 20% herbs, by weight. He includes a high proportion of birdsfoot trefoil to help reduce the risk of red gut in lambs (intestinal torsion). James feels it's important to have more upright growing grasses that leave space for the herbs and legumes to establish and thrive. He has some leys that still have good species diversity after 5 to 6 years.

Early experience was that set stocking greatly reduced the persistence of many of the herb and legume species. Apart from a brief period of set stocking for lambing at the end of April, all stock are either rotationally grazed or, for the winter crop, strip grazed. Surplus growth is made into silage using a mower conditioner, allowing a 48 hour wilt before baling. He aims to avoid turning the crop if possible.

All pastures are established via direct drilling. Areas that were in fodder beet are subsoiled and disced to level. Any existing swards are sprayed with a quarter rate of glyphosate, mixed with 2L/ha of fulvic acid. He doesn't plough and feels that full cultivation results in newly establishing plants have less of a 'hold'. James aims for a soil pH in the high 6's for the winter grazing area, falling to around 6 for the rest of the farm. Sowing date is also important and he finds late April to the end of June gives the best results, anything after the end of July is much less successful.

KEY BENEFITS

- Having these clear objectives for his pastures allows James to run a successful low input, high output forage based grazing system

AHDB (2021) Establishing and growing clover. https://projectblue.blob.core.windows.net/media/Default/Beef & Lamb/ManagingClover2871_210310_WEB-1.pdf.

Berard, N.C., Y. Wang, K.M. Wittenberg, D.O. Krause, B.E. Coulman, T.A. McAllister, and K.H. Ominski. 2011. Condensed tannin concentrations found in vegetative and mature forage legumes grown in western Canada. Can. J. Plant Sci. 91:669-675.

Burggraaf, V. & Woodward, S. & Woodfield, Derek & Thom, E. & Waghorn, G. & Kemp, Peter. (2006). Morphology and agronomic performance of white clover with increased flowering and condensed tannin concentration. New Zealand Journal of Agricultural Research. 49. 147-155. 10.1080/00288233.2006.9513704

Emily C. Cooledge, Nigel R. Kendall, Jonathan R. Leake, David R. Chadwick, Davey L. Jones (2024) Herbal leys increase forage macro- and micronutrient content, spring lamb nutrition, liveweight gain, and reduce gastrointestinal parasites compared to a grass-clover ley, Agriculture, Ecosystems & Environment, Vol 367, https://doi.org/10.1016/j.agee.2024.108991. (https://www.sciencedirect.com/science/article/pii/S0167880924001099)

Cotswold Seeds (online). Knowledge Hub - https://www.cotswoldseeds.com/knowledgehub.asp

Cotswold Seeds (online) Sowing & Growing Sheep's Parsley https://www.cotswoldseeds.com/articles/772/sowing-and-growing-sheeps-parsley

Dairy NZ Management of 'Choice' chicory special purpose crops - https://www.dairynz.co.nz/media/cxejzxyg/management-of-choice-chicory-crops.pdf

Darch, T.; McGrath, S.P.; Lee, M.R.F.; Beaumont, D.A.; Blackwell, M.S.A.; Horrocks, C.A.; Evans, J.; Storkey, J. The Mineral Composition of Wild-Type and Cultivated Varieties of Pasture Species. Agronomy 2020, 10, 1463. https://doi.org/10.3390/agronomy10101463

Darch T, Blackwell MSA, Hood J, Lee MRF, Storkey J, Beaumont DA, et al. (2022) The effect of soil type on yield and micronutrient content of pasture species. PLoS ONE 17(11): e0277091. https://doi.org/10.1371/journal. pone.0277091

Desrues, O., Pena-Espinoza, M. A., Hansen, T. V. A., Mueller-Harvey, I., Enemark, H., & Thamsborg, S. M. (2015). Anthelmintic effects of sa infoin against different catt le nematodes may be linked to concentration of condensed tannins in different gut compartments. In 25th International Conference of the World Association for the Advancement of Veterinary Parasitology: Abstract Book (pp. 58-58). https://scispace.com/pdf/anthelmintic-effects-of-sainfoin-against-different-cattle-1no2q3bzwi.pdf

Douglas (1991) Establishment and early regrowth of sheep's burnet (Sanguissorba Minor sap *Muricata*). Thesis presented in partial fulfilment of the requirements for the degree of Doctor of

Douglas, G B & Foote, A G (1993) Growth of sheep's burnet and two dryland legumes under periodic mob-stocking with sheep. New Zealand Journal of Agricultural Research. Vol 36: 393-397 https://www.tandfonline.com/doi/abs/10.1080/00288233.1993.10417739

Finn & Kirwan, Laura & Connolly, John & Sebastia, M.-Teresa & Helgadottir, Aslaug & Baadshaug, & Bélanger, & Black, Alistair & Brophy, & Collins, Rosemary & Cop, & Dalmannsdottir, Sigridur & Delgado, & Elgersma, Anjo & Fothergill, & Frankow-Lindberg, B. & Ghesquiere, An & Golińska, Barbara & Golinski, Piotr & Lüscher, Andreas. (2013). Ecosystem function enhanced by combining four functional types of plant species in intensively managed grassland mixtures: A 3-year continental-scale field experiment. Journal of Applied Ecology. 50. 365-375. 10.1111/1365-2664.12041

Germinal white clover seed guide https://germinal.com/white-clover-seed-guide/.

Hughes M, Phillips E J, Jones R A (2023) Supplementation of minerals and vitamins influences optimal targeted selective treatment thresholds for the control of gastro-intestinal nematodes in lambs, Veterinary Parasitology, Volume 322, ISSN 0304-4017, https://doi.org/10.1016/j.vetpar.2023.110026

Holtham D, Matthews P G & Scholefield P S (2007) Measurement and simulation of void structure and hydraulic changes caused by root-induced soil structuring under white clover compared to ryegrass, Geoderma, Volume 142, Issues 1–2, 2007, Pages 142-151. https://doi.org/10.1016/j.geoderma.2007.08.018.

Li, S., et al., Competition between cocksfoot (Dactylis glomerata L.) and companion species: Evidence for allelopathy. Field Crops Res. (2016), http://dx.doi.org/10.1016/j.fcr.2016.08.005

Marley, C L, R. Cook, J. Barrett, R. Keatinge, N.H. Lampkin (2006). The effects of birdsfoot trefoil (Lotus corniculatus) and chicory (Cichorium intybus) when compared with perennial ryegrass (Lolium perenne) on ovine gastrointestinal parasite development, survival and migration. Veterinary Parasitology, Volume 138, Issues 3–4, 2006, Pages 280-290

MacAdam, JW & Villalba, JJ (2015) Beneficial Effects of Temperate Forage Legumes that Contain Condensed Tannins. Agriculture 2015, 5, 475-491; doi:10.3390/agriculture5030475

Marley, C L, Rhun Fychan, John W. Davies, Mark Scott, Felicity V. Crotty, Ruth Sanderson, John Scullion (2024) Grasslands and flood mitigation – Contrasting forages improve surface water infiltration rates. Science of The Total Environment, Volume 951. https://

Morris, P., Carter, E., Hauck, B., Hughes, J-W., Allison, G., & Theodorou, M. K. (2021). Responses of Lotus corniculatus to environmental change 4: Root carbohydrate levels at defoliation and regrowth climatic conditions are major drivers of phenolic content and forage quality. Planta, 253(2), 1-11. [38]. https://doi.org/10.1007/s00425-020-03523-x

Ryan KB, De Menezes A, Finn JA, Brennan FP. Plant species and soil depth differentially affect microbial diversity and function in grasslands. J Sustain Agric Environ. 2023; 2: 397–411. https://doi.org/10.1002/sae2.12077

Schaefer, M.R., Albrecht, K.A. and Schaefer, D.M. (2014), Stocker Steer Performance on Tall Fescue or Meadow Fescue Alone or in Binary Mixture with White Clover. Agronomy Journal, 106: 1902-1910. https://doi.org/10.2134/agronj14.0075

Stapledon, G R & Davies, W (1941) - Ley Farming https://journeytoforever.org/farm_library/ley/ley13.html

TOMS (2021), Toolbox Of Multi-species Swards (TOMS) https://www.multispeciessward.co.uk/ accessed February 2025

Vellema, V.P.M.G. Rutten, A. Hoek, L. Moll, G.H. Wentink (1996) The effect of cobalt supplementation on the immune response in vitamin B12 deficient Texel lambs, Veterinary Immunology and Immunopathology, Volume 55, Issues 1–3 151-161. ISSN 0165-2427. https://doi.org/10.1016/S0165-2427(96)05560-2

van Eekeren N, Jan BokhorstA and Lijbert Brussaard B (2010) Roots and earthworms under grass, clover and a grass-clover mixture. Preoceedings from 19th World Congress of Soil Science, Soil Solutions for a Changing World https://orgprints.org/id/eprint/18120/1/2403_.pdf

van Eekeren, N, Diederik van Liere, Franciska de Vries, Michiel Rutgers, Ron de Goede, Lijbert Brussaard (2009), A mixture of grass and clover combines the positive effects of both plant species on selected soil biota Applied Soil Ecology, Volume 42, Issue 3, 2009, Pages 254-263, https://doi.org/10.1016/j.apsoil.2009.04.006

Waghorn, G.C., Douglas, G.B., Niezen, J.H., McNabb, W.C., Foote, A.G., 1998. Forages with condensed tannins—their management and nutritive value for ruminants. Proc. N.Z. Grassland Assoc. 60, 89–98.

Younie, David (2008) Grass clover ley species, variety selection and management. Research Topic Review. Institute of Organic Training and Advice (IOTA), Craven Arms, Shropshire, UK. https://www.organicresearchcentre.com/wp-content/uploads/2022/01/grass-clover-ley-species-and-variety-selection-and-management.pdf