Project Number: 408090

Optimization of subterranean clover for dryland pastures in New Zealand

Sustainable Farming Fund 2015-2016

Guide for subterranean clover identification and use in New Zealand

First Edition

Compiled by the Lincoln University Dryland Pastures Research Team

Lincoln University

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www.lincoln.ac.nz/dryland

Dedication

Malcolm Macfarlane

The Dryland Pastures Research team acknowledge the work of Malcolm Macfarlane in progressing the introduction of legumes onto dryland hill country farms. Malcolm was overseeing the technical aspects of the 'Sub 4 Spring' research work in Southern Wairarapa. We were all saddened by his sudden passing in April 2016. His passion and commitment to New Zealand hill country farmers' remains with us as we continue the work he started and we will continue in his memory in the Wairarapa.

Acknowledgements

The Lincoln University Dryland Pastures Research Team acknowledges the significant contribution of earlier research on subterranean clover in both Australia and New Zealand towards this "Guide for subterranean clover identification and use in New Zealand".

The sections relating to the identification of sub clover cultivars in this publication have followed the template provided in the New South Wales Agriculture Agfact P2.5.16 'Subterranean clover in NSW – identification and use' by B.S. Dear and G.A. Sandral (1997).

We also acknowledge the use of information in the paper by P.G.H. Nichols *et al* 'Genetic improvement of subterranean clover (*Trifolium subterraneum* L.) - Germplasm, traits and future prospects' (in *Crop & Pasture Science*, 64, 312–346, 2013) which presented details on the characteristics of all Australian sub clover cultivars which had been commercialised up to that date.

Mr Roland Stead kindly provided financial assistance to the Lincoln University Dryland Pastures Research Team for the completion of several post graduate programmes that contributed data to this publication.

We also wish to thank the Lincoln University photographer David Hollander for his patience and skill in sub clover cultivar portraiture.

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INTRODUCTION

Dryland pastures in New Zealand

In New Zealand, dryland (rain fed) pastures are dry hill and unirrigated lowland pastures that receive rainfall below evapotranspiration rates in summer and autumn which creates a period of soil moisture deficit that restricts pasture growth. These pastures often have a low (< 5%) legume content and are therefore nitrogen deficient.

There are more than 2 million hectares of summer dry hill country pastures. These semi-arid environments can be found on lowland shallow, stony soils on the east coast of both islands (e.g. Canterbury, Marlborough, Wairarapa, and Hawkes Bay) and also inland in the rain shadow of the alpine ranges where there are warm summers and cold winters (e.g. Central Otago).

These areas may experience 4 to 5 months of summer dry and that limits white clover growth. Lucerne can grow for longer into summer by accessing soil moisture deeper in the profile than other legumes and grasses. Sub clover avoids the drought by producing seed.

The value of subterranean clover

Subterranean clover (sub clover, *Trifolium subterraneum*) is the best adapted clover for dryland pastures in New Zealand. This winter annual clover provides more high quality biomass during late winter and early to mid-spring than the more frequently sown perennial white clover (**Figure 1**). Sub clover is particularly advantageous for high demand livestock such as lactating ewes.

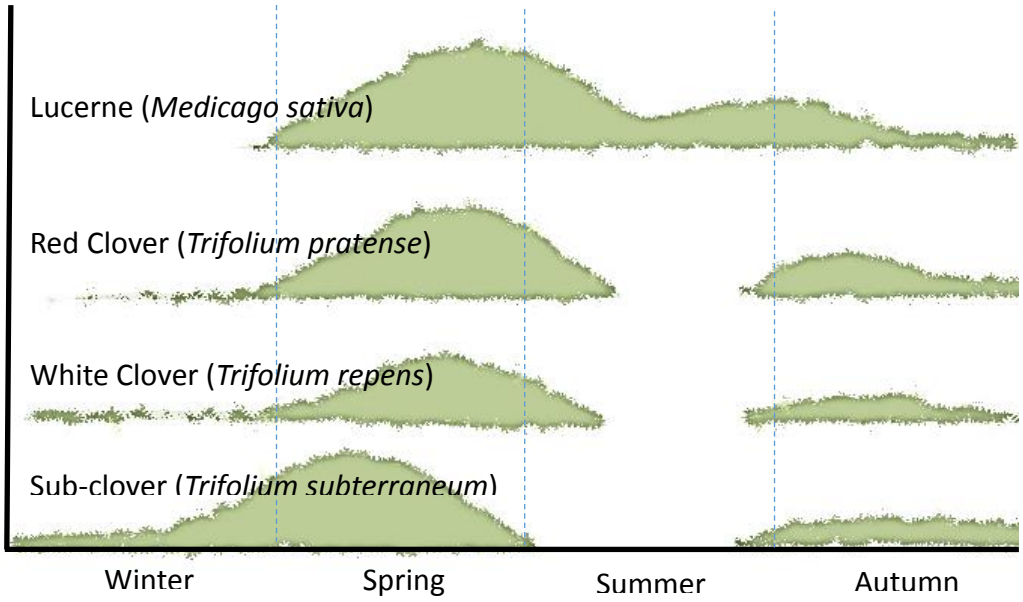


Figure 1: Seasonal biomass production of common pasture legumes under dryland conditions
(adapted by Lucas, R. 2016 from Undersander *et al*. 2002 and Mills *et al*. 2014)

There is a renewed interest in sub clover in New Zealand because:

♣ There is pressure on hill country to intensify production due to the expansion of dairying, grape growing, urban spread and the retirement of high country from grazing.

♣ Legumes are a vital component of hill country pastures for both nitrogen (N) fixation and superior nutritive value.

♣ Recent expansion of lucerne and clover/herb pastures on sheep and beef farms has resulted in increased productivity, particularly in summer.

♣ Sub clover is our earliest growing legume (**Figure 1**).

♣ Summer dry hill country, where lucerne and clover/plantain are difficult to establish and manage, requires improvement so that hill pastures can complement the improved flats and terraces.

The SFF 'Sub 4 Spring' project

The Ministry of Primary Production has supported the Sustainable Farming Fund (SSF) funded 'Sub 4 Spring' research project to identify, describe and promote agricultural practices that will increase the subterranean clover establishment and productivity on dryland farms throughout New Zealand. Experimental plots of sub clover cultivars have been established in sites from Hawkes Bay to North Otago.

This guide

This first edition of "Guide for subterranean clover identification and use in New Zealand" provides information for dryland farmers to:

♣ gain knowledge of sub clover

♣ identify the main sub clover cultivars currently available in New Zealand, and

♣ understand their suitability for different dryland farm environments.

Subsequent editions of the guide will draw on the results of the 'Sub 4 Spring' extension programme and associated post-graduate research projects will then provide farmers with more detailed information about:

♣ choosing sub clover cultivars best suited to their farming environment,

♣ optimising management decisions related to establishment and grazing management for pastures that include sub clover,

♣ effective weed control in the New Zealand context, and

♣ soil fertility to maximise sub clover establishment and growth.

Sub clover runners spreading through the danthonia dominant pasture on an uncultivated west face at Mt Benger Station, North Canterbury (Photo: RJ Lucas)

SUB CLOVER

Legumes in New Zealand

Clovers, along with other legumes such as lucerne, are an essential component of New Zealand pasture systems because of their ability to fix N from the air through a symbiotic relationship with bacteria which form nodules on legume root systems. This fixed N in the soil is available for uptake by the pasture plants. The three most common commercially available clovers in New Zealand pastures are the perennials white clover (*Trifoilum repens*) and red clover (*T. pratense*) and the annual sub clover (*T. subterraneum*). They fix about 30 kg N per tonne of clover grown.

Description of sub clover

The main characteristic of the winter annual sub clover is that it flowers and buries its burrs (seed pods) before the onset of summer drought. This adaptation allows it to provide valuable late winter/early spring feed for stock before it dies off during the dry late spring/early summer months. The buried seed germinates in the autumn as soil moisture increases. These are the essential features of sub clover's winter annual life cycle. Some of these features are shown in **Figure 2**.

Figure 2: Morphological photos for the Mt Barker sub clover cultivar (Photos: David Hollander, 2015)

Cotyledon

Unifoliate

First trifoliate

Seven trifoliate leaves

Single trifoliate leaf

Flower

Stipule

Burr development:

Early

Mature

Dry seeds

Identification photos for sub clover life cycle

Sixteen sub clover cultivars were grown in the Lincoln University nursery and were photographed at key phenological stages during their life cycle in 2015. The photographic catalogue starts with seedlings at the cotyledon stage and finishes with the dry seed. The full set of photos for each cultivar, as shown for Mt Barker in **Figure 2**, are available online.

Sub clover subspecies

Sub clovers are found in a range of different climatic and soil conditions partly because over many generations the *T. subterraneum* species has branched into the following three main subspecies:

- *Trifolium subterraneum* subspecies *subterraneum,*
- *T. subterraneum* subspecies *yanninicum,* and
- *T.subterraneum* subspecies *brachycalycinum*.

The *subterraneum* subspecies is the most versatile subspecies found in areas ranging from 3.7 to 27.3 °C (mean annual temperature), in elevations from sea level to 2940 m above sea level (a.s.l.), in acidic to slightly alkaline soils (**Figure 3**) and in average annual precipitation ranging from <100 to 1540 mm. Most sub clover cultivars found in New Zealand belong to subspecies *subterraneum* (e.g. Campeda, Narrikup, Woogenellup, Denmark, Mount Barker, Rosabrook and Leura). These sub clovers have black seeds and are adapted to well-drained soils with pH_{H_2O} down to about 5.2.

The subspecies *yanninicum* is adapted to soils which may be waterlogged during the cool wet season. Cultivars Monti, Trikkala and Napier have amber coloured seeds (**Figure 3**).

The subspecies *brachycalycinum* has evolved to tolerate more calcareous soils. A pH of at least 5.8 is recommended. The cultivar Antas belongs to this subspecies and has black seeds.

Ewes and lambs grazing sub clover in spring at Tempello, Marlborough (Photo: Jo Grigg)

Figure 3: Summary of sub clover subspecies with recommended soil characteristics. Example images of flowers, burrs and seeds of a cultivar of each subspecies. (Photos by D. Hollander, 2015)

subterraneum e.g. 'Denmark'
Soil acidity: moderately acidic soils of pH_{H2O} 5.2 - 8.0
Drainage: well-drained sandy loam to loamy clay soils

Calyx about ½ the flower length

Immature burr
Mature burrs are buried

Round seed black to dark purple in colour

yanninicum e.g. 'Monti'
Soil acidity: moderately acidic soils of pH_{H2O} 5.2 - 8.0
Drainage: Poorly drained, high water-holding capacity soils; sandy loam to clay soils

Longer calyx on the flower

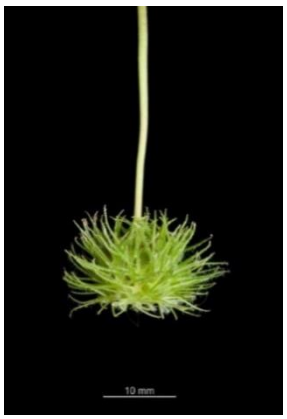
Mature burrs are buried

Seed colour is cream to amber

Yanninicum cultivars have parts that are hairless or less hairy but the leaf is still hairy.

brachycalycinum e.g. 'Antas'
Soil acidity: slightly acidic to alkaline soils of pH_{H2O} 5.8 - 8.0
Drainage: well-drained soils

Calyx about ½ the flower length
Peduncle is long and twisting



Larger 'spikey' burr
Brown when mature

Seed colour is black to dark purple.
Seeds are flat

Commercially available sub clover cultivars

This guide will focus on the main commercially available sub clover cultivars in New Zealand and the most common resident sub clovers which have been sown in the past.

All sub clover seed is currently grown in Australia and imported into New Zealand. From season to season, seed supplies and cultivar choices can be limited by drought in Australia and/or New Zealand biosecurity requirements.

The sub clover cultivars listed in **Table 1**, except for Bindoon, were grown and photographed for identification purposes in 2015 as part of the 'Sub 4 Spring' research project.

Table 1: Sub clover cultivar seed widely sown historically and those currently available in New Zealand (correct at 30 June 2016).

Cultivar	Main supplier/wholesaler[#]	Additional retailers
Antas	Luisetti Seeds (brochure online)	Yes
Bindoon	PGG Wrightson (brochure online)	Yes
Campeda		Specialty Seeds
Coolamon	Agricom (brochure online)	Yes
Denmark		Kiwi Seed Co, Luisetti Seeds
Karridale		Kiwi Seed Co
Leura		Specialty Seeds
Monti	Luisetti Seeds (brochure online)	Yes
Mt Barker*****	No longer available	
Napier	Not available at present	
SF Narrikup	Seed Force (brochure online)	Yes
SF Rosabrook	Seed Force (brochure online)	Yes
Tallarook*****	No longer available	
Woogenellup	Widely sown in the past, seed still available	Farmlands, Kiwi Seed Co, Luisetti Seeds, Specialty Seeds

Key:

Definitely available	Downloadable brochure online
Available	Seed noted on website of seed suppliers
No longer available	Seed 'subject to availability' or not available

[#] Companies named as the 'Main supplier/wholesaler' have the Plant Variety Rights (PVR) to the sub clover cultivar. Seeds may also be available through other seed retailers in New Zealand. See **Appendix 1** for a list of sub clover seed suppliers.

***** While no longer available these sub clover cultivars were historically widely sown in New Zealand and are likely to be resident in dryland hill country pastures.

The main sub clovers cultivars available, as at June 2016, are Antas, Bindoon, Coolamon, Monti, Narrikup and Rosabrook. The cultivars Campeda, Denmark, Karridale, Leura, and Woogenellup are also imported and available through seed retailers.

Some sub clover cultivars have been superseded due to high oestrogen levels (e.g. Tallarook), pest and disease susceptibility and/or a lack of persistence in the grazed pasture environment. Current and new sub clover cultivars are low in oestrogen, selected to be resistant to diseases such as clover scorch (e.g. Monti), and /or are very persistent under grazing (e.g. Denmark). Bindoon, Narrikup and Rosabrook were selected for red legged earth mite (RLEM) tolerance.

Sub clover cultivar identification

Identification features of sub clover

It is recommended that at least two sub clover cultivars should be sown in new pasture seed mixes. Therefore it is important to be able to identify the sub clover cultivars that thrive on different sites. Over several seasons one cultivar may dominate showing that it is better adapted to that site. The location of sub clover plant parts are shown in **Figure 4**. Features which differ between cultivars are:

- trifoliate leaf markings,
- hairiness of runners (stems), petioles (leaf stems), and peduncles (flower stems),
- stipule colour (structure at base of petiole), and
- flower colour (calyx pigmentation).

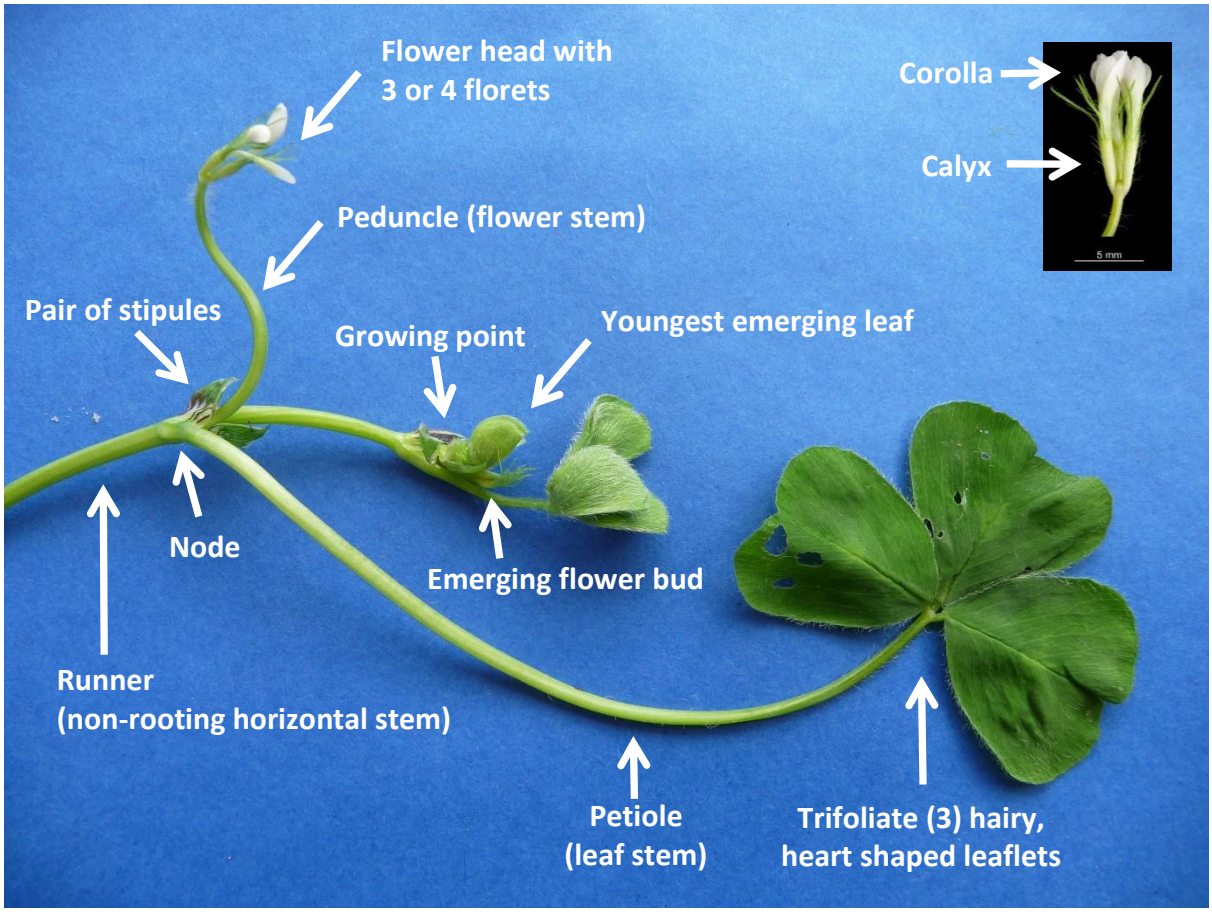


Figure 4: Runner of Monti sub clover and its component parts. Inset shows the parts of a Monti flower (Photo: RJ Lucas, inset David Hollander).

Note that each sub clover node has a leaf, and may have a flower, but no roots (compared with white clover, see **Figures 4 and 5**).

Compared with white clover

You can tell the difference between a white clover (**Figure 5**) and sub clover because white clover:

- ♣ has no hairs
- ♣ has stolons (not runners) which can root at the nodes if they touch the soil, and
- ♣ the white flowers (inset) have many more florets (10-20[1]).

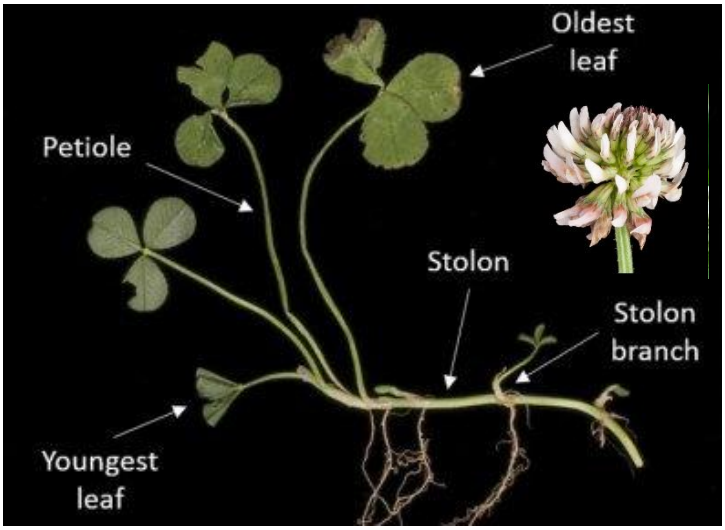


Figure 5: White clover stolon and flower.
(Photo: Dr Alistair Black, inset: David Hollander)

Compared with red clover

You can tell the difference between red clover (**Figure 6**) and sub clover because red clover:

- ♣ does not have runners or stolons and its growth habit is erect and flowering stems can reach 'above knee height', typically about 50 cm in height;
- ♣ has hairy leaves, like sub clover, but the leaflets are more oval in shape, rather than heart shaped as in sub clover, may be larger and usually have a pale "v" mark;
- ♣ flowers (shown) are aerial, have more florets (15 to 30[1]) and are red/purple in colour.

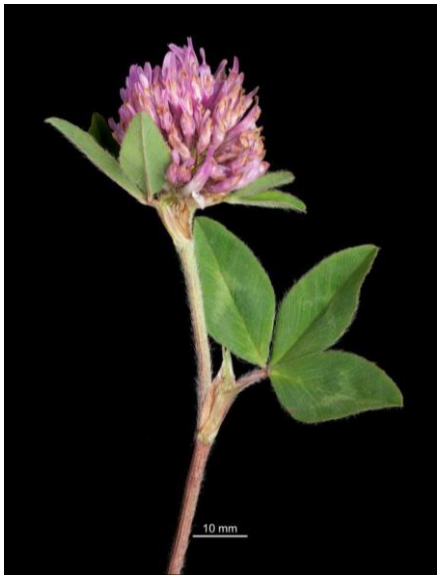


Figure 6: Red clover flower and trifoliate leaf
(Photo: David Hollander)

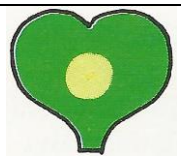
[1] Information from: http://pastureinfo.massey.ac.nz/intropages/welcome.html

Main characteristics for identifying sub clover cultivars

Figure 7: Identification key for sub clover (adapted from Dear and Sandral, 1997).

Trifoliate leaf markings

The colour, shape and position of leaf markings differ between cultivars and are a relatively reliable characteristic. However leaf markings change from winter to spring; and the brown anthocyanin pigment, often seen as 'flecks' or blotches, disappears in leaves produced in spring.

Centre: light green area in the centre of the leaflet				
				
Description	Small central spot	Crescent ½ way across leaflet	Crescent ¾ way across leaflet	Crescent > ¾ way across leaflet
Code	C1	C2	C3	C4

Band: Light green band extending across the leaflet		**Arms**: white 'arms' extending from the crescent (if any) to leaflet margin		
				
Description: Narrow	Broad	Narrow	Moderately broad	Very broad
Code: B1	B2	A1	A2	A3

Stipule

On the stipules, the small leaves at the base of the petiole stem, look for the presence of coloured veins and/or patches:

Stipule pigmentation				
				
Description	Veins green, no red colour	Veins red	Veins red plus narrow red bar	Most of surface red
Code	S0	S1	S2	S3

Hairiness

Note: there are no runners in cool season vegetative rosettes but petioles and stipules are always there.

Runner/stipule hairiness	**No hairs**	**Few hairs**	**Hairy**	**Very hairy**
Code	H0	H1	H2	H3

Flower

The corolla (petal) is usually pure white or white with pink veins and not useful for identification. However the colour of the calyx does varies with cultivar and is a very useful characteristic in spring:

Calyx pigmentation						
						
Description	Whole calyx pale green	Teeth and tip of calyx lightly pigmented	Upper ¼ to ⅓ calyx red	Upper ½ of calyx red	Upper ⅔ calyx red	Upper ¾ to whole tube strongly red
Code	CX0	CX1	CX2	CX3	CX4	CX5

A note about sub clover leaf markings

The trifoliate leaf in **Figure 8**, from the Narrikup sub clover, highlights how the leaflet marking can be made from two separate characteristics. In this case a light green crescent that extends about half way across the leaf (C2) and two narrow white arms extending to the crescent from the edge of the leaflet (A2).

For identification purposes the photos included for each cultivar in this guide are the trifoliate leaf, flower and stipule. **Figure 7** contains a key for identifying sub clover cultivars.

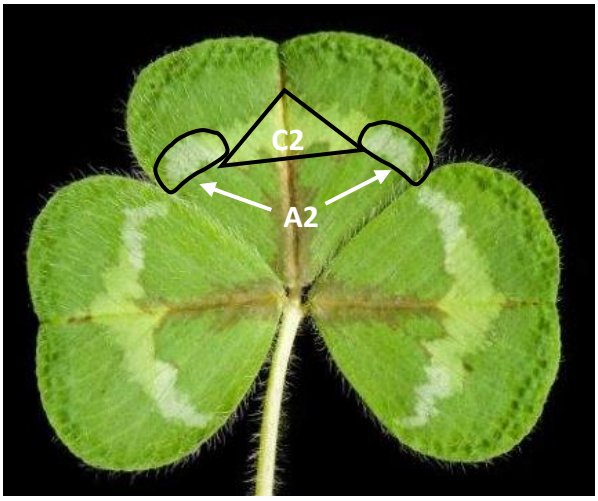


Figure 8: Trifoliate leaf from sub clover cultivar Narrikup showing the C2 and A2 components of the leaflet marking (Photo: David Hollander, 2015)

What to look at in the field

Equipment such as a hand lens or magnifying glass may be helpful for looking more closely at the sub clover plants. Hairs can also be felt with the finger or the tongue.

Identifying which cultivar a sub clover may be will depend on the time of year.

In **autumn/winter** look for:

1. distinctive trifoliate leaf markings,
2. the hairiness of the petiole and leaf
3. stipule pigmentation/colouring

(Note: leaf marks are not obvious in young seedlings)

In **spring**, when flowers are present, look for:

1. red markings on the flower calyx,
2. distinctive trifoliate leaf markings,
3. the hairiness of the runner, petiole, and leaf
4. stipule pigmentation/colouring.

How many plants should you look at?

Examine at least five plants to get a representative sample if there appears to be only one cultivar present. But if there are several cultivars then 20 plants should be sampled and identified. This will give a general idea of the proportions of each cultivar in the pasture. Also be alert to the presence of resident sub clover cultivars (e.g. Mt Barker).

Winter sub clover leaf versus spring leaf

A photographic record of winter and spring leaves of sub clover cultivars will be taken and, where there are clear differences for a cultivar that will assist with identification, will be included in future guides. An example of the effect of cold temperatures on leaf colour is shown in **Figure 9**.

Leaf size – a useful guide?

While some sub clover cultivars such as Antas and Woogenellup tend to have larger leaves than other cultivars, leaf size is affected by environmental factors, such as phosphorus deficiency or water stress, and the frequency of grazing (set stocking = smaller leaves). Leaf size is therefore not always a useful characteristic for identifying cultivars.

Figure 9: Effect of cold on colouring of a Napier trifoliate leaf showing strong red anthocyanin colouring (Photo: David Hollander, 2016)

Flowering time

Flowering times differ among the sub clover cultivars (**Table 3**) and this could be a useful characteristic for identification where cultivars in a pasture mixture have different flowering times.

Seed colour

As noted in **Figure 3** the seeds of the *yanninicum* subspecies cultivars, such as Monti and Napier, are amber in colour. This could be a useful characteristic for identification where a *yanninicum* is one of the cultivars in a pasture mix.

Using a plant identification key

A key is a useful tool for identifying plants in the field and uses a systematic series of questions based on key characteristics that allow the user to identify particular plants.

The SFF 'Sub 4 Spring' research programme will provide the opportunity to expand the photographic catalogue of the studied sub clover cultivars and support the development of a sub clover cultivar identification key to assist with the identification process in the field. This additional information will be used to update future guides.

Because it is strongly recommended to sow at least two complementary sub clover cultivars in all new dryland pasture sowings it is vital that farmers are able to identify the cultivars that are sown.

The following photos provide images of sub clover cultivars that are currently on the market plus those which are likely to have persisted from earlier sowing.

Persistence of cultivars in sub clover mixtures over time will indicate which cultivars are best adapted to the fluctuating climate interacting with variations of soil depth, aspect, slope and drainage within a paddock. Observations of success or failure should guide cultivar choices for future sowings.

Identifying commercially available sub clover cultivars

All photographs in this section were taken by David Hollander unless noted otherwise.

Antas

Trifoliate leaf	Stipule	Flower
		
A1	S1, H1	CX0

Identification comments

Leaf: strong leaf mark (usually stronger than shown in the photo above). Very large leaves and long petioles.

Stipule: green stipules at petiole bases have red stripes. The redness of the runner in the photo above is not always apparent.

Flower: white. Peduncle (flower stem) is longer than other cultivars.

Hairiness: runners are weakly hairy or hairless. Note hairy peduncle.

Flowering time: late flowering time similar to Denmark.

Hardseededness: rating is 3.

Seed colour: black.

Burr: very large (see Figure 3).

Additional comments

Antas is the only commercially available sub clover from the subspecies *brachycalycinum*. Currently there is limited experience with this cultivar in New Zealand.

Bindoon

Trifoliate leaf	Stipule	Flower
		
C4	S0, H1	CX4

Photos are courtesy of Wrightson Seeds, Australia fact sheet[4].

Identification comments

Leaf: pale green crescent positioned in the centre of the leaflet and extending to the margins[4].

Stipule: green.

Flower: red pigmentation on upper ⅔ of the calyx.

Hairiness: Photos suggest H1 (TBC).

Flowering time: early (NZ).

Pest and disease resistance: red legged earth mite (RLEM) cotyledon tolerance[2].

Hardseededness: 5[4] – noted as similar to Campeda.

Seed colour: black.

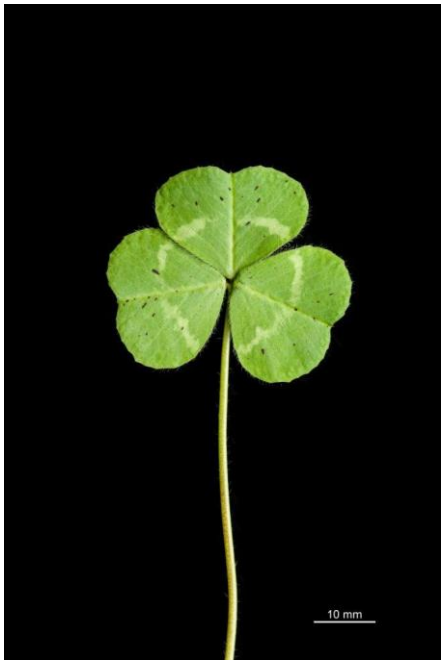
Additional comments

Note that Bindoon and Monti are the earliest flowering cultivars available in New Zealand and flower at least two weeks earlier than the mid flowering cultivars such as Campeda, Coolamon and Narrikup.

Bindoon has only been recently bought into New Zealand.

[2] 'Forage Focus – Bindoon Subterranean Clover' 2010 Wrightson Seeds, Australia. Fact sheet retrieved from: http://www.pggwrightsonseeds.com.au/assets/Learning/Cultivar/Legume/FF-Bindoon.pdf

Coolamon

Trifoliate leaf	Stipule	Flower
		
C1 A1	S1, H1	CX0

Identification comments

Leaf: the arm markings are strong.

Stipule: red veins on the stipule. Vein colour is faint in this photo.

Flower: no red pigmentation on the calyx.

Hairiness: some hairiness.

Flowering time: mid.

Hardseededness: rating of 5.

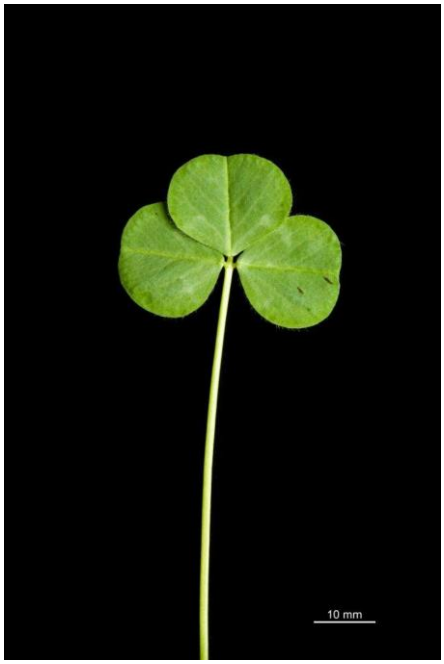
Seed colour: black.

Additional comments

Limited experience with Coolamon in New Zealand as it was only introduced in 2015.

Like Rosabrook it is one of the recently introduced cultivars with a high hardseededness rating (**Table 3**).

Denmark

Trifoliate leaf	Stipule	Flower
		
Faint A1	S1, H0	CX0

Identification comments

Leaf: very faint leaf marks, small leaves.

Stipule: the S1 colour of the veins is strong.

Flower: the white flower petals shown have pink veins which is common in Denmark.

Hairiness: hairless runners, petioles and peduncles.

Flowering time: late.

Hardseededness: rating of 2.

Seed colour: black.

Additional comments

High seed yield. Denmark has a prostrate growth habit and persists well under intensive grazing. It was productive for 10 years with cocksfoot on Templeton soil at Lincoln University in the MaxClover grazing experiment.

Denmark is well adapted to New Zealand sheep and beef farms where set stocking throughout spring is the norm.

Leura

Trifoliate leaf	Stipule	Flower
		
C2, A1	S0, H2	CX0

Identification comments

Leaf: see **Figure 8** regarding the two separate leaf markings.

Stipule: S0, green stipule with no colouring, is very characteristic of Leura

Flower: no red colour on the calyx of the flower.

Hairiness: runners are hairy.

Flowering time: latest flowering sub clover cultivar available in New Zealand.

Hardseededness: rating of 2.

Seed colour: black.

Additional comments

Leura is best suited to deeper soils in areas with >700 mm/year rainfall or >800 mm/year on north-west facing hills, and higher rainfall stony soils where pastures regularly brown off in summer. It has been the main sub clover cultivar on a drought prone, but well sheltered farm at Hawarden (North Canterbury) where rainfall is between 450 to 900 mm/year.

Leura is regarded as a superceded cultivar in Australia and seed supply may be limited in the future.

Monti

Trifoliate leaf	Stipule	Flower
		
C3	S1-S2, H0	CX0 – see note

Identification comments

Monti is typical of the *yanninicum* subspecies.

Leaf: a single light green crescent that extends about ¾ across the leaflet. There may be some brown flecks in late autumn/winter as in the photo above.

Stipule: is green with red stripes (S1) that may join to form a bar (S2).

Flower: while there is no red pigmentation of the calyx, the 'hairs' of the calyx are long, reaching at least ¾ of the length of the flower, which is characteristic of the *yanninicum* subspecies.

Hairiness: hairless runners and petioles, also typical of *yanninicums.*

Flowering time: early (NZ)

Hardseededness: rating of 2.

Seed colour: cream/white.

Additional comments

Monti is a newly released cultivar that belongs to the *yanninicum* subspecies of sub clover and cultivars derived from this subspecies can tolerate periodic wet soil conditions better than other subspecies.

Monti is one of the earliest flowering cultivars in New Zealand and flowers at least two weeks earlier than the mid flowering cultivars such as Campeda, Coolamon and Narrikup. Because it flowers early it is adapted to lower rainfall areas with its shorter active growth season.

Narrikup

Trifoliate leaf	Stipule	Flower
		
C2, A2	S0, H2-H3	CX3

Identification comments

Leaf: see **Figure 8** regarding the two separate leaf markings. Red/brown pigment on leaflet midrib may be present in autumn/winter.

Stipule: green with no markings although the photo suggests a faint red colour may be possible.

Flower: calyx has a strong red band on the upper half.

Hairiness: hairy to very hairy.

Flowering time: mid-season.

Pest and disease resistance: tolerant of RLEM.

Hardseededness: rating of 3.

Seed colour: black.

Additional comments

Narrikup was introduced to New Zealand in 2014 so there is no long term farmer experience but it is performing well in small plot experiments at Lincoln University.

Burr burial ability is outstanding.

Rosabrook

Trifoliate leaf	Stipule	Flower
		
C2, A1	S0, H1	CX3

Identification comments

Leaf: it has a more obvious leaf mark than Denmark but the leaf markings are not as wide as those on Narrikup (which is also more hairy).

Stipule: green.

Flower: The obvious dark red band on its flower means it could be confused with Mt Barker but Rosabrook is much less hairy than Mt Barker.

Hairiness: slightly hairy petioles and runners.

Flowering time: late.

Pest and disease resistance: selected for tolerance to RLEM. If RLEM is shown to be a significant challenge to sub clover in New Zealand then tolerant cultivars should be used. Note: Narrikup and Bindoon came out of the same RLEM breeding programme in Australia.

Hardseededness: rating is 5 which is higher than older cultivars such as Mt Barker, Tallarook and Woogenellup which have been successful in New Zealand conditions.

Seed colour: black.

Additional comments

Rosabrook has a larger leaf and is taller than Denmark in a grazing experiment at the Lincoln University dryland research farm Ashley Dene.

Identifying common resident sub clover cultivars

On many dryland pasture sites in New Zealand, resident sub clover cultivars are already be present. The most common ones to look for are Mt Barker and Tallarook, followed by Woogenellup.

Mt Barker

Trifoliate leaf	Stipule	Flower
		
C2	S2-S3, H3	CX3

Identification comments

Leaf: brown flecks on leaflet blade and midrib (**Figure 10**) are typical of the autumn/winter leaf but are not present in the spring leaf.

Stipule: red stipules

Flower: distinct red calyx band

Hairiness: very hairy runners

Flowering time: late

Hardseededness: rating of 1. Very soft seeded and susceptible to false breaks.

Seed colour: black.

Figure 10: Mt Barker in late autumn/winter with a 10 x 10 cm scale. Note significant pigmentation of the leaves and prostrate rosette growth form.

Additional comments

Mt Barker is the oldest sub clover cultivar in New Zealand and will be surviving on many hill farms where it was over-sown 50 to 90 years ago. By adopting grazing management aimed at encouraging sub clover, it may become more productive in some paddocks where its seed is present in sufficient quantities in the seed bank. The introduction of new, improved cultivars should lift dryland pasture productivity considerably if the Mt Barker population is low.

Tallarook

Trifoliate leaf	Stipule	Flower
		
C1-2, A1	S0, H3	CX0

Identification comments

Stipule: green, no pigmentation.

Flower: no red colour on the calyx.

Hairiness: is hairy.

Flowering time: very late. It is about a month later then Leura.

Hardseededness: rating of 1 and is prone to false strike.

Seed colour: black.

Additional comments

Tallarook is no longer available. It was widely sown with ‘Mt Barker’ in the 1940s and ‘50s and has persisted mainly in the North Island in areas where summer droughts are less frequent and not as prolonged. If the Tallarook cultivar is present it is an indication that late flowering cultivars should be successful in that environment.

Woogenellup

Trifoliate leaf	Stipule	Flower
		
C3	S1, H1-H2 (see comments below)	CX0

Identification comments

Leaf: light leaf markings, large light green leaves with long petioles.

Stipule: larger than normal. The photo above shows the stipule with red stripes (S1) but Dear and Sandral (1997) note the pigmentation as more pronounced at S2-S3.

Flower: white. Hairy peduncle.

Hairiness: Woogenellup **normally** has hairless runners but may have hairy petioles and runners.

Flowering time: mid-season.

Hardseededness: rating of 1.

Seed colour: black.

Additional comments

Woogenellup is very productive but has a reputation in Australia for false strikes because of its very low hardseededness.

Woogenellup yield was second to Antas in the establishment year in recent cultivar comparisons.

Resident Woogenellup is the dominant sub clover cultivar on ‘Tempello’ dryland hill pastures near Blenheim.

Identifying volunteer adventive annual clovers

It is assumed the adventive annual clovers came to New Zealand many years ago as impurities in white and red clover imports. To some extent the presence of these species in a pasture can be regarded as indicators of the suitability of the environment for the introduction of more productive clover species as noted for each species below.

These clovers fix nitrogen (N) in a similar manner to more productive legume species and the general "30 kg N is fixed per ton legume DM produced" formula holds true. We assume that vigorous growth of an adventive clover indicates that strains of *Rhizobium* in the soil will be suitable for other annual clovers. No problems have been reported with sowing un-inoculated bare seed of sub or balansa clovers where good populations of vigorous adventive clover have been present.

In this guide four adventive clovers are briefly described with accompanying photographs: suckling clover, cluster clover, striated clover and haresfoot clover.

Suckling clover

Suckling clover is widely adapted throughout New Zealand but not usually dominant so it is not a good indicator of what improved species to sow. Suckling clover is an early flowering adventive clover. It has distinctive yellow flowers, thin red stems and the middle leaflet has a longer stem than the two side leaflets.

Figure 11: Suckling clover

Figure 12: Hairless cluster clover flower and leaflets showing the pale dot present on some plants

Cluster clover

Cluster clover is not common at higher altitudes. It is the main adventive species on the stony soils at Lincoln University's Dryland Research, Farm Ashley Dene near Burnham in lowland Canterbury where sub clover is the most productive legume after lucerne.

Cluster clover is hairless and looks a bit like white clover but it has no stolons. Leaves are smaller than white clover and some plants have leaflets with a brown spot and some a light coloured central spot. Unfortunately, the leaf markings are variable and some forms will have no leaf markings for identification purposes. The small pink flower clusters form a ball in the leaf axils and there is no flower stem (peduncle).

Striated clover

Striated clover can become dominant in low fertility sites and this can indicate the need for increased fertiliser to get success with sub clover introduction. Striated clover has fine hairs all over leaves and stems. The leaves have no distinguishing marks and feel like velvet. Pink flowers develop into harsh feeling seed heads.

Figure 13: Hairy striated clover in flower.

Figure 14: Flower head of haresfoot adventive annual clover. Note hairy elongated green-grey leaves.

Haresfoot clover

Haresfoot clover is another hairy annual legume and has a distinctive green-grey appearance due to its hairiness. Young plants form a prostrate rosette with rounded leaflets but later in the season, as stem elongation occurs, the new leaves also elongate. Pink flowers and seedheads resemble a hare's foot. Haresfoot clover is most likely to be the dominant adventive clover in the high country because of its later flowering and cold tolerance. It is the dominant adventive clover in Omarama (south Mackenzie Country).

SELECTING SUB CLOVER CULTIVARS

Sub clover evolved in the Mediterranean area with winter rain and dry summers. New Zealand's oceanic climate with inconsistent summer rain and cooler temperatures can adversely affect the normal sub clover life cycle. However, up to a third of our total pastoral area has a summer moisture deficit where annual clovers can make a significant contribution.

Currently all sub clover seed is imported from Australia and most cultivars have been selected for Australian conditions with emphasis on flowering date, persistence, disease resistance, productivity and hardseededness. There has been much more research done on sub clover in Australia than in New Zealand (see **Table 3**) therefore we have to extrapolate Australian findings to our conditions until there is more New Zealand information.

Table 3: Agronomic data for sub clover cultivars registered in Australia. Data are long-term means of irrigated plants from an early May sowing in Perth, Western Australia (adapted from Nichols *et al* 2013).

Cultivar	Year[1]	Sub Species[2]	Flowering time[3]	Minimum growing season (months)[4]	Burr burial category[5]	Hardseededness (1-10)[6]
Mt Barker	1900	S	Late	7.5	Low	1
Tallarook	1936	S	Very late	9	Medium	1
Woogenellup*	1959	S	Mid	7	Low	1
Karridale	1985	S	Late	7.5	Medium	2
Denmark	1992	S	Late	7.5	Medium	2
Leura	1992	S	Very late	8	Medium	2
Antas	1999	B	Late	7.5	Low	3
Campeda	1999	S	Mid	6	Medium	5
Napier**	2001	Y	Late	7.5	Medium	5
Coolamon	2003	S	Mid	6.5	High	5
Bindoon	2008	S	Early	5.0	High	3
Narrikup	2009	S	Mid	6.5	High	3
Rosabrook	2009	S	Late	7.5	Medium	5
Monti	2013	Y	Early	5.5	Medium	2

Colour key: Old cultivars that are likely to be resident and part of the sub clover seed bank
Older cultivars that are still in use
Newer cultivars sold under Plant Variety Rights.
* Woogenellup is sometimes a resident cultivar
** Napier seed is currently not available

1. Year seed first sold/date registered as a cultivar in Australia (Nichols *et al*. 2013).
2. Subspecies: S = *subterraneum*, Y = *yanninicum*, B = *brachycalycinum.*
3. Flowering times are suggested categories for New Zealand conditions.
4. Minimum growing season for reliable seed production/persistence (Nichols *et al*. 2013).
5. Burr burial category: low (Nichols *et al* 2013 burr burial rating 1 to 3), medium (4-6), high (7-9)
6. Hardseededness: 1= least hard, 10 = most hard (Nichols *et al*. 2013)

Five sub clover cultivars Mt Barker, Tallarook, Woogenellup, Denmark and Leura listed in **Table 3** have been proven under New Zealand conditions for at least 20 years. Less is known about the more recent cultivars, such as Antas, Bindoon, Coolamon, Narrikup, Monti and Rosabrook.

Sub clover cultivar differences

Sub clover cultivars released since the late 1990's have been selected in Australia for persistence and productivity, flowering time and seed maturity, hardseededness and pest and disease resistance and low oestrogen content (Wurst 2004). There are very large differences among cultivars and it is vital to sow cultivars which will be well adapted to local New Zealand conditions.

Table 3 presents a range of agronomic data for sub clover cultivar characteristics. The following explanations highlight why these characteristics are important.

Sub clover subspecies

The sub clover subspecies gives an indication of the preferred soil conditions (e.g. pH, drainage and soil moisture, see **Table 1**) for the associated cultivars and therefore the environment they prefer.

Minimum growing season

In Australia the minimum growing season for the main sub clover cultivars ranges from 5 to 9 months (**Table 3**). Tallarook, which is no longer available is well established in moist areas of New Zealand. It has a growing season of 9 months. There is currently a gap in the New Zealand market for a very late flowering cultivar.

> The SFF 'Sub 4 Spring' research programme will study the growing season of sub clover cultivars in New Zealand conditions by recording flowering times and the time required to develop mature seeds.

Flowering time

Cultivar flowering time indicates the environment it is best suited to and its management (grazing strategies and reseeding). There are two scenarios to consider:

- later flowering cultivars have a longer growth cycle and the opportunity to exploit favourable growth conditions in November/December but will be ill adapted if drought starts in early November in most years.
- if the strategy is to maximise early spring biomass production for ewe lactation then earlier flowering cultivars are desirable in the seed mix.

> The SFF 'Sub 4 Spring' research programme will identify the relationship between sowing date and days to flowering of sub clover cultivars grown in New Zealand conditions.

Hardseededness

A hard seed protects against false strikes. Some of the seed set by sub clover contains hard seeds. Some of these seeds will germinate one or two years later than most. This helps protect the plant from 'false strikes' where early germination in late summer is followed by autumn drought and loss of seedlings.

Sub clover cultivars which have a low percentage of hard seed in February are more susceptible to false strike than cultivars with a higher hard seed rating. Hard seeds 'soften' faster in hot dry conditions with wide day/night temperature fluctuations. These conditions crack the seed coat. This creates 'soft' seed that is then permeable to water and can germinate with the next rain event.

Hardseededness is a quality valued in Australia where soil surface temperatures are higher. However, under cooler summer conditions in New Zealand seed 'softening' may be much slower than in Australia. Sunny north facing hills with a high proportion of bare ground in summer will require cultivars with greater hardseededness than shady faces which tend to have denser grass swards and more litter on the soil surface.

Historically sub clover cultivars which have been successful in New Zealand have had low hardseededness ratings of 1-2. Several of the newer cultivars have higher ratings (**Table 3**).

Hardseededness of sub clover cultivars is being investigated in the SFF 'Sub 4 Spring' research programme.

Burr burial

Burr burial is an important characteristic. Cultivars with low ratings tend to be less persistent on some soil types and may require special management.

Other characteristics important for New Zealand-grown sub clover cultivars

There are a number of other sub clovers characteristics that are important for New Zealand hill country conditions.

Prostrate growth habit and leaf size

A prostrate growing habit and a dense crown are positive characteristics for sub clover in set stocking situations. Cultivars with a prostrate growing habit have shown the highest levels of reseeding and regeneration (Chapman *et al.*, 1986; Sheath and MacFarlane, 1990; Widdup and Pennell, 2000).

Small leafed, prostrate sub clover types have been a feature of some of the more recently released cultivars (e.g. Demark). These were sourced from Sardinia. Larger leafed types such as Antas and Woogenellup are considered to be more vulnerable to intensive set stocking.

Cold sensitivity and tolerance

After germinating in autumn, sub clover needs to grow during the cool season at low temperatures to produce a considerable amount of biomass early in spring. Sub clover cultivars can survive low winter temperatures. The cultivar Tallarook withstood temperatures as low as -6 to -7˚C (Caradus 1995). But there is little information about the frost-cold tolerance and subsequent regrowth of the three different subspecies nor of the newly registered Australian cultivars. Frost during seedling and flowering phases is an issue in southern New Zealand and this is being investigated in the SFF 'Sub 4 Spring' research programme.

Biomass production

Yields of up to 16 t DM/ha/yr are achievable from sub clover monocultures under ideal conditions. In grazed swards mixed with grasses or herbs sub clover DM contribution ranges 1 to 5 t DM/ha/yr.

The growth habit, cold tolerance and biomass production of sub clover cultivars will be investigated in a number of experiments in the SFF 'Sub 4 Spring' research programme.

SUB CLOVER ESTABLISHMENT

Cultivar selection according to site characteristics

Early cultivars best for low rainfall areas

The earlier flowering cultivars are suited to areas with low rainfall (less than 500mm) while the later flowering cultivars are adapted to higher rainfall (more than 700mm). Moisture is required for 10 weeks from the start of flowering for good seed yields.

For example, Woogenellup starts flowering in early to mid-September so it is better suited to dry areas with short growing seasons than the later flowering Leura which starts flowering in early October. Dry areas include steep/sunny faces or soils with low water holding capacity (eg. very stony river terraces). On these sites the dry season may average five months even though rainfall is 650 mm.

In an average year in the droughty-soil site, Woogenellup is more likely to set seed than the later-flowering Leura.

Late cultivars like Leura are suited to soils that are moist throughout November and ideally moist into December.

Sow early and late cultivars together

Where rainfall is variable from late October to December, it is a useful strategy to sow an earlier cultivar such as Woogenellup with a later one, like Leura. The pasture should then be better able to exploit both dry and wetter seasons.

Sow sub with perennial clover in more summer moist sites

In more favourable summer dry sites (shady hill faces, deep soils) with about a three month dry season the early spring production of annual clovers such as sub, followed by their strong flush in October, complements the late spring start of rapid growth by perennial clovers. A mix of annual and perennials gives greater legume production over a range of seasons.

Recommended sub clover mixtures

Always include at least 2 cultivars of sub clover in seed mix unless experience over a long period (> 10 years) shows a single cultivar is best. Mixtures of sub clover cultivars with complementary characteristics are strongly recommended so that variations in climate, topography and soil depth within a paddock are covered.

The following suggestions for complementary mixtures are based on current information and experience pending further on-farm experience and research results.

Suggested cultivar mixtures or the following environmental conditions are:

5-6 month summer dry - Woogenellup plus Narrikup and/or Campeda or Bindoon

4-5 month dry - Denmark plus Narrikup or Campeda for sites which normally get dry in mid-November but can dry out in late October or stay green until early December.

4 month dry - Leura plus Denmark with Rosabrook or Coolamon or Narrikup for higher rainfall areas which dry out later than mid-December in an average year.

3 month dry - Denmark plus Leura or Rosabrook + white clover.

Poorly drained sites with wet soils in winter/early spring - use Monti or Napier plus Woogenellup or Denmark depending on average length of dry season.

Early spring feed with high rates of winter growth – use Antas and/or Woogenellup plus Denmark.

If Leura is unavailable try one of the hardseeded newer cultivars such as Rosabrook or Coolamon but insist on the inclusion of a soft seeded cultivar such as Denmark or Woogenellup as at least a third of the sub clover mix.

Sub clover seed

All seed is currently imported from Australia and is available through most seed agents (see **Appendix 1**). However, sometimes seed supplies and cultivar choices are limited by drought in Australia and/or New Zealand biosecurity requirements.

Seed preparation

Inoculation

Nitrogen fixation by clover species depends on their symbiotic relationship with the *Rhizobium* bacteria. If sowing sub clover in areas where annual clovers are scarce or absent, sub clover seed should be inoculated with the correct Group C strain of *Rhizobium* bacteria in peat inoculant, immediately before sowing. If resident sub and other annual clovers look healthy and pink nodules are present on the roots, inoculation for nitrogen fixation should not be necessary. Sub clover needs a different *Rhizobium* bacteria inoculant from white clover (Group B).

Seed coating

Most sub clover seed available in New Zealand is uncoated but some seed is coated. Seed coatings can include fungicides that can assist seedling survival where a known fungal pathogen is present.

Seed coating increases the size of the seed and therefore reduces the number of seeds per kilogram. This must be remembered when looking at sowing rates per hectare.

Site preparation

The methods of site preparation will depend on the topography of the site and previous use (e.g. cropping or pasture).

Weed control

Sub clover is a poor competitor and sensitive to shading so effective weed control is essential for successful establishment (Dear and England, 1987). Weed control treatments may start months before seed sowing. About a week before seed sowing, herbicides can be applied to eradicate newly emerged weed seedlings especially if the area has been cultivated.

> The type, rate and timing of herbicide treatments to optimise the establishment of sub clover cultivars across a range of sites is the subject of a number of experiments in the SFF 'Sub 4 Spring' research programme.

Cultivation

On flat to rolling terrain normal fine, firm seed bed recommendations apply.

> Two experiments investigating methods of establishing sub clover cultivars on uncultivatable dryland hill country are part of the SFF 'Sub 4 Spring' research programme. These experiments are located in North Canterbury and the Wairarapa.

Sowing

Sow more sub clover if you can't 'step on it' in spring

The need to sow sub can be determined by the lack of it. If you can walk across the paddock in September without standing on sub clover at each step you have not got enough. You either have a poorly adapted cultivar and/or what you have has been mismanaged. Low populations can be increased by:

a. reducing grazing intensity during spring flowering and seed set and/or

b. drilling or broadcasting more sub seed in autumn.

Seed sowing methods

The method of sowing sub clover seed in dryland pastures depends on the topography.

Direct drilling

If possible, sub clover seed should be drilled rather than broadcast. This is because the seed is adapted to germinate from seed burrs buried in the top 10 mm of soil.

On cultivatable land direct drilling is efficient to establish an initial high seedling population and can also be used to increase legume content in grass dominant swards (Ates *et al.*, 2013). Direct drilling into a run-out cocksfoot-dominant pasture at Lincoln University's light land farm gave excellent results. The establishment of sub clover in this situation relied on grazing hard (i.e. down to 600 kg dry matter per hectare) until the first good rain in March (> 20 mm) and then drilling sub clover.

Seed should be drilled to a depth of at least 10 mm. Ideally after sowing the area should be lightly rolled.

Broadcasting

In steep hill country areas, aircraft are used to spread seed by over-sowing. It is recognised that rates of establishment using over-sowing are usually much lower compared with drilling.

Broadcasting success is more dependent on the weather. Hill slopes should be prepared by hard grazing. Stock may be used to tramp seed into the ground immediately after broadcasting. Best results are seen when seed is spread just before a prolonged wet spell in March/April.

Sub clover establishment from February broadcasting of seed on hill (no herbicide or cultivation) on Alice's Block west face at Mt Benger, North Canterbury (Photo: RJ Lucas)

Loss of soil moisture through evaporation and transpiration is greater in March. A week of moist, dull weather will give a good result but a wet day followed by dry northwesterly weather will result in a false strike. Early April seeding is more likely to achieve a good strike but seedlings will be smaller in winter and more vulnerable to frost.

When to sow

Sub clover should be sown in autumn. Soil moisture is an important environmental factor for germination so bare (unpelleted) seed should be sown between late February and mid-April in response to individual summer rainfall pattern and soil moisture accumulated during any summer fallow.

Sub clover should not be sown in spring as it is unlikely to set seed before summer drought.

What rate to sow

Sowing date of sub clover cultivars is being investigated in two experiments in the SFF 'Sub 4 Spring' research programme – one at Lincoln University, Canterbury, and the other at the Poukawa Research Station in Hawkes Bay.

Cultivars differ in seed size but in most cases there are only 15 seeds per square metre for each kilo sown. Therefore 10 kg per hectare will give about 100 established plants per square metre. The best way to rapidly build a large sub clover seed bank is to sow it alone or with 5 - 8 kg perennial ryegrass per hectare.

Sub clover with other pasture species

High sowing rates of grass species supress sub clover establishment. Therefore it is important to sow pastures with high legume rates (e.g. 10 kg/ha sub clover) and low grass rates (e.g. 2 kg/ha cocksfoot or 5 - 8 kg/ha ryegrass). Note that a sub clover seed is about 10 times heavier than a white clover seed. Sub clover seed rates are therefore much higher (10 kg/ha) than those for white clover (2 kg/ha).

Comparison of clover seed size. Left to right: 'Nomad' white clover, 'Rossi' red clover, and 'Mt Barker' sub clover (Photos: Bridget Thomas)

Options for inclusion of other species with your base sub clover mixes for a productive, persistent and high quality pasture will depend on your environment:

♣ **moister regions** use maximum of 8 kg/ha perennial ryegrass (AR37 if needed).

♣ **drier regions/areas** use 2 kg/ha of cocksfoot (slower establishing but more persistent in the dry). Note that the small cocksfoot seed should be broadcast if sub is to be drilled at 10 – 20 mm.

♣ **innovators** don't sow a grass as a companion species but use 2 kg/ha of plantain and/or 1 kg/ha chicory. Note that herbicide control of broadleaf weeds is difficult in herb/clover mixtures but grass weeds can be controlled in those clover friendly pastures.

♣ **another innovative option** is to sow sub clover in autumn with rape (rape at 1kg/ha or less if soil is fertile). The rape is a good nurse crop for the clover and will provide a couple of winter grazings. After the sub clover has given a large spring seed set, grass can be over-drilled the following autumn.

Mixtures of sub clover

The number of sub clover seeds sown per m^2 ranges from about 90 to 180 due to differences in seed size of individual cultivars. However, with two complementary cultivars, a mix of 5 kg/ha + 5 kg/ha = 10 kg sub/ha is recommended.

Post-sowing treatments

Herbicides

Post-emergent herbicides may be considered if there is a flush of germinating weed species.

Slug bait

If predation of newly-established sub clover seedlings by slugs is likely then a molluscicide can be applied at time of sowing or shortly after.

MANAGING THE SOIL FERTILITY OF DRYLAND PASTURES

Principles of dryland pasture nutrition

In most cases pasture legume content will not magically increase by continuing with the standard policy of annual superphosphate application and "good" grazing management if well adapted legumes are absent from the nitrogen (N) deficient pasture.

Despite being considered a "robust" plant, sub clover is known for its high fertility demand, especially for phosphorus (P), sulphur (S), and the micronutrient molybdenum (Mo) (Frame, 2005). Its fertiliser requirements are similar to white clover.

Nitrogen supply and water use efficiency of dryland pastures

Nitrogen drives grass productivity once other nutrients such as P, S and potassium (K) have been brought up to moderate levels and soil pH has been amended with lime.

Soil N supply can be gauged by the colour of grass dominant pastures (yellow-green through to dark green) and the prominence of urine patches. Yellow-green N-deficient grass in October growing at 40 kg dry matter (DM)/ha/d uses water at the same rate (say 4 mm/d) as dark green urine patch grass growing at more than 100 kg DM/ha/day. Therefore, N deficient grass has a water use efficiency of 10 kg DM/mm water used but the grass in the dark green urine patch has an efficiency of over 25 kg DM/mm.

Legumes have a high spring water use efficiency because they contain nitrogen levels similar to grass in a urine patch. Legume dominant pastures in dryland pastures during spring will therefore use the limited soil water more efficiently than N deficient grass dominant pastures.

Dryland pastoral farms, typically with N deficient grass dominant pastures with less than 10% clover, use scarce water inefficiently and can improve this through increased total legume production. Pasture legumes fix N in proportion to their DM production; for every 1 t/ha of legume DM grown about 25 – 30 kg N/ha will be fixed. Therefore if a sub clover/ryegrass pasture produces 8 t DM/ha/yr, with 3 t/ha/yr clover and 5 t/ha of grass, we can assume at least 75 kg N/ha was fixed.

Phosphorous

Phosphorus is one of the most important macronutrients to promote the growth of annual legumes. Phosphorous is necessary to promote rhizobium nodulation (Robson *et al.*, 1981) and photosynthesis. Phosphate applications can increase sub clover biomass yield (Moir *et al.,* 2012). Soil analyses for Olsen P between 15 and 20 are adequate for dryland hill country.

Visual P deficiency symptoms

Visual P deficiency symptoms are the reddening petioles and small leaves (Paynter, 1990) when growing conditions (soil moisture and temperature) are satisfactory.

Sulphur

Sulphur deficiency is most likely on inland soils. Sulphur is leached from soils quite rapidly so therefore should be applied regularly. Sulphate-S soil test values of at least 8 should be maintained to get vigorous clover growth.

Visual S deficiency symptoms

Sulphur deficient legumes have light green leaves because nitrogen fixation is inhibited.

Molybdenum

Molybdenum is an essential trace element for nitrogen fixation. Mo deficiency in clovers is possible in acid soils with pH values less than about 5.7. Applications of Mo to acid soils tend to be ineffective because Mo is less available at low pH.

Soil pH

Soil pH is an important factor in the growth of sub clover as it affects the plant-rhizobium relationship.

Table 1 highlights that the *subterraneum* and *yanninicum* subspecies of sub clover tolerate moderately acidic soils while *brachycalycinums* prefer neutral to alkaline soils. The recommendation is to maintain soil pH_{H_2O} above 5.6 for most sub clover cultivars and above 6.0 for 'Antas' sub clover.

In Australia soil pH is measured using a $CaCl_2$ solution, pH_{Ca}, while in New Zealand it is measured using water, pH_{H_2O} or pH_{water}. Australian pH values for the same soil are nearly a pH unit lower. This difference is important to remember when reading Australian references.

FERTILISER ADDITIONS

Nitrogen

Avoid the use of nitrogen fertilisers if legume dominance is desired in a pasture. Nitrogen fed grass is very competitive for light, water, phosphorus, sulphur, potassium and some trace elements and this restricts legume growth.

Lime

Lime applications to get soil pH of 5.6 or higher are recommended.

Soil pH can be increased by lime. Rates of lime addition and the tolerance of sub clover cultivars to acidic soil conditions are being investigated in a field experiment in the SFF 'Sub 4 Spring' research programme.

MANAGING SUB CLOVER PASTURE

Sub clover dry matter production

Pure swards of sub clover produce 5 to 16 t DM/ha/yr depending on rainfall. This is similar to mixed grass and clover pastures at the same site. However, clover content often only 10 to 20 per cent of the total production in mixed pastures. Clover herbage has a higher feeding value than grass.

Therefore farming for legumes rather than grass is advisable to maximise lamb growth during ewe lactation.

The Beef + Lamb New Zealand-funded 'Maxclover' grazing experiment carried out by Lincoln University showed that superior clover content in sub clover/cocksfoot pastures gave greater liveweight gain per hectare from August to October than white clover/ryegrass or white clover/cocksfoot pastures.[3]

Sub clover can withstand heavy grazing but careful grazing management, particularly during flowering, is key to sub clover persistence in permanent pastures.

The aim of the 'Maxclover' project was to develop grazing management guidelines for sub clover so it can provide high quality feed from August to October in summer dry areas. Recommendations developed in that project are included below.

Graze lightly in first season

Grazing management during the first spring flowering of newly established sub clover should be lax (i.e. over 2000 kg DM/ha). This ensures the cost of establishment is not squandered. Seedling populations re-establishing in the first autumn a year after sowing will be much greater than the 50 to 100 seedlings per square metre achieved after drilling the seed at 10 kg/ha. Minimum satisfactory populations are 500 seedlings per square metre in grass/clover pastures and 1000 seedlings/m^2 in pure stands. If you have an average of five seedlings under the area of your hand (approximately 10 cm x 10 cm or 0.01 m^2) then that is equivalent to 500 seedlings/m^2.

Autumn

Before sub clover germination in autumn, aim to keep grass in pastures short with a mass of 700-1000 kg of DM/ha (1-2 cm). After a good strike, spell the pasture until sub has at least four trifoliate leaves. Sub thrives when it is given a chance to establish before its first grazing.

The longer the sub clover has to establish and put roots down in autumn, the greater the dividends come spring. Pasture growth rate in a moist March is likely to be twice the April rate. In May, growth is usually half that of April.

Don't be tempted to feed the green 'pick' in autumn if pasture mass is under 1000 kg DM/ha (2 cm).

During late autumn, pasture may need to be grazed hard (ie. 700-800 kg DM/ha) to remove dead grass material. Clover rich lambing paddocks can then be spelled until lambing in spring.

Spring

Reap the rewards. The spelled sub clover-dominant pastures will provide maximum ewe lactation during lambing.

Light grazing (to 1500-2000 kg DM/ha) encourages seed production. A light graze is recommended for every paddock once every five years or when sub clover populations are low (i.e. less than 100 plants/m^2 or an average of one seedlings under your hand).

Spring stocking rate trials

Grazing intensity studies on the stony soils at Ashley Dene, Lincoln, investigated how to avoid overgrazing sub clover during seed set yet control grasses such as cocksfoot or tall fescue.

[3] For more information see: http://www.beeflambnz.com/Documents/Farm/Using%20clover%20and%20nitrogen%20to%20improve%20dryland%20pastures.pdf

These studies showed that high stocking rates with 20 ewes/ha and their twin lambs gave satisfactory lamb liveweight gains of 310 g /hd/day and 12 kg/ha/day. However, the sub clover seed set was severely reduced and seedling population the following autumn was down to only 220/m^2. Seed size was reduced to about 3 mg which resulted in smaller less competitive seedlings.

A lower stocking rate of 10 ewes per hectare with twin lambs gave 370 g per head per day with only 7.5 kg/ha/day, but it provided a greater opportunity for seed production and sub clover persistence.

Basics for Dryland Lamb Producers - Principles for fast lamb production

Ewes bearing twins and triplets need top quality feed in late pregnancy and throughout lactation. Sheep will select a diet of about 70% legume (lucerne or clover) and 30% grass when given a free choice. Legume rich pastures will give faster twin lamb live weight gain (LWG) than grass dominant pastures.

Therefore, twin lamb LWG pre-weaning is directly proportional to the % clover DM on offer. With over 50% clover on offer LWG of twins pre-weaning should be well over 300 g/hd/day. This assumes bite size (= DM intake) is not limited by forcing ewes to graze the pasture mass down to below 1200 kg/DM/ha.

Use the following management strategies:

♣ Young pastures will be legume dominant, ideal for twins. As N builds up through N fixation by legumes, grasses will become more vigorous and competitive in older swards.

♣ Therefore appropriate management is vital to maintain legume content (e.g. manage sub clover for high seed production if sub clover drops below 20% on offer in early October).

Managing sub clover to rapidly get a high producing, persistent clover dominant pasture

The best way to rapidly build up a sub clover seed bank is through early spelling in the first spring after autumn drilling or broadcasting seed at 10 kg/ha. Newly sown sub clover/grass pasture should be grazed no lower than about 1200 kg DM/ha through late autumn and winter. It's alright to lamb on it but at a lower stocking rate than normal. The new paddock should be closed to reseed about a week after flowers become obvious. For mid flowering cultivars this will be in the first week of October in lower altitude Canterbury. Do not take a last few days grazing to 'clean up the green leaf' before spelling the paddock as that will result in runners being eaten and seed yield will be greatly reduced. There needs to be 6 to 8 weeks of soil moisture available to the sub plants to get maximum seed set. Check the seed burrs for fat ripe seeds.

During the late spring, spell from grazing, sub clover runners can grow a further 20 to 30 cm in length. This means that individual plants will have the potential to get to about 60 cm in diameter. These runners can colonize vacant space by pegging down seed burrs. Each burr will contain 3 or 4 large seeds. Each sub clover plant will have about five runners each with six burrs containing mature seeds. So each spelled plant can produce over 100 seeds.

It is suggested that cattle will be best to clean up the "standing hay" after spelling new sub clover/ grass pasture in its first year. Once the paddock has been grazed hard by cattle keep on top of summer grass growth with sheep. Aim to create some bare ground during February so that the fluctuating soil surface temperatures will more rapidly soften hard seed to give a good strike of sub clover with the first significant autumn rains. If all goes well the pasture should then provide excellent ewe lactation feed in its second spring season.

On some hill country it may not be necessary to reseed the sub clover if there is sufficient sub present in the old pasture. Grazing management alone, perhaps helped by some judicious chemical topping, may achieve a sward which can regularly produce over 40% sub clover in spring. Assess the suitability for this approach by measuring the frequency of sub clover presence in the pasture. Do this by **walking over it**. If sub clover is under your boot more often than two thirds of your steps during the spring flush there may be enough sub present to bring it back to full potential through management only. This will require hard summer grazing, briefly spell the paddock after autumn sub clover germination until seedlings have four leaves, control grass competition by keeping pasture mass to under 2 t DM/ha through autumn/early winter, lamb on paddock but get off it a week after flowers are visible. Time the spelling of the pasture to your prediction of when there is 6-8 weeks of soil moisture remaining before the summer dry sets in. Graze the standing hay with cattle in summer. This pasture rejuvenation process may be successful without herbicides but strong grass competition may need to be challenged by more than 'hoof and tooth'.

Runner damage caused by overgrazing prior to close-up in early October. Flowers from recovery growth of these sub clover runners may be too late to form seed burrs.

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APPENDICES

Appendix 1: Sub clover seed suppliers

The following are the current suppliers (wholesalers and retailers as noted in **Table 1**) of sub clover seed in New Zealand and links to their respective website pages where there is sub clover information.

Agricom: www.agricom.co.nz/products/clover1/annual-clover

Farmlands: www.farmlands.co.nz/Productsandservices/GrainAndSeed/

Kiwi Seed Co: kiwiseed.co.nz/specialist/dryland-pasture/

Luisetti Seeds: luisettiseeds.co.nz/portfolio-item/clover-range/

Seed Force: www.seedforce.co.nz/ ('Product' tab, 'Clovers' tab)

Specialty Seeds: www.specseed.co.nz/portfolio-item/clover/

PGG Wrightsons: pggwrightson.co.nz/products/product-category/seed/clovers

Contact information for local reps and seed stores can also be found on the respective websites.