Registered cultivars of subterranean clover: their characteristics, origin and identification

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Co-operative Research Centre for Legumes in Mediterranean Agriculture (Australia)

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REGISTERED CULTIVARS OF SUBTERRANEAN CLOVER
their characteristics, origin and identification

P.G.H. Nichols, W.J. Collins and M.J. Barbetti
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Preface
This Bulletin updates Bulletin No. 4083, which was written in 1984. Since that time, 11 new subterranean clover cultivars have been released, making a total of 33. This Bulletin is largely applicable across all the subterranean clover areas of Australia. However, specific mention is made in the text to applications in Western Australia.

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Role of subterranean clover in Western Australia

Subterranean clover (*Trifolium subterraneum* L.) is the most important annual pasture legume species in Western Australia. It is well adapted to the moderately acidic, light and medium textured soils found through much of the agricultural area. It provides nutritious feed for livestock and is well adapted to grazing.

Subterranean clover is also an important source of nitrogen for non-leguminous species in pastures and for cereal crops grown in following years. The key to its widespread use is a diversity of cultivars. This enables subterranean clover to be grown successfully in areas ranging from the high rainfall, long growing-season districts of the lower south-west, through to much of the dry wheatbelt.

The use of subterranean clover in pastures in Western Australia began very slowly during the economically difficult 1930s and 1940s, but was followed by a marked increase in its use during the 1950s and 1960s. In the early 1970s there were about 7,000,000 hectares of pastures containing significant subterranean clover content. This has since declined to about 6,000,000 hectares. This is particularly the case in the low rainfall wheatbelt zone, where large areas originally established with subterranean clover now contain little or no subterranean clover.

(a) Wool  
(b) Cereals  
(c) Dairy  
(d) Meat

*Agricultural industries that utilise subterranean clover pastures*
Origin of subterranean clover

The species subterranean clover is not native to Australia. It originates from the Mediterranean region and Western Europe (see Figure 1). However, it is not surprising that subterranean clover grows well in the agricultural districts of Western Australia. Here there is a predominance of acidic to neutral, light textured soils, to which it is particularly suited, and a typically Mediterranean climate with cool, wet winters and hot, dry summers.

Subterranean clovers in Australia are derived from three main sources:

- **naturalised strains**, which have been accidentally introduced from other countries and have subsequently become established in localised areas;
- **introductions**, which have been collected by scientists from their native habitat and brought into Australia; and
- **crossbreds**, which are the products of breeding programs, involving crossing between selected parents and selection in subsequent generations for desirable characters.

Any clovers from these sources that are registered and released for commercial use are termed **cultivars**. In order to qualify for registration as a cultivar, it must be different from, and possess some character of merit, in comparison with previously registered cultivars.

Naturalised strains

Subterranean clover was probably introduced to Western Australia as early as the 1830s, with the first settlers. Collections made by Dr John Gladstones and colleagues since the early 1960s have resulted in the discovery of over 100 naturalised strains, the majority of which were found along stock routes used by the early settlers. A further 300 or so naturalised strains have been identified in eastern Australia.

In Western Australia, it is generally thought that most of the original introductions came into the colony from or near the Atlantic seaboard of western Europe, that is, from southern England to southern Portugal and Spain. However, some may have come from the Mediterranean basin proper, particularly after the opening of the Suez Canal in 1869.

In the absence of any precise records, the mode of introduction of subterranean clover has been the subject of considerable speculation. It is generally assumed that the naturalised strains came into Australia either accidentally with livestock and fodder, or as contaminants of agricultural seeds imported from the United Kingdom and continental Europe. It is also possible that subterranean clover was deliberately introduced, since the value of clovers was already well known in Europe by the time settlers began to arrive in Western Australia.

Introductions

Since 1951, there have been several plant collecting missions to the Mediterranean region. These have resulted in the acquisition of over 8000 genetically distinct introductions of subterranean clover. These, along with the naturalised strains collected in Australia, are maintained by Agriculture Western Australia at South Perth in the Australian Trifolium Genetic Resource Centre.
Steps involved in the development of a new subterranean clover cultivar

Cross-pollination to generate new crossbred subterranean clovers.

Seed increase of promising subterranean clovers for field evaluation trials.

Early generation selection rows in Perth.

Grazed field evaluation trial of promising subterranean clovers.

Recording data on early generation subterranean clover breeding rows in Perth.

Basic seed increase of a newly released cultivar.
Table 1. Important agronomic characters of the subterranean clover cultivars registered in Australia. Recordings from undefoliated, irrigated rows in Perth, Western Australia.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Sub-species</th>
<th>Origin</th>
<th>Days to first flowering (sown in early May)</th>
<th>Days to first flowering (flowering begins about)</th>
<th>Seed formation completed by</th>
<th>Minimum growing-season length (months)</th>
<th>Isoflavone content (% of dry matter)</th>
<th>Relative hard-seededness</th>
<th>Relative seed weight</th>
<th>Burr burial strength</th>
<th>Embryo dormancy</th>
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<tr>
<td>Bacchus Marsh</td>
<td>S</td>
<td>Victoria</td>
<td>132</td>
<td>Mid-late Sept.</td>
<td>Mid-late Nov.</td>
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<td>0.1 0.3 2.3</td>
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<td>6</td>
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<td>7</td>
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<td>Late Nov.</td>
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<td>4</td>
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<td>Early-mid Nov.</td>
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<td>Trace 1.3</td>
<td>9</td>
<td>3</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

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**Notes:**
- **S** = *subterraneum*, **Y** = *yannincum*, **B** = *brachycalyxica*
- **Sub-species:** a variation between plants
- **Trace:** <0.05% of dry weight
- **Embryo dormancy:** 1 = very weak; 2 = weak; 3 = strong; 9 = very strong
Breeding programs

The major breeding program for subterranean clover in Australia has been conducted in Perth. It began in 1949 with a small project by Dr John Millington of the University of Western Australia. The program expanded in the 1960s with the involvement of the Department of Agriculture Western Australia (now Agriculture Western Australia). From 1970 onwards, there was increasing participation by the Departments of Agriculture in other States, both in field testing of breeding lines and in feedback of information on cultivar requirements. In 1983, this structure was formalised, with the formation of the National Subterranean Clover Improvement Program.

The subterranean clover breeding program became part of the Australasian Subterranean Clover and Alternative Legumes Improvement Program (ASCALIP) in 1992, when the improvement programs for the other main pasture species in southern Australia were organised on a more formal basis.

The crossing and early generation selection phase of the breeding program is largely conducted in Perth. It is operated by Agriculture Western Australia, in collaboration with the University of Western Australia, and is part of the Cooperative Research Centre for Legumes in Mediterranean Agriculture (CLIMA). This subterranean clover breeding program is the only one currently operating in Australia. Other smaller breeding programs have been operated in the past by the Departments of Agriculture in South Australia and Victoria and by the CSIRO Division of Plant Industry.

In recent years, several countries have started their own programs to select subterranean clovers adapted to their local environments. Such work is currently being conducted in Spain, Portugal, Italy, New Zealand and the United States.

Of the 33 registered cultivars in Australia, eight are naturalised strains from Western Australia, four are naturalised strains from Victoria, three are

Figure 2. Illustration of the botanical terms used in the text.
naturalised strains from South Australia, seven are overseas introductions and eleven are the products of breeding programs (see Table 1).

Subspecies of subterranean clover

There are three subspecies of subterranean clover, each of which is suited to particular soil and environmental conditions.

(i) *Trifolium subterraneum* ssp. *subterraneum* is the most commonly used subspecies and does best on well-drained, slightly acidic soils. There are 24 Australian cultivars belonging to this subspecies (see Table 1).

(ii) *Trifolium subterraneum* ssp. *yanninicum* also prefers slightly acidic soils. It is especially adapted to waterlogged conditions but also grows well on well-drained soils with good water holding capacities. There are six Australian cultivars of this subspecies (see Table 1).

(iii) *Trifolium subterraneum* ssp. *brachycalyicum* is best adapted to neutral to alkaline, cracking or self-mulching soils. There are only three Australian cultivars of this subspecies (see Table 1). In Western Australia there are very few areas suited to subspecies *brachycalyicum*.

There are morphological differences between the three subspecies, which can be used to distinguish them (see Figure 2 for plant parts used for cultivar identification). Members of ssp. *yanninicum* have very tough leathery pods surrounding the seed, compared with the thin papery pods of ssp. *subterraneum* and ssp. *brachycalyicum*. They also tend to have much longer calyx lobes than ssp. *subterraneum*. All members of ssp. *yanninicum* have white or amber seeds and hairless runners. All current cultivars of ssp. *subterraneum* have black seeds, although some non-commercial members of this subspecies have white or amber seeds. They also range in the degree of hairiness of their runners.

Subspecies *brachycalyicum* can be distinguished from the other two subspecies by its very long, thin peduncles (flower and burr stalks) which do not actively bury their burrs, but push them along the soil surface until they find protection in a soil crack or under a stone. This contrasts with ssp. *subterraneum* and ssp. *yanninicum*, which actively bury their seeds in the soil. Subspecies *brachycalyicum* also tends to have flattened seeds, which are only partially enclosed by papery pods. Of the three ssp. *brachycalyicum* cultivars, Rosedale is amber-seeded, while Clare and Nuba have black or purplish-black seeds.

Variation between subterranean clovers

In the Mediterranean region and Western Europe, a vast number of different subterranean clovers occur naturally. Most of these are members of subspecies *subterraneum* or *brachycalyycinum*, both of which are widely distributed throughout the region. Fewer members of ssp. *yanninicum* are known to exist. Most of these come from Greece and Yugoslavia, although some have also been found in Turkey, Sardinia and Spain.

Different subterranean clovers vary markedly in their appearance, as well as in a number of important agronomic characteristics. Many of the visible differences, such as leaf markings and pigmentation of flowers are useful in seed certification schemes. They enable quick and accurate identification, ensuring that pastures being used for certified seed production are true to type. The existence of wide variation in many important agronomic characters is a major reason for the significant progress that has been made in developing improved cultivars of subterranean clover.

Desirable characters in subterranean clover cultivars

The characters required in subterranean clover, if it is to make a successful pasture component, vary from district to district, and often within a district.

The ability to tolerate heavy grazing is perhaps one of the more fundamental attributes for any pasture species, particularly in sheep grazing districts. In general, subterranean clover is particularly well adapted in this regard. Even 'showy' varieties, with tall, upright growth habits, which intuitively might be considered non-grazing types, appear to be able to adapt fairly well to heavy grazing.

In the early 1950s, almost the only criterion for selection of clover cultivars was flowering time. This was important in identifying cultivars capable of performing across the complete array of rainfall zones. Today, many other criteria are considered important and there is little doubt that with further field experience and additional research, the list of requirements for the 'ideal' clover for any environment will be further modified.

It is convenient to group the characters considered desirable in subterranean clover cultivars into two categories:

- Characters related to persistence — these include flowering time and rate of seed maturation, seed production, seed conservation through hard-seededness, capacity to bury burrs and tolerance of grazing, diseases and insect pests.
- Characters related to productivity — which include good winter and spring growth, ability to grow in winter-waterlogged or other specific soil situations, oestrogenicity and palatability.
However, it should be noted that there is some overlap between these two categories. For instance, pasture productivity in early winter is largely influenced by the density of seedlings which establish at the break of the season. This in turn is closely related to seed production and seed conservation. The effects of diseases and insects also directly influence pasture productivity.

**Flowering time and maturity**

Appropriate maturity has long been considered to be of major importance in determining the suitability of cultivars for particular environments. Maturity is best referred to as the time from sowing to the production of first viable seed. However, time to first flowering is usually used as an estimate of maturity differences between cultivars, as it is easier to observe. The aim in selecting suitable cultivars should be to match the maturity of the cultivar to the growing-season length of the environment.

Subterranean clover, being an annual species, has a vegetative phase followed by a flowering phase. It is the length of the vegetative phase that varies most between cultivars, giving rise to maturity differences. Senescence (haying-off) then occurs naturally after a flowering period of about three months, or occurs prematurely if moisture stress sets in. The correct cultivar for a given environment should remain green long enough to fully exploit the length of the growing season. However, flowering must start early enough for adequate seed to be produced by the end of the growing season. There are marked differences between cultivars in their time to first flowering (see Table 1). This facilitates the selection of suitable cultivars for a wide range of growing-season lengths.

Time to first flowering in Perth from an early-May sowing of all cultivars has been averaged over several seasons and is shown in Table 1. From this we recognise three broad flowering-time groups referred to below.*

**Early flowering** – less than 105 days to first flowering.

**Mid-season flowering** – between 105 and 130 days to first flowering.

**Late flowering** – greater than 130 days to first flowering.

Flowering time in all cultivars is influenced by the timing of the break of season. If the break is delayed, flowering will start on a later date than that occurring with a normal break. However, the extent of the delay varies between cultivars, with early flowering cultivars such as Nungarin, Northam and Dwalganup, being much more affected than later ones such as Woogenellup, Mount Barker and Tallarook.

The location in which a cultivar is grown can also affect its flowering time. For example, at more northerly and relatively warmer locations such as Geraldton and Perth, flowering in early cultivars may be two to three weeks earlier than at cooler and more southerly sites such as Mount Barker and Esperance.

In addition to differences in time of flowering, cultivars vary in their rate of seed development. For example, in the early flowering group, cultivars such as Dwalganup and Northam flower early, but their seeds mature very slowly. In contrast, Geraldton starts flowering later, but because of rapid seed development, its maturity is similar to that of Dwalganup and Northam. Thus, the date of commencement of flowering alone is not necessarily an accurate index of final maturity.

The development of early flowering cultivars has enabled subterranean clover to be used in the drier margins of the wheatbelt. Nungarin is the earliest flowering cultivar in the current range. It was originally thought to be capable of growing in areas with as little as 250 mm annual rainfall, i.e. very close to the dry margins for agriculture. However, with the short crop/pasture rotations currently being practised in the wheatbelt, Nungarin is not able to regenerate and persist reliably under such low rainfall conditions.

It can be argued that the emphasis on earliness for low rainfall clovers may involve some loss in the potential for dry matter production and perhaps a lower quality of dry feed, resulting from the maturation of the plant while conditions are still moist. However, there must always be some compromise between the above considerations and the requirement for seed production.

In the low rainfall areas (275 to 400 mm annual rainfall) consistent seed production and good clover density in the pasture are more useful than the occasional benefit that a later cultivar might give in good seasons. The development of cultivars with greater hard-seededness could result in slightly later maturing cultivars being used. These would produce a large quantity of hard seeds in good seed-setting seasons, which would ‘top up’ seed reserves following poorer seasons.

The cultivars now available span a wide maturity range (see Table 1), with Nungarin the earliest cultivar and Tallarook the latest. It seems unlikely that the range will need to be expanded in the future. In fact, at the late end, Tallarook is probably too late-maturing in Western Australia for all but the wettest part of the south coast, where perennial clovers can be grown. Any later flowering type would probably be less persistent and useful than perennial species.

* In the past, subterranean clover flowering categories have been termed ‘early’, ‘early-mid-season’ or ‘late-mid-season to late’. We have chosen to simplify this terminology to ‘early’, ‘mid-season’ and ‘late’ flowering.
Clover disease symptoms

(a) Prolapsed vagina

(b) Difficult lambing

known that flower up to a week earlier than Nungarin but all tend to have very limited herbage production potential.

Oestrogenic activity

Since the 1940s, subterranean clover has often been associated with sheep infertility, and lambing percentages of 20 per cent or less have been recorded in some subterranean clover districts. Infertility can exist at two levels. Temporary infertility occurs when ewes graze oestrogenic pastures at the time of mating, but does not persist if sheep are moved to non-oestrogenic pastures. Permanent infertility occurs if sheep have been grazing oestrogenic pastures for several years and is characterised by a progressive decline in ewe fertility. The main cause of infertility is impaired transport of sperm through the cervix, associated with the production of abnormal cervical mucus.

Characteristic features of this syndrome, which is commonly known as clover disease, include maternal dystokia (difficult births), increased death rates and uterine prolapse in ewes, post-natal mortality of lambs and lactation and bladder distension in wethers. Fertility of rams is not affected. Although the more extreme symptoms are rarely seen today, infertility at sub-clinical levels appears widespread and is of economic significance.

Clover disease is caused by oestrogenic isoflavones, which are compounds formed in the green leaves of subterranean clover. Three isoflavones, formononetin, genistein and biochanin A, have all been found in large quantities, with individual levels in some subterranean clovers of as much as 2 per cent or more of the leaf dry weight. Of these, formononetin is the one responsible for most of the oestrogenic activity.

The Yarloop, Dwalganup and Dinninup cultivars have been associated with serious clover disease problems and Geraldton has been implicated in less spectacular cases. The other potentially oestrogenic cultivars, Howard and Tallarook, have limited distribution in this State. All recent cultivars have much lower formononetin levels, although Meteora has a higher than desirable level. Esperance and Enfield should also be regarded as slightly suspect with respect to clover disease.

Isoflavone content of the leaves can be influenced by the growing environment. Isoflavone (and in particular formononetin) content is increased by low temperatures and deficiencies of phosphorus, sulphur, nitrogen or zinc. It is decreased by low light intensity and severe defoliation. Isoflavone content also decreases from mid-flowering as plants approach senescence. Table 1 outlines typical levels of the three oestrogenic isoflavones, prior to mid-flowering in the registered cultivars. It should be noted that some cultivars, including Daliak, Woogenellup, Karridale and Trikkala, can have moderate levels of formononetin early in the season, but low levels from about mid-winter onwards.

All new cultivars should be low in formononetin, even if their use is intended for cattle grazing because, under different economic circumstances, sheep may become part of the farm enterprise in such localities. A maximum formononetin content of 0.20 per cent of leaf dry weight is used in the breeding program. Cultivars with higher levels are culled. Cultivars with lower levels than this can be

Subterranean clover is able to flower and set seed under moderately hard grazing pressure.
easily produced, as such levels are found in many introductions and naturalised strains in the subterranean clover collection.

**Seed production and burr burial**

As with any annual species, the success of subterranean clover is largely determined by its ability to produce seed. The level of seed production in a cultivar is influenced by a number of factors, including its maturity in relation to the length of the growing season, its burr burial ability, its capacity to set seed above ground, the level of grazing, the degree of competition from other species in the pasture and the effects of pests and diseases.

Seed yields in subterranean clover cultivars vary markedly from year to year, primarily because of differences in the amount of available soil moisture during the flowering and seed production phase, which in turn is a reflection of variability in rainfall. Nevertheless, within flowering-time groups, some cultivars have been more reliable, with respect to seed production, than others. Nungarin, Dalkeith and Geraldton have proven superior to Dwalganup and Northam in dry areas. York generally produces more seed than Seaton Park in medium to high rainfall areas, while Trikkala is generally better than Yarlool. Amongst the late flowering cultivars, Denmark and Goulburn have shown outstanding seed-setting ability.

The ability to bury burrs in the soil, a characteristic feature of subterranean clover, is of considerable importance in relation to seed production. Compared with unburied burrs, buried burrs are larger, they produce more and larger seeds, and the seeds have higher levels of viability and hard-seededness. Sensitivity to light in the developing burrs is the main reason for the differences between seeds formed above and below ground.

Burr burial is important for pasture re-establishment in the following season. Seeds situated below ground usually establish more successfully than seeds on the soil surface, where seedling losses may be very high as a result of desiccation. Buried burrs are also less likely to be eaten by grazing animals over the summer-autumn period.

Despite the significance of burr burial for seed production and seedling survival, cultivars differ greatly in their capacity to bury burrs. Late flowering cultivars such as Mount Barker, Woogenellup and Bacchus Marsh have rather poor burial ability compared with early flowering cultivars such as Northam, Nungarin and Dalkeith. Table 1 outlines relative differences between the commercial cultivars in strength of burr burial.

Burr burial is markedly influenced by soil texture. On soft sandy soils there is less need for cultivars with strong burr burial; even the weaker cultivars in this respect are able to achieve some penetration. Burial is also affected by the amount of moisture in the surface soil; generally more burrs are buried in the early part of the seed production phase, when soils are usually moist, than later on when the surface is drying out. On heavier textured soils, the surface sets hard in spring, and even strong buriers like Nungarin, Northam and Dalkeith cannot bury their burrs. In other situations, burr burial may be reduced because of compaction of the soil by grazing animals. In some traditional grazing areas, lack of burial undoubtedly contributes to deterioration of subterranean clover pastures.

It is generally accepted that frequent grazing of subterranean clover swards up to the start of flowering greatly increases seed production. This is a result of increased burr production and increased burr burial. In addition, grazing reduces competition, particularly for light, from taller growing components of a pasture such as grasses and some weeds.

**Hard-seededness and embryo dormancy**

Under dryland conditions, some form of over-summer germination regulation is generally required to reduce losses of seeds that germinate and die following 'false-breaks' (early summer or autumn rains without follow-up rainfall). A further requirement for environments with unreliable spring rainfall and, in particular, where high cropping frequencies are practised, is the spread of germination beyond one or more growing seasons.

For irrigated pastures, however, the requirements differ markedly from those of dryland pastures. Here prevention of early germination can be a distinct disadvantage, where maximum germination is required following late summer or early autumn irrigations.

Two germination regulating mechanisms operate in subterranean clover. These are hard-seededness and embryo dormancy. Of these, hard-seededness is the most important.
cultivars produce a large quantity of hard-seeded that soften over several seasons. If poorer seed-setting seasons follow, these seeds can add to the pool of seeds germinating each year, to increase the potential for good regeneration densities. In years of little or no seed-set, such as severe droughts or years in which the area is cropped, hard-seededness ensures that some seed will remain for future pasture regeneration. This buffering effect also implies that if cultivars with greater hard-seededness are developed, they can be of slightly later maturity than those previously recommended, and still be capable of reliable regeneration.

The second function of hard-seededness is to cushion the effects of false breaks on loss of seed reserves. If a false break occurs, a proportion of seed is still available in the soil for subsequent germinations. The amount lost from the seed reserve is less for hard-seeded cultivars than for softer-seeded ones (Figure 3). Should a poor seed-setting season follow a false break, seed reserves of soft-seeded cultivars become depleted to a much greater extent than more hard-seeded cultivars. If false breaks occur very early in the season, further softening can occur in the remainder of the summer/autumn period, to allow some clover regeneration when the true break-of-season arrives (Figure 3).

The pattern of hard-seed breakdown during the summer-autumn period also plays a role in determining the extent of germination following false breaks. In most cultivars, the rate of softening during this period is approximately linear (see Figure 3). In contrast, most of the annual medic softens very little over most of this time, but have a rapid burst of softening in late autumn. This has the effect of minimising seed losses from any false breaks during summer and early autumn. Such a pattern of hard-seed breakdown would also be advantageous in subterranean clover for reducing seed losses following false breaks. There do appear to be some subterranean clover introductions that have patterns of seed softening similar to the medics. It is likely that future cultivars will be bred with such seed softening patterns.

Insufficient hard-seededness is widely recognised as a major limitation to persistence of subterranean clover, particularly when grown in rotation with crops. In the low rainfall wheatbelt, cropping frequency over the last two decades has been very high, often every second year. Under this farming system, current cultivars are not hard-seeded enough to regenerate at satisfactory densities in pasture phases of the rotation. Reliable regeneration

Hard-seededness serves two useful functions. The first is to act as a buffer to smooth out seasonal peaks and troughs in seed reserves. In seasons favourable for seed production, hard-seeded

Hard-seededness, or seed coat impermeability, is due to an impermeable layer in the seed coat which prevents uptake of water by the seed. Germination is thereby prevented. Individual seeds that are impermeable to water are referred to as hard seeds.

The proportion of hard seeds in all subterranean clovers is commonly greater than 90 per cent when seeds first mature and dry out. During the summer and early autumn, the impermeable layer of some seeds breaks down, in a process known as seed softening. Soft seeds are then able to take up soil moisture after rainfall or irrigation.

The rate of seed softening varies between cultivars (see Table 1). Soft-seeded cultivars have a rapid rate of hard seed breakdown, resulting in a high proportion of seed ready to imbibe water in the following autumn. Hard-seeded cultivars, however, have a high proportion of seed able to survive beyond the following autumn without imbibing water and germinating. These hard seeds remain in the soil for germination in future seasons.

Breakdown of hard-seededness is largely governed by the summer temperatures to which the seeds are exposed, and in particular, by the range of diurnal fluctuations in temperature which occur. Breakdown is faster in environments which have high summer temperatures and large diurnal ranges in temperature. Burial of seeds through tillage operations reduces the rate of hard-seed breakdown. Shading of the soil surface by dry vegetation through the summer-autumn period also reduces the rate of seed softening. Such plant material acts to insulate seed from the high diurnal temperature extremes that exist on bare soil. Tillage also has the same effect.

Hard-seededness serves two useful functions. The first is to act as a buffer to smooth out seasonal peaks and troughs in seed reserves. In seasons favourable for seed production, hard-seeded
is further complicated by the frequent occurrence of false breaks, low spring rainfall and the effects of spray-topping, all of which diminish the seed pool.

The first early flowering cultivars, Geraldton and Dwalganup, with about 20 per cent hard-seeds at the break of the season in the wheatbelt, fall well below requirements. Nungarin and Dalkeith have 40 per cent or more hard-seeds at the break of the season. Even these cultivars are not hard-seeded enough to regenerate reliably in years following cropping. By way of contrast, annual mediccs have about 75 per cent of their seed still hard at the break of the season, and can regenerate satisfactorily following two or more crops. Computer modelling by Graham Taylor and colleagues of CSIRO indicates that subterranean clover cultivars with at least 60 per cent of seed still hard at the true break of season are required for reliable persistence in 1 crop/1 pasture rotations. Increasing the levels of hard-seededness in subterranean clover cultivars intended for low rainfall wheatbelt areas remains an important objective of the breeding program.

In medium to high rainfall areas, some degree of hard-seededness is important. In such areas, mixed farming is often practised, with cropping frequencies typically one year in every four. To ensure adequate regeneration after the cropping phase, and to reduce the carry-over effects of false breaks and poor seed-setting seasons, a moderate level of hard-seededness is required. Under this farming system, the hard-seededness of Seaton Park and particularly Woogenellup and Trikkala, is too low. The more recent cultivars Junee and York have much more appropriate levels of hard-seededness among mid-season flowering cultivars for mixed farming enterprises.

The need for cultivars with high levels of hard-seededness is less important in high rainfall, semi-permanent pasture environments, where cropping is rare. The summers are also shorter and cooler and there is a greater bulk of dry pasture residues. Thus breakdown of seed coat impermeability during summer is relatively slow. Cultivars with excessive hard-seededness may in fact be at a disadvantage in these areas, particularly in the year after establishment, if too much of the previous year’s seed crop remains impermeable. The resultant poor stand in the second year may allow competitors, such as less desirable clovers, grasses and herbs to predominate. This has been observed in the late flowering ssp. \textit{yanninicum} cultivar, Meteor, which is very hard-seeded for its maturity. Nevertheless, the inherent hard-seededness of Mount Barker and Woogenellup commonly grown in these areas, is too low. Here, the more recent cultivars, Karridale, Denmark, Goulburn and Gosse seem to be hard-seeded enough to ensure good persistence.

Hard-seededness can also be beneficial in disease-prone areas, enabling subterranean clover to survive severe losses of seed production in one or more years. For example, there is evidence at Esperance, that Woogenellup-based pastures have been more severely reduced in clover density by clover scorch disease (caused by the fungus \textit{Kabatiella caulivora}) than the harder-seeded, but equally scorch susceptible Yarloop and Seaton Park cultivars.

\textbf{Embryo dormancy} is a mechanism that prevents soft seeds from germinating, even after they have imbibed water. There are conflicting views about the importance of embryo dormancy. It is believed to have two roles. The first is to prevent premature germination in early summer before newly matured seeds have fully dried out and developed their hard-seededness. The second is in reducing germination of softened seeds following summer and early autumn rains that are only marginally sufficient for germination. Embryo dormancy has no role in preventing germination beyond the autumn-winter period.

The expression of embryo dormancy is substantially influenced by the temperature to which imbibed seeds are exposed, and to the time since seeds achieved full maturity. Early in the summer, soft seeds can only germinate when temperatures are very mild. However, as the summer-autumn period progresses, the maximum temperature at which germination of soft seeds can take place increases. Embryo dormancy can be broken down by a succession of rain events and by short periods of low temperature.

There are differences among the cultivars in their expression of embryo dormancy. Dinnup is widely recognised as having a high level, while Woogenellup, Clare and Enfield have low levels. Ratings for the cultivars are shown in Table 1. These are based on limited field observations. Little formal screening has been conducted for embryo dormancy in the breeding program.

\textbf{Disease resistance} During the early part of its history in Western Australia, subterranean clover was largely free from serious diseases. However, some major problems have arisen since 1970.

\textbf{Clover scorch} Serious outbreaks of this disease, which is caused by the fungus \textit{Kabatiella caulivora}, were first reported in 1970 from the Albany and Bunbury areas and this was followed by a severe epidemic in 1971 affecting areas from Bunbury to Esperance. The damaging effects of clover scorch on subterranean clover growth and persistence were best illustrated in the Esperance area where, following the first outbreak in 1971, many pastures deteriorated rapidly, resulting in a reduction of potential carrying capacity.
Table 2. Disease and pest resistance ratings of the subterranean clover cultivars registered in Australia.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Clover scorch</th>
<th>Phytophthora root rot&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Pythium damping off</th>
<th>Rhizoctonia damping off</th>
<th>Fusarium damping off</th>
<th>Leaf rust</th>
<th>Powdery mildew</th>
<th>Cercospora leafspot</th>
<th>Redlegged earth mite (seedling)</th>
<th>Bluegreen aphid</th>
<th>Subterranean clover mottle virus</th>
<th>Bean yellow mosaic virus</th>
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<sup>a</sup> Race 0, the only confirmed race in Western Australia. Ratings may differ for other races found in eastern Australia.

**Ratings:**
- **HS** – Highly susceptible.
- **S** – Susceptible.
- **MS** – Moderately susceptible.
- **MR** – Moderately resistant.
- **R** – Resistant.
- **HR** – Highly resistant.
The fungus most commonly affects the junction of the leaflets and the petiole, causing the earliest symptoms of the disease — a characteristic turning of the leaves to expose the under-surface. Lesions then develop, cutting off the water supply to the leaves, and causing the leaves to wilt. As the disease progresses, the clover stand gradually collapses and in cases of total collapse, takes on a scorched appearance. In seasons favouring the disease, susceptible cultivars can have both herbage yield and seed yield reduced by 90 per cent or more. The reduced seed bank often leads to unproductive, weed dominated pastures which require resowing.

Commercial cultivars differ markedly in their ability to withstand clover scorch (see Table 2). Daliak, Esperance, Junee, Green Range, Denmark, Goulburn, Gosse and Meteor have all shown considerable resistance to the disease. Yarloop, Woogenellup, Dininiup, Seaton Park and all the early flowering cultivars, other than Daliak, are susceptible and are not recommended for areas prone to clover scorch. Other cultivars such as Mount Barker, Karriade, Riverina, Larisa, Trikka, York and Leura are intermediate in their reaction to clover scorch — they may suffer some production losses, but are rarely destroyed by the disease.

Although clover scorch has not been as serious as it was in the early 1970s, it is still a major pasture problem in many years, particularly along the south coast of Western Australia, because of its adverse effects on spring growth and seed production. Resistance to clover scorch is a major selection criterion of the breeding program for mid-season and late-flowering cultivars.

Of recent concern is the discovery of a new race of clover scorch which appeared in field plots at Denmark in 1990. This race is capable of attacking many previously highly resistant cultivars such as Esperance, Green Range and Junee and other cultivars with useful field resistance such as Mount Barker and Karriade. If this or a similar race was to become widespread, about 4 million hectares of subterranean clover-based pastures in southern Australia would be at risk of devastation. Strategies implemented to limit spread of this new race have been successful to date, as it has not been found outside the initial outbreak site. During 1995, a further breakdown of host resistance occurred on a farm at Esperance.

Root rots

Root rot diseases, caused by a number of fungal pathogens including *Pythium*, *Phytophthora*, *Rhizoctonia*, *Aphanomyces* and *Fusarium* species, have the potential to seriously affect subterranean clover productivity in high rainfall areas. They are an important cause of poor persistence of subterranean clover in parts of these areas and, hence, a major contributor to the problem of pasture deterioration. In many cases, root rotting problems are the result of several soil-borne fungi acting together.
Damage caused by root rotting pathogens can take two forms. Firstly, they can cause 'damping off' in seedlings. Levels of pre-emergence damping off, in which seedlings fail to emerge, can be more than 90 per cent in root-rot affected paddocks. Post-emergence damping off, in which seedlings emerge but then collapse, can also result in high losses. This substantial loss of seeds and seedlings from damping off is not always obvious and often goes unnoticed. The second form of damage occurs in plants that survive the damping off stage. In these plants, damage is manifested by root rots. The growth of affected seedlings can be greatly reduced. Plants are stunted and discoulored, with roots having a brown discoulouration. In severe cases, tap roots may be 'pinched off'.

Screening of subterranean clovers for their reaction to root rots has been undertaken by Agriculture Western Australia, as part of the breeding program. A large number have been tested in the field to identify field resistance to root rots in general, while glasshouse experiments have sought resistance to specific root rot pathogens, particularly *Pythium irregulare*, *Rhizoctonia solani* and *Fusarium avenaceum*. For each of these fungi, the damping off stage, which affects seedling survival, is considered more important that any root-rotting that may occur on surviving plants. Table 2 shows glasshouse ratings for susceptibility to damping off by each of these fungi. In Western Australia, damping off caused by *Pythium irregulare* and *Rhizoctonia solani* is more severe than that caused by *Fusarium avenaceum*, although they often interact together and with other soil-borne pathogens.

Cercospora leaf spot damage.

is the only cultivar rated as resistant to *Rhizoctonia* damping off, although York, Goulburn and Leura have moderate resistance. All other cultivars are at least moderately susceptible. Several cultivars appear to have good levels of resistance to *Fusarium* damping off. Those rated as resistant include Nungarin, Northam, Dwalganup, Dallak, Trikkala, Dinninup, Enfield, Riverina, Junee, Green Range, Mount Barker, Karridale, Larisa and Goulburn. The most susceptible cultivars to *Fusarium* damping off are Woogenellup, Bacchus Marsh, Denmark, Nangeela and Meteora.

Rust pustules on Green Range.


Powdery mildew infection.

Screening for resistance to *Phytophthora clandestina* is conducted by the Victorian Department of Agriculture as part of the ASCALIP subterranean clover improvement program. Four different races of *Phytophthora clandestina* (Races 0, 1, 2 and 3) have been identified in eastern Australia. Cultivars resistant to one race may not always be resistant to the others. In Western Australia, only Race 0 is confirmed to exist. The cultivars Trikkala, Larisa, Gosse, Seaton Park, Riverina, Denmark, Goulburn, Leura, York and Dinninup all have good resistance to Race 0, while Woogenellup, Yarloop, Green Range, Esperance, Mount Barker, most of the early flowering cultivars and all the ssp. *brachycalyicllum* cultivars are susceptible to it (see Table 2). Some of the cultivars resistant to Race 0 are susceptible to the
other races of Phytophthora found in eastern Australia. Only Riverina and Seaton Park are resistant to all four races of Phytophthora. A national survey is currently being undertaken to define the distribution of P. clandestina races.

Other foliar diseases
The leaf diseases, rust (Uromyces trifolii-repentis), Cercospora leaf spot (Cercospora zebrina), powdery mildew (Erysiphe polygonii), and Pseudopeziza leaf spot (Pseudopeziza trifolii) can all affect subterranean clover under favourable conditions. Rust, powdery mildew and Pseudopeziza generally only cause problems in higher rainfall areas, while Cercospora is more widespread. These diseases usually only severely damage ungrazed swards for hay or seed production. It is uncommon for them to cause problems in well-grazed swards. There are differences among the cultivars in their reactions to these diseases (see Table 2).

Green Range is the only cultivar that is highly susceptible to leaf rust. Typical symptoms of rust consist of reddish brown pustules on the leaflets, particularly the under surfaces, and petioles. Affected leaves frequently wither and die. Under favourable conditions for the disease, Green Range will suffer enormous herbage and seed production losses. In fact, total loss of seed production has been reported in some seed crops of Green Range. It is no longer recommended because of its extreme susceptibility to this disease. Mount Barker, Karridale, Denmark, York, Woogenellup and Seaton Park have susceptibility to rust, but generally suffer little economic losses. The ssp. yunninicum cultivars Larisa, Meteor, Trikka, Riverina and Gosse are highly resistant. Enfield and Clare are also very resistant.

Cercospora leaf spot is widespread in Western Australia. The disease is characterised by salmon-pink or brown leaf spots, which coalesce to cause leaf collapse. It can result in severe defoliation and reduced seed production in susceptible cultivars. Nungarin, Northam, Daliak, Esperance and Rosedale are particularly susceptible to Cercospora leaf spot. Complete stand collapse has been observed in cultivar Esperance. Seed yield reductions of up to 45 per cent in Esperance have also been recorded where conditions have been favourable for the disease. Meteor, Yarloop, Gosse, Riverina, Clare and Larisa are highly resistant to Cercospora leaf spot. Leura also has resistance.

Powdery mildew is common on subterranean clover in coastal districts of Western Australia, particularly along the south coast. The most obvious symptom of the disease is a whitish powdery growth on the leaflets, which yellow and die prematurely when infection is severe. Junee is the most susceptible of all cultivars to powdery mildew, although actual herbage and seed production losses from this disease have not been determined in Western Australia. Losses caused by powdery mildew are likely to be less significant in other cultivars. Tallarook is the most resistant of the commercial cultivars to powdery mildew. York, Esperance and Clare also have good resistance.

Pseudopeziza leaf spot is generally only of importance in the long growing-season areas of Western Australia. The disease symptoms are brown to black spots on the leaf blade, causing them to shrivel up and die when infection is severe. Seed yield losses of up to 35 per cent have been attributed to the disease under conditions favourable for its development. Cultivars vary in resistance, although detailed comparisons have not been made. Dalkeith appears to be highly susceptible to the disease, while Larisa, Woogenellup and Trikka appear to have good field resistance.

Breeding lines are screened for reaction to rust, Cercospora leaf spot and powdery mildew, prior to registration as new cultivars, to ensure that none are super-susceptible to any of them. No formal screening has been conducted yet for resistance to Pseudopeziza leaf spot.

Virus diseases
Plant viruses have become more prominent in subterranean clover pastures in Western Australia in recent years. Subterranean clover mottle virus (SCMV) and bean yellow mosaic virus (BYMV) are
Redlegged earth mites showing typical silvering damage to leaves.

Blue-green aphids on subterranean clover.

Infection levels are normally low, but where the level of infection is high, the virus can seriously reduce herbage and seed production. The virus is transmitted from infected to healthy plants by aphids, particularly the bluegreen aphid. No subterranean clover cultivars are highly resistant to BYMV (see Table 2). The earlier flowering cultivars are generally less affected by the virus than the later flowering ones. This may be due to the earlier flowering cultivars escaping the effects of the disease late in the season, rather than due to true resistance. Nungarin, Dwalganup and Rosedale are least affected by BYMV. Bacchus Marsh, Marridale, Leura, Meteor and Tallarook suffer the most damage while Denmark, Goulburn, Mount Barker, Clare and Green Range are also badly affected.

**Pest resistance**

**Redlegged earth mite**

Redlegged earth mite (RLEM) (*Halotydeus destructor*) is the most important pest of subterranean clover. It was first recorded in Western Australia in 1917 and is now widespread throughout the south-west of the State. Redlegged earth mites can attack germinating seedlings in autumn, resulting in stunting and even death. They can also cause reductions in herbage and seed production in mature plants in spring. Damage in both situations results in reduced pasture productivity and clover persistence. None of the

Subterranean clover mottle virus is widely distributed in the higher rainfall areas of Western Australia. It is spread during the growing season from infected to healthy plants by plant damage as a result of grazing and trampling. In susceptible cultivars, the virus can result in large losses in late spring herbage production and in seed production. There is a range among the cultivars in their susceptibility to SCMV (see Table 2). The ssp. *yanninicum* cultivars Gosse, Meteor, Trikkala, Larisa and Yarloop and the ssp. *brachycaulicum* cultivars, Clare and Rosedale, are highly resistant. No ssp. *subterraneum* cultivars are highly resistant, although several, including Denmark, Goulburn, Leura, Esperance, Seaton Park and Dwalganup, have moderate resistance. Dalkeith, Daliak, Dinninup, Junee and Woogenellup are all highly susceptible to SCMV. Mount Barker, Green Range and York are also susceptible to the virus.

Bean yellow mosaic virus is present in subterranean clover pastures in Western Australia from Geraldton to Esperance in high and medium rainfall zones.

Measuring herbage production in subterranean clover trial plots.
Regeneration and herbage production

Farmers like to be able to boast about having clover 'up to their knees' in spring. However, in Western Australia, it is the herbage produced early in the season that is most valuable. In fact, Agriculture Western Australia economists have estimated that in wheatbelt pastures, each additional 1 kg of herbage in autumn-winter can be worth up to 10 times its value in spring. This is because the autumn-winter period is usually a time of critical feed shortage. In contrast, feed is usually abundant in spring and extra herbage is often not fully utilised. Clover herbage production in autumn-winter is strongly determined by the density of seedlings regenerating after the autumn break. By late winter and spring, less dense swards often catch up to denser ones, to produce similar herbage quantities. They are able to make compensatory growth due to reduced competition between seedlings.

The clover density of regenerating pastures in any season is influenced by many factors, including seed production in preceding years, the proportion of seed softened during the previous summer, the amount lost to false breaks and whether the paddock was in a crop or pasture phase in the previous season. Over a

Registered cultivars of subterranean clover - their characteristics, origin and identification 21

Dense seedling regeneration leads to clover-dominant pastures.

Field evaluation trial illustrating denser subterranean clover regeneration in better adapted cultivars.

registered cultivars have significant resistance to RLEM, particularly at the seedling stage (see Table 2). Glasshouse trials suggest that Clare, Bacchus Marsh and Mount Barker have slightly less seedling susceptibility to RLEM than the other cultivars, while Yarloop, Nuba, Meteora and Leura appear to be the most susceptible. Fortunately, it appears that some introductions in the subterranean clover collection have much improved seedling resistance to RLEM. It is hoped that cultivars with resistance to this pest can be released in the future.

Bluegreen aphid

Damage to subterranean clover caused by bluegreen aphids (BGA) (Acrystosiphon kondoi) was first reported in 1979. Bluegreen aphids reduce the herbage and seed production of subterranean clover. So far they have not caused widespread damage, although there have been isolated reports of the premature collapse of clover swards in spring as a result of aphid attack. Amongst the commercial cultivars, Daliak, Uniwager, Yarloop, Trikkala and Larisa appear to be the most susceptible (Table 2). Bluegreen aphid resistance is not a high priority in the breeding program. However, promising breeding lines are checked prior to registration as new cultivars to ensure that they are not super-susceptible to BGA.

Counting regenerating seedlings in subterranean clover field evaluation trials.
long time-frame, persistence of the clover content of a pasture is related to the average clover density over a number of seasons.

There appear to be differences among the cultivars in their regeneration ability and long-term persistence. Maturity is obviously a major factor influencing persistence in a particular environment, but there are differences between cultivars of similar flowering time. Denmark and Goulburn consistently produce much denser regenerating pastures than Mount Barker, Karriade and Woogenellup. Similarly, York has generally produced denser early season pastures than Seaton Park and Junee in trials. While some of the factors contributing to improved persistence are known, much needs to be known before we have a greater understanding of the processes involved.

Winter vigour is regarded as a valuable character in subterranean clover cultivars and contributes strongly to 'farmer appeal'. Woogenellup became a widely sown and popular cultivar because it appears to have good winter growth. Yarloop, Gosse and Trikkala have also been observed to grow vigorously in winter. In contrast, cultivars such as Daliak, Larisa and Mount Barker appear to make much less growth in winter. While there may well be differences between cultivars in winter growth, visual assessment of this character is complicated by differences in growth habits. With respect to the above cultivars, the erect growth habit of Woogenellup, Yarloop, Gosse and Trikkala gives an impression of more vigorous growth than that in Mount Barker, Daliak and Larisa, which have a more prostrate habit.

**Animal production response**

Animal production refers to the amount of meat, wool or milk produced from a pasture, after animal maintenance requirements have been satisfied. The animal production capacity of a pasture is determined by its nutritive value and feeding value. These two terms, while often used interchangeably, are different. **Nutritive value** of a pasture is the animal production response per kilogram of feed ingested. It is largely determined by plant digestibility and also by the efficiency of utilisation of digested nutrients. **Feeding value** of a pasture refers to the animal production response when feed available is non-limiting. It is determined primarily by feed intake and also by nutritive value.

The feeding value of a pasture is most readily improved by increasing its legume content. This is because legumes in general have a much higher feeding value than grasses and other plants in the pasture, particularly so during summer and autumn. With this in mind, breeding and selection has primarily concentrated on developing subterranean clovers better able to persist from season to season, thereby maintaining a high legume content in the pasture. The increased nitrogen inputs into the soil, arising from a greater clover density, also improve the productivity of grasses and other plants in the pasture. Use of subterranean clover cultivars with characters leading to greater persistence from season to season will, therefore, result in pastures with improved feeding value in the long-term.

Until recently, little attention has been devoted to actively selecting subterranean clovers with improved nutritive value. Selection for improved nutritive value is possible, provided that sufficient genetic variation exists and that it does not accompany a loss of pasture productivity. To conduct such selection as part of a plant breeding program, simple laboratory techniques for predicting animal production responses need to be available. Measuring actual animal production responses, due to different subterranean clovers, is both time-consuming and expensive. Field measurements require large areas and many animals, while pen feeding experiments require much animal handling. In both cases, a very small number of subterranean clovers can be evaluated at any one time, precluding their use as routine screening techniques.

Limited evidence suggests that when green, there are not major differences for nutritive value between subterranean clover cultivars. However, differences in feeding value have been implicated among some of the cultivars, with Dinnup pastures producing lower wether liveweights in early spring than those of Geraldton, Daliak and Seaton Park. Such differences have been attributed to differences in feed intake.

The nutritive value of all subterranean clovers rapidly declines during senescence (haying-off). Further losses in nutritive value occur through leaching of nutrients from the dry herbage following summer and autumn rains. Improving the nutritive value of dry herbage could have major benefits in reducing stock weight losses over the summer-autumn period.

The maturity of a cultivar is a major factor in determining the nutritive value of its dry residue over summer in any given environment. In general, early maturing cultivars will have a lower nutritive value by late summer than later maturing ones. Early maturing cultivars senesce earlier than later maturing ones and so have a greater chance of rainfall events spoiling their dry residues, particularly in mid to late spring.

Sowing cultivars that are too early maturing, that senesce before available soil moisture runs out, results in a lost opportunity for maintaining green feed of high nutritive value further into the season, in addition to reduced herbage production. The high nutritive value of a green pasture can be retained longer into the spring or early summer by using later maturing cultivars. However, this benefit needs to be balanced against the long-term need for the clover to have enough time to produce sufficient seed for reliable regeneration.

There is some evidence for differences in both nutritive and feeding values of dry herbage among subterranean clovers of similar maturity. CSIRO Division of Animal Production are investigating
differences in nutritive and feeding value in both green and dry herbage of a range of subterranean clovers. Other work is investigating methods for predicting animal performance, utilising laboratory techniques that require only small quantities of plant material.

CSIRO Division of Plant Industry are currently undertaking a project to incorporate high-sulphur proteins from sunflower seeds into the leaves of subterranean clover, by genetic engineering. Such proteins are known to increase wool production under most physiological conditions. Field trials of these genetically engineered clovers will be undertaken over the next few years.

**Palatability** is a term often used to describe preferences by animals for one pasture feed type over another. It can be regarded as any feed characteristic that affects the intake of a feed whether offered alone or as a choice, and may include factors such as taste, smell, limiting nutrients, toughness and digestibility. Palatability contributes to the feeding value of the pasture, due to its effect on intake.

Palatability differences between green subterranean clovers have been commonly observed, with Dinninup and Yarloop in particular, being regarded as relatively unpalatable. High fomononetin content is often considered to be the main cause of unpalatability in subterranean clover, although there is limited evidence to support this.

Plant disease is also believed to lower palatability. In a mixed-species pasture, unpalatability of the clover results in increased grazing pressure on the non-clover components. In pastures containing mixtures of subterranean clover cultivars, selective grazing can often occur, to the detriment of the more palatable cultivars. This is particularly the case with the older cultivars, where the relative unpalatability of Dinninup appears to be a major reason for its rapid build-up and eventual dominance in many higher rainfall pastures. A consequence of this is a gradual decline in the feeding value of the pasture.

There is evidence that the recently released cultivars of Sardinian origin (Denmark, Goulburn, Leura and York) are able to dominate Dinninup after a few seasons in mixed pastures. Trikkala is also able to dominate mixed pastures with Yarloop. These newer cultivars appear to be very palatable to grazing animals. Their palatability, coupled with their greater regeneration ability and early season herbage production, mean that these cultivars are better able than older cultivars to maintain a high feeding value of the pasture in both the short and long term.

**Herbicide resistance**

The development of subterranean clovers with resistance to an inexpensive broad-spectrum herbicide would enable cheap and effective weed control in pastures to maximise the legume content. Several grass control herbicides are available on the market that are effective in controlling grasses and have little, if any, damaging effects on clovers. However, their relatively high cost generally restricts their use to specialist seed growers. A range of herbicides is also available for control of broad-leaved weeds in clover pastures. However, all of them damage clover plants to varying degrees, resulting in herbage and seed production losses.

Resistance to an inexpensive broad-spectrum herbicide would offer several advantages. Spray-topping could be done without decreasing clover seed yields. Old oestrogenic cultivars could be readily replaced by over-sowing low oestrogen, herbicide-resistant ones and spraying the relevant herbicide. Basic and certified seed production of herbicide-resistant cultivars would be easy, as any contaminant clovers could be sprayed out.

Genes for resistance to several herbicides, and the technology for incorporating them into subterranean clover are available. However, before cultivars with herbicide resistance are released, the ramifications of their use need to be widely debated. Such issues include the effect on weed control options in a cropping phase and environmental concerns about the increased use of herbicides on pastures. It also remains to be seen whether the incorporation of genes for herbicide resistance has any effect on plant growth.
Identification of the registered cultivars

There are several visible characters that can be used to distinguish subterranean clover cultivars. These can be classified into:

(i) 'primary' characters, which vary greatly between the cultivars and also tend to remain relatively constant across environments and throughout much of the growing season; and

(ii) 'secondary' characters, which either vary considerably with growth conditions and stage of plant development, or do not vary greatly between most cultivars.

'Primary' characters are the most useful for identification. However, 'secondary' characters can act as an aid to help confirm identification.

Even within the 'primary' characters, expression of some characters can vary slightly, both within individual plants and between different plants of the same cultivar. For this reason, it is always advisable to look at more than one leaf or runner of a plant and better still to look at more than one plant in a given sample.

The plant parts used for identifying cultivars are shown in Figure 2. Identification is based on variation in attributes of the leaf, petiole, stipule, runner, flower and seed, together with data on the time of flowering.

The categories of variation and their ratings for the registered cultivars are shown in Table 3. This data has been collected from healthy, undefoliated, irrigated rows or single plants sown at Perth in mid-May. The rating system used for some characters differs to that used in previous editions of this Bulletin. We have opted to use the same rating systems used in the Australian Trifolium Genetic Resource Centre (ATGRC).

To identify a plant, its characters should be related to those in Table 3. To confirm the identification, the specimen should be compared to the colour plates showing leaf, flower and runner for each cultivar included in the text. In this edition of this publication, we have included photographs of the leaves of each cultivar in winter, as well as spring, to encompass some of the variation in leaf appearance as the season progresses.

The early flowering stage is the most suitable time to attempt identification. At this time, characteristics of the flower can be used for identification. Before flowering, identification is not easy and often impossible. The late flowering stage also presents difficulties, as leaf markings tend to fade and leaf shape becomes somewhat distorted.

The main characters used for identification are briefly described below.

Primary characters

Trifoliate leaf mark

This is the most useful character for distinguishing cultivars. Leaf marks refer to the central pale green or white markings found on the upper surface of the trifoliate leaves of most subterranean clovers. They do not refer to the brown or purple anthocyanin pigmentation patterns found on some leaflet upper surfaces, which are described as leaf flushing or flecking (see secondary characters).

Leaf marks are best observed from about the 4th leaf stage onwards until mid-flowering. In some cultivars, the first few trifoliate leaves fail to fully express their leaf mark. Leaf marks also tend to fade from mid-flowering onwards.

A standard system is used to describe different leaf mark patterns. Leaf marks can be described in terms of the widths and size of bands, crescents and arms (see Figure 4). These can be defined by the following:

(a) Crescent – a pale green triangle in the leaf centre, which varies in size between different cultivars.
  \( C_1 \) = small dot.
  \( C_2 \) = extending approximately from centre to halfway towards leaf margins.
  \( C_3 \) = extending approximately from centre to two-thirds distance towards leaf margins.
  \( C_4 \) = extending from margin to margin.

(b) Arms – usually white, extending from the edge of or underneath the crescent to the margins. These vary in width.
  \( A_1 \) = narrow arms.
  \( A_2 \) = intermediate arms.
  \( A_3 \) = thick arms.

(c) Band – a pale green strip extending from margin to margin, which varies in width between different cultivars.
  \( B_1 \) = narrow band.
  \( B_2 \) = thick band.

The leaf mark of a cultivar can consist of:

(i) a crescent alone (e.g. Mount Barker, Gosse, Meteor, Riverina, Bacchus Marsh);

(ii) a band alone (e.g. Nungarin, Geraldton, Northam);

(iii) arms alone (e.g. Yarloop);

(iv) a crescent with arms (e.g. Seaton Park, Junee, Dalkeith, Dwalganup, Larisa, Goulburn, York, Clare, Trikkala, Karridale, Leura); or

(v) no marking (e.g. Uniwager).

In some cultivars, the true leaf mark only becomes apparent under ideal conditions for its expression. Daliak and Esperance often appear to have no leaf
Leaf marking patterns.

Arms are generally white. However, Woogenellup, Rosedale and Nuba have pale green arms, while Karridale, Green Range and Nangeela tend to have cream arms. The arms of Denmark are quite unusual in being very diffuse and are often quite faint. A, arms often fade from mid-flowering onwards. This is the case with Dwalganup, Dalekith, Yarloop and Leura.

**Calyx tube pigmentation**

The calyx tubes of any cultivar have a characteristic pigmentation pattern, which remains relatively constant through most of flowering. Pigmentation extends along the calyx tube from the calyx lobes and can vary from no pigmentation (e.g. Woogenellup, Denmark, Seaton Park, Trikkala, Karridale) to the whole tube being pigmented (e.g. Daliak). The colour of pigmentation also varies between cultivars, ranging from a pale brownish pink (e.g. Yarloop) to a deep purplish red (e.g. Daliak, Esperance). Towards the end of flowering, the intensity of pigmentation often becomes somewhat weaker. Pigmentation in some cultivars is often only apparent when calyces are exposed to sunlight. This is the case with Dalekith, Dwalganup, Yarloop, Meteor, Riverina and Gossie. Under cold growing conditions, occasional calyces of Bacchus March, Junee, Karridale, Nangeela, Junee and Seaton Park can have a trace of pigmentation when exposed to sunlight.

In previous editions of this Bulletin, calyx pigmentation has been rated from Cx0 (= no pigmentation) to Cx5 (= whole tube pigmented). Here we have used the rating system used by the ATGRC.

**Hairiness of runners, petioles, peduncles and leaf upper surfaces**

Cultivars differ in the degree of hairiness in each of these plant parts. In Table 3, we have elected to use the nine-point rating system for hairiness used in the ATGRC, compared with the four-point system in previous editions of this Bulletin. Here, ratings vary from 1, glabrous (no hairs) to 9, very strong hairiness.

For runners, petioles and peduncles, ratings are made when they are fully extended. Upper surface hairiness is best looked at on fully opened leaves, up to the early flowering stage. In late flowering, hairiness of leaf upper surfaces becomes greater. The hairiness of each of these parts also increases under conditions limiting growth. Conversely, apparent hairiness is less under conditions conducive to lush growth.

Because the division between the ratings is somewhat subjective, the differential degree of hairiness is not often used as a primary means of cultivar identification. However, it can be used to distinguish a cultivar having one or more plant parts which are completely hairless from one that is hairy for that part(s). For example Goulburn, having hairless runners, can be distinguished from Dinninup, which has strongly hairy runners and from York, which has
Table 3. Some morphological characters of the registered cultivars of subterranean clover in Australia.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Leaf mark</th>
<th>Calyx tube pigmentation</th>
<th>Hairiness</th>
<th>Anthocyanin flecking tendency</th>
<th>Anthocyanin flush tendency</th>
<th>Stipule pigmentation</th>
<th>Seed colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacchus Marsh</td>
<td>C_{3.4}</td>
<td>Nil^d</td>
<td></td>
<td></td>
<td>6</td>
<td>1 = absent</td>
<td>Black</td>
</tr>
<tr>
<td>Clare</td>
<td>C_{3} A_{2.3}</td>
<td>Nil</td>
<td>5</td>
<td>7</td>
<td>7 = strong</td>
<td>1</td>
<td>1 = strong</td>
</tr>
<tr>
<td>Dalak</td>
<td>(C_{1})^a</td>
<td>Whole tube</td>
<td>5</td>
<td>3</td>
<td>5 = very strong</td>
<td>4</td>
<td>2 = 7</td>
</tr>
<tr>
<td>Dalkeith</td>
<td>C_{2} A_{1}</td>
<td>Nil-1/4 tube</td>
<td>5</td>
<td>5</td>
<td>7 = strong</td>
<td>3</td>
<td>1 = strong</td>
</tr>
<tr>
<td>Denmark</td>
<td>C_{2} A_{1.2}</td>
<td>Nil</td>
<td>3</td>
<td>1</td>
<td>1 = strong</td>
<td>1</td>
<td>1 = 5</td>
</tr>
<tr>
<td>Dimmington</td>
<td>(C_{3-4})</td>
<td>1/2-3/4 tube</td>
<td>1</td>
<td>5</td>
<td>7 = strong</td>
<td>1</td>
<td>5 = 5</td>
</tr>
<tr>
<td>Doolganaup</td>
<td>C_{2} A_{1}</td>
<td>Nil-1/4 tube</td>
<td>5</td>
<td>5</td>
<td>7 = strong</td>
<td>3</td>
<td>5 = 3</td>
</tr>
<tr>
<td>Enfield</td>
<td>C_{3-4} A_{1.2}</td>
<td>Nil</td>
<td>2</td>
<td>3</td>
<td>5 = strong</td>
<td>5</td>
<td>2 = 4</td>
</tr>
<tr>
<td>Esperance</td>
<td>(C_{1})^b</td>
<td>3/4-whole tube</td>
<td>7</td>
<td>5</td>
<td>7 = strong</td>
<td>4</td>
<td>3 = 6</td>
</tr>
<tr>
<td>Geraldton</td>
<td>C_{1} A_{1}</td>
<td>Nil</td>
<td>5</td>
<td>5</td>
<td>7 = strong</td>
<td>3</td>
<td>4 = 3</td>
</tr>
<tr>
<td>Goose</td>
<td>C_{4}</td>
<td>Nil^e</td>
<td>1</td>
<td>1</td>
<td>1 = strong</td>
<td>1</td>
<td>3 = 3</td>
</tr>
<tr>
<td>Goulburn</td>
<td>C_{2} A_{1.2}</td>
<td>1/2 tube</td>
<td>3</td>
<td>3</td>
<td>1 = 3</td>
<td>1</td>
<td>3 = 3</td>
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<tr>
<td>Green Range</td>
<td>C_{3} A_{2.3}</td>
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<td>5</td>
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<td>3 = 5</td>
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<tr>
<td>Howard</td>
<td>C_{1} A_{2}</td>
<td>Nil</td>
<td>5</td>
<td>5</td>
<td>7 = strong</td>
<td>2</td>
<td>5 = 1</td>
</tr>
<tr>
<td>Junee</td>
<td>C_{1} A_{1.2}</td>
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<td>3</td>
<td>4 = 3</td>
<td>2</td>
<td>5 = 1</td>
</tr>
<tr>
<td>Karridale</td>
<td>C_{3} A_{2.3}</td>
<td>Nil</td>
<td>2</td>
<td>5</td>
<td>7 = strong</td>
<td>3</td>
<td>3 = 5</td>
</tr>
<tr>
<td>Larisa</td>
<td>C_{2} A_{1.2}</td>
<td>Nil</td>
<td>1</td>
<td>1</td>
<td>1 = 5</td>
<td>1</td>
<td>5 = 5</td>
</tr>
<tr>
<td>Leura</td>
<td>C_{2} A_{1}</td>
<td>Nil</td>
<td>7</td>
<td>3</td>
<td>5 = 3</td>
<td>1</td>
<td>2 = 3</td>
</tr>
<tr>
<td>Mount Barker</td>
<td>C_{4}</td>
<td>Nil^e</td>
<td>1</td>
<td>1</td>
<td>1 = 4</td>
<td>5</td>
<td>4 = 6</td>
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<tr>
<td>Nangeela</td>
<td>C_{3} A_{2.3}</td>
<td>Nil</td>
<td>2</td>
<td>5</td>
<td>7 = strong</td>
<td>3</td>
<td>2 = 5</td>
</tr>
<tr>
<td>Northam</td>
<td>C_{1} A_{2}</td>
<td>Nil</td>
<td>7</td>
<td>3</td>
<td>5 = strong</td>
<td>1</td>
<td>1 = 3</td>
</tr>
<tr>
<td>Nuba</td>
<td>(C_{2}) A_{2}</td>
<td>Nil</td>
<td>1</td>
<td>5</td>
<td>5 = 7</td>
<td>1</td>
<td>1 = 6</td>
</tr>
<tr>
<td>Nungarin</td>
<td>C_{2} A_{1}</td>
<td>3/4 tube</td>
<td>7</td>
<td>5</td>
<td>7 = strong</td>
<td>1</td>
<td>3 = 3</td>
</tr>
<tr>
<td>Riverina</td>
<td>C_{4}</td>
<td>Nil^e</td>
<td>1</td>
<td>2</td>
<td>1 = 5</td>
<td>5</td>
<td>3 = 4</td>
</tr>
<tr>
<td>Rosedale</td>
<td>C_{1} A_{2}</td>
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<td>5</td>
<td>3</td>
<td>1 = 5</td>
<td>1</td>
<td>1 = 4</td>
</tr>
<tr>
<td>Seaton Park</td>
<td>C_{3} A_{2}</td>
<td>Nil^d</td>
<td>3</td>
<td>3</td>
<td>7 = strong</td>
<td>1</td>
<td>2 = 2</td>
</tr>
<tr>
<td>Tallarook</td>
<td>C_{1} A_{2.1}</td>
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<td>3</td>
<td>7 = strong</td>
<td>5</td>
<td>4 = 1</td>
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<tr>
<td>Trikkala</td>
<td>C_{2} A_{1.2}</td>
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<td>2</td>
<td>2</td>
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<td>1</td>
<td>5 = 5</td>
</tr>
<tr>
<td>Uniwager</td>
<td>Nil</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>7 = strong</td>
<td>1</td>
<td>1 = 1</td>
</tr>
<tr>
<td>Woogelnieil</td>
<td>C_{2} A_{2}</td>
<td>Nil</td>
<td>3</td>
<td>3</td>
<td>1 = 5</td>
<td>3</td>
<td>1 = 7</td>
</tr>
<tr>
<td>Yarloo</td>
<td>A_{1}</td>
<td>Nil-1/4 tube</td>
<td>1</td>
<td>1</td>
<td>1 = 5</td>
<td>1</td>
<td>5 = 7</td>
</tr>
<tr>
<td>York</td>
<td>C_{2} A_{1}</td>
<td>3/4 tube</td>
<td>1</td>
<td>3</td>
<td>5 = 5</td>
<td>1</td>
<td>5 = 5</td>
</tr>
</tbody>
</table>

^a = Only present under ideal conditions for expression.

^b = Armes a pale green colour.

^c = Arms very diffuse and faint.

^d = When exposed to sunlight, a trace of pigmentation can sometimes be seen.

^e = When exposed to sunlight, much of the calyx tube can have a pale brownish-pink pigmentation.

• oestrogenic

() = pre 1985 release

■ = not common in W.A.
moderately hairy runners. Junee, having weakly hairy peduncles, can also be distinguished from Howard, which has strongly hairy peduncles.

Secondary characters

Leaf flush pattern

A flush is the purple or brown anthocyanin pigmentation pattern that in some cultivars tends to surround the central leaf mark or extend outwards from the midrib. Cultivars differ both in their tendency to produce flushing and in the patterns produced. Leaf flushing is generally strongest in Clare and is absent from Northam, Dalkeith, Woogenellup, Denmark, Rosedale, Nuba, Uniwar and Bacchus Marsh. Table 3 shows ratings for the tendency of cultivars to produce a flush pattern under favourable conditions. Ratings vary from 1, no flushing, to 7, strong flushing.

Be aware that flushing is dependent on environment and stage of plant development. Patterns are most prominent during the early stages of the season, particularly in closely grazed or newly sown pastures. They tend to fade once flowering commences and often disappear completely late in the season. In a cold environment and adverse growing conditions, such as waterlogging and nutrient deficiencies, tends to enhance flushing. If a given cultivar grown in the cooler climates of southern Western Australia will have greater expression of its flush pattern, and for a longer period, than if it is grown in the northern agricultural areas.

As a result of flushing, the appearance of some cultivars is often different in autumn and winter from that in mid to late spring. This can be a major source of confusion when attempting to identify cultivars. For this reason, in this edition of the Bulletin we have included photographs of leaves taken in winter that highlight flush patterns, as well as in spring when they have largely disappeared, to aid identification. It should be noted that flushing is only present in winter under ideal conditions for expression. The underlying leaf mark pattern, however, tends to remain relatively constant throughout most of the season and should be looked at in isolation from the flush pattern. The characteristic flush patterns can themselves be a useful aid in cultivar identification, although it requires a greater familiarity of the cultivars and the way their expression of this character varies.

Leaf flecking

Some cultivars, notably Bacchus Marsh, Enfield, Mount Barker, Meteora, Gosse and Tallarook, have a tendency to produce dark purple or black anthocyanin flecks on their upper leaf surfaces. As with flush patterns, these tend to fade once flowering commences and eventually disappear. Cold environments and adverse growing conditions, as described for flush patterns, also tend to enhance flecking. Table 3 shows ratings for the tendency of cultivars to produce a flecks under favourable conditions. The 1 to 7 rating system is the same as for flushing.

Stipule pigmentation

Stipule pigmentation is usually fully expressed in a dense vigorous sward by early to mid-flowering. It fades to varying degrees as plants mature. In previous editions of this Bulletin, stipule pigmentation has been rated from S0 (= no pigmentation) to S1 (= most of stipule red). In Table 3, we have selected six of the seven-category rating system of the ATGRC. Cultivars range from having a rating of 1 for completely pale green stipules (e.g. Junee, Bacchus Marsh, Tallarook) through to those having a rating of 7 for a red flush covering half or more of the stipule surface (e.g. Daliak, Yarloop, Rosedale, Woogenellup and Mount Barker).

Leaflet shape

This is a subtle character that an experienced observer can use to differentiate between two cultivars that are similar in other ways. The main differences are in the breadth and roundness of leaflets and the size of indentation. Northam, for example, has very broad, rounded leaves which are quite different in shape to the narrow, triangular leaves of Geraldton. Dalkeith has moderately indented leaves that differ from the leaves of Dwaiganup, which have little or no indentation. These characters are useful up until mid-flowering. Late in the season, leaflets of all cultivars tend to become more narrow and triangular and less indented.

Seed colour and shape

Seed colour is only useful for distinguishing all the subspecies yanninicum cultivars, Yarloop, Trikala, Larisa, Gosse, Riverina and Meteora and the ssp. brachycalyicum cultivar, Rosedale, (which all have cream to amber seeds) from the other registered cultivars, which generally have black seeds. Mount Barker and Clare frequently have purplish black seeds but this colour is not sufficiently distinct to be used for identification. The ssp. brachycalyicum cultivars, Clare, Rosedale and Nuba, tend to have flattened seeds, compared with the round seeds of the other two subspecies.

Description of the cultivars of subterranean clover registered in Australia

There are 33 registered cultivars of subterranean clover in Australia, for which seed has been, is, or probably soon will be, available commercially. Most are included in certification schemes. Some cultivars are no longer recommended for use. They are described in order of their flowering time in Perth. Institutions and breeding programs involved in the registration of a cultivar are referred to by their names used at the time of registration.
Nungarin (ssp. subterraneum)

Nungarin is the earliest maturing cultivar and was developed by Dr Clive Francis, Dr John Gladstones and Dr Brian Quinnivan of the Institute of Agriculture, University of Western Australia, and Department of Agriculture Western Australia. It was registered in 1976. Nungarin is the result of a cross between the two local naturalised strains, Daglish and Northam A2, and was selected because of its superiority to Geraldton, in terms of earliness of maturity and hard-seededness. It is low in formononetin and will not cause clover disease.

Nungarin flowers about two weeks earlier, and produces mature seed about seven to ten days earlier, than Geraldton. In low rainfall cereal and sheep districts it has consistently outyielded Geraldton in seed production. At the end of summer, Nungarin still retains some 40 to 45 per cent of its original seed as hard seeds, whereas Geraldton retains only some 20 per cent. Nungarin also has good burr burial strength. In the areas where Nungarin is recommended, its main purpose is to improve soil fertility for following crops, rather than to provide a large quantity of feed for livestock. Herbage yield was not considered especially important during its selection.

Nungarin is very susceptible to clover scorch, Cercospora leaf spot, Phytophthora root rot and both Pythium and Rhizoctonia damping off. However, except for Cercospora these diseases rarely cause problems in the low rainfall areas to which it is suited. Nungarin appears to suffer less damage from bean yellow mosaic virus than most cultivars and has resistance to Fusarium damping off.

More certified seed of Nungarin was produced in Western Australia during the 1980s than any other cultivar. Dalkeith has since replaced Nungarin as the most widely used cultivar in new sowings in Western Australia, although Nungarin is still being sown over large areas of the wheatbelt.

Distinctive features

Very early flowering. Purplish red pigmentation along most of calyx tube. Narrow triangular leaflets. A weak tendency to produce a brown flush along the midrib. Most similar to Northam and Geraldton, but can be distinguished from them by its much broader stripe-like B₁ band.
**Northam (ssp. subterraneum)**

This is a naturalised strain, although its exact origin is obscure. It is believed to have been first found growing on the Northam golf course in 1931 by Mr A.B. Adams. It was originally known as Northam A, and first came under consideration as a potential cultivar in the 1960s because of its earliness, low formononetin content and promising results in the field experiments of Dr Reg Rossiter of CSIRO. No official release of seed was made, but small areas were established by seed growers. It was first registered in 1972. In 1976, when it was included in the seed certification scheme, the suffix ‘A’ was officially dropped from the name.

Northam is an erect-growing, tall, somewhat 'showy' cultivar which is early flowering, has very strong burr burial strength, and has a reasonably high level of hard-seededness. Although it commences flowering about two days later than Nungarin, its rate of seed development is much slower. Therefore its true maturity is about ten days later than Nungarin. Northam is susceptible to clover scorch, Cercospora leaf spot, Phytophthora root rot and Rhizoctonia damping off. Apart from Cercospora, these diseases rarely cause problems to Northam in the low rainfall areas where it has generally been sown. It has resistance to Fusarium damping off.

Since its release, Northam has not been sown nearly as widely as Nungarin. This is partly due to low supplies of certified seed. Nungarin has proved more popular with seed growers due to its greater seed production ability.

**Distinctive features**

Very early flowering. Purplish-red pigmentation along most of calyx tube. Broad, rounded leaflets which tend to overlap. No anthocyanin flushing or flecking. Most similar to Nungarin and Geraldton. Can be distinguished from Nungarin by its much narrower B₁ band. Can be distinguished from Geraldton by its much broader, rounded leaflets.
Dwalganup (ssp. subterraneum)

Dwalganup, the original ‘early’ cultivar, was discovered by the late Mr P.D. Forrest on his ‘Dwalganup’ property at Boyup Brook, where it was thought to have been accidentally introduced as a contaminant of imported seed in about 1890. Graded seed was available commercially by 1929 and it was first certified in Western Australia in 1934. It is the most widely established cultivar in Western Australia, occurring on nearly one-third of the total area of improved pasture. In much of this area, it now exists in a mixture with more recently released cultivars. In old pastures in high rainfall areas, Dwalganup appears to have outcrossed readily with Mount Barker over time to form hybrid types, which are typically later maturing, but otherwise similar to Dwalganup.

Dwalganup has a high level of oestrogenicity and has caused widespread infertility, particularly in the 400 to 600 mm annual rainfall cereal and sheep districts. As a result it is no longer recommended for use. Geraldton, Daljak and Seaton Park were initially released to replace it. More recently Dalkeith has been widely recommended throughout the old Dwalganup zone. Apart from being less oestrogenic, each of these cultivars has tended to have better seed production and regeneration densities than Dwalganup. Dalkeith is also considerably more hardseeded and has stronger burr burial strength. Dwalganup is susceptible to clover scorch, Phytophthora root rot, and to Pythium and Rhizoctonia damping off. However, it suffers less damage than most cultivars from bean yellow mosaic virus and has some resistance to subterranean clover mottle virus. It also has resistance to Fusarium damping off.

Distinctive features
Early flowering. Leaflets with little or no indentation. Purplish brown flush commonly seen in winter in the area below the leaf mark. Flecking sometimes seen. C₃A₄ leaf mark, although arms tend to fade late in season. Corolla sometimes distinctly pinkish. Calyx tubes with narrow ring of pinkish red anthocyanin immediately below lobes, although this is not always apparent in shaded canopies. Most similar to Dalkeith. Can be distinguished from it by its lack of leaflet indentation, presence of a flush pattern and its high formononetin content.
Geraldton (ssp. subterraneum)

This naturalised strain was first found on the roadside near Moonyoonooka, 20 km east of Geraldton on the road to Mullewa in 1950 by Dr John Millington. Subsequent collections showed Geraldton to be common and long-established in much of the Perth metropolitan area and in several country towns. It may well have first become established in the Perth region, with subsequent spread from there.

Geraldton was released commercially by the Institute of Agriculture, University of Western Australia in 1959. It was the main cultivar sown in the cereal and sheep districts from the early 1960s until the late 1970s, when Nungarin was released. Dalkeith in recent years has largely been sown in place of Geraldton. However, it is still a popular variety and is widely distributed throughout the wheatbelt.

Geraldton begins flowering 7 to 10 days after Dwalganup, but because of faster seed development, produces mature seed some 10 to 14 days earlier. It has a relatively prostrate growth habit, strong burr burial strength, and is quite hard-seeded. The seed yields of Geraldton in districts with less than 375 mm annual rainfall are usually higher than those of Dwalganup and Northam, but generally are not as high as those of Nungarin and Dalkeith.

Geraldton has a moderate to high level of formononetin and can cause clover disease. In most seasons in the drier cereal and sheep districts where Geraldton has become established, clover disease is not as important as in the higher rainfall areas. However, in exceptionally good clover years with high clover densities, Geraldton can cause clover disease. Geraldton is susceptible to clover scorch, Phytophthora root rot and to Pythium and Rhizoctonia damping off, although these diseases have not been important in the drier cereal and sheep districts.

Distinctive features

Narrow, triangular, distinctly spaced leaflets. Brown flush often seen along midrib and outlining its B, leaf mark early in season. Purplish red pigmentation along most of calyx tube. Most similar to Nungarin and Northam. Can be distinguished from Nungarin by its much narrower B, band. Can be distinguished from Northam, as the latter has broad, rounded leaflets which tend to overlap.
Dalkeith (ssp. subterraneum)

This is a naturalised strain which was first collected by Dr John Gladstones next to the Dalkeith Bowling Club in Perth in 1967. It was selected as a new cultivar in 1983 by Dr Roger Southwood and Dr Ted Wolfe of the NSW Department of Agriculture, following testing as part of the National Subterranean Clover Improvement Program.

Dalkeith is characterised by a very low formononetin and total isoflavone content, a high level of hard-seededness (similar to Nungarin) and very strong burr burial. It is susceptible to a range of diseases, including clover scorch, Phytophthora root rot, Pythium and Rhizoctonia damping off, Cercospora and Pseudopeziza leaf spots and subterranean clover mottle virus. Fortunately these diseases do not generally cause major problems in the low and medium rainfall areas where Dalkeith is best suited. Dalkeith appears to have quite an elastic flowering time. In Perth it flowers at the same time as Dalik and about two weeks later than Dwalganup. In northern and eastern agricultural districts it often flowers only 7 to 10 days later than Nungarin, particularly following late breaks to the season, while in southern districts its flowering time is often similar to Seaton Park.

Dalkeith has become very popular with farmers since its release and has dominated certified seed sales in Western Australia for the past eight years. It is a 'showy' variety with very good herbage and outstanding seed production. Seeds are the largest of all subspecies subterraneum cultivars. It has been sown widely into areas with rainfall ranging from 325 mm to 600 mm. It is now recommended as a replacement in all areas where Dalik was formerly recommended, except those prone to clover scorch. Dalkeith has also been sown widely into the wetter areas recommended to Nungarin and the drier areas recommended to Seaton Park.

Distinctive features
Early flowering. C₃₂₋₄ leaf mark with arms tending to fade in spring. Most similar to Dwalganup and Leura. Can be distinguished from Dwalganup by its less rounded and more indented leaflets, lack of anthocyanin pigmentation on the leaves and low level of formononetin. Different to Leura in being earlier flowering and having calyx tubes with a narrow ring of pinkish red anthocyanin immediately below the lobes (not always apparent in shaded canopies).
Daliak (ssp. subterraneum)

This cultivar was known to have been growing on Mr A.J. Monger’s property ‘Daliak’ at York before 1920. It was sown to a limited extent, mainly on other properties in the York district, during the 1930s. However, it has also been found to be widely naturalised throughout the south-west of Western Australia, especially along railways, and was probably introduced well before the 1880s. Daliak was officially released in 1967, on the basis of its low oestrogenicity and persistence in the long-term CSIRO mixture experiments of Dr Reg Rossiter.

Daliak forms a dense and relatively short sward. It has a moderately high level of hard-seededness and good burr burial, combined with a good capacity to form viable seeds when burial is prevented. Seeds are relatively small. Daliak generally has low formononetin content, although it can have moderate levels early in the season and when grown under stress. Although Daliak begins flowering about two weeks later than Dwalganup, because of faster seed development, it is only about one week later in the formation of viable seed.

Daliak has excellent resistance to clover scorch and has been widely used as a parent in the breeding program for this reason. It is resistant to Fusarium damping off, but is highly susceptible to Cercospora leaf spot, and to subterranean clover mottle virus. Daliak is also very susceptible to bluegreen aphids.

Following its release to farmers in 1967 it became reasonably well accepted. In south coastal districts from east of Esperance to Albany it is still popular because of its resistance to clover scorch disease. It has also performed well in the Upper and Lower Great Southern and lower-rainfall south-west districts. Daliak persists well when growing in competition with other subterranean clover varieties. It has now been largely superseded by the equally well adapted, but much ‘showier’ cultivar, Dalkeith, except in areas prone to clover scorch.

Distinctive features

Broad leaflets with little indentation. Small C, leaf mark, which is often not readily apparent. Flecking often seen early in the season. A purplish brown flush sometimes seen along the midrib and surrounding crescent. Deep reddish purple pigmentation along whole of calyx tube. Strong stipule pigmentation tendency. Identical in appearance to Esperance and can only be distinguished from it on the basis of its earlier maturity.
**Uniwager (ssp. subterraneum)**

This was derived as a mutant of the Geraldton cultivar by treatment with the chemical mutagen ethyl methanesulfonate in a program conducted by Dr John Millington and Dr Clive Francis at the Institute of Agriculture, University of Western Australia. Uniwager was developed in a program to produce a low formononetin version of Geraldton and is virtually free of any oestrogenic activity. It was released in 1967.

Uniwager flowers about a week later than Geraldton and has a more prostrate growth habit. It is not as hard-seeded and its burr burial is not as strong. It is similar to Geraldton for susceptibility to important diseases, but is more susceptible to bluegreen aphids. Under trial conditions, Uniwager was found to persist as well as Geraldton in dry areas. It was sown to a small extent in the late 1960s, but was not popular because it lacked the vigour of its Geraldton 'parent'. Freedom from oestrogenic isoflavones did not compensate for lack of vigour. Seed has not been available commercially for over 20 years.

**Distinctive features**

No leaf mark. No anthocyanin pigmentation on stems, calyx tubes or stipules. No flush or fleck patterns.
Howard (ssp. subterraneum)

This cultivar is a crossbred, developed at CSIRO Division of Plant Industry, Canberra, by Dr Jack Peak and Dr Fred Morley from a cross between Northam and Tallarook, chosen as a parent for its apparent resistance to clover stunt virus. It is derived from a third generation (F3) selection and was first certified in Western Australia in 1964.

Howard is variable with respect to the time of flowering, with a range of up to six weeks between plants. The earliest plants flower at a similar time to Geraldton, while the latest plants begin flowering at about the same time as Woogenellup. Howard has a high level of formononetin, which could cause infertility in sheep. It is highly susceptible to clover scorch and susceptible to Rhizoctonia damping off.

Howard has not been sown as a pasture in Western Australia, although a few areas were established during the early 1960s specifically for seed production. Howard's main merit lies in its high degree of resistance to the aphid-transmitted, clover stunt virus. As this is not a disease of any significance in Western Australia, there appears to be little place for the cultivar.

Distinctive features
No anthocyanin pigmentation of calyx tube and stipule. Strong purplish brown flush in basal area below leaf mark early in the season. C, A leaf mark. Arms very white. Very similar morphologically to Junee and Tallarook. Distinguishable from Tallarook by its earlier maturity. Distinguishable from Junee by its hairy peduncles and higher formononetin content. Howard is unlikely to be found in pastures in Western Australia, due to its very limited sowing; plants with a strong morphological resemblance to Howard are likely to be Junee.
Yarloop (ssp. yanninicum)

This cultivar was first found in the Yarloop district at Cookernup by Mr J.M. Riegert in 1935, who subsequently distributed it to other farmers. By 1939 it had come into prominence as a commercial cultivar and was variously known as ‘Albino’, ‘White-seeded’ and ‘Riegert’s white’. Yarloop was first certified in Western Australia in 1947. It is a member of subspecies yanninicum, and, like all members of this group, can grow successfully on winter-waterlogged soils.

Yarloop is an erect and tall growing cultivar, noted for its vigorous autumn-winter growth. It commences flowering in Perth about the same time as Seaton Park. For many years it was used mainly on the heavy clay, waterlogged flats west of Waroona, Harvey and Brunswick, where other cultivars failed. Later, it was also found to grow well on well-drained loamy soils in medium rainfall districts (450–600 mm annual rainfall) and many thousands of hectares were sown during the 1950s, particularly in the Esperance, Kojonup and Boyup Brook districts. These large scale sowings of Yarloop in areas used largely for sheep grazing eventually led to serious sheep infertility problems. Later, these were explained on the basis of the high formononetin levels in Yarloop, causing marked oestrogenic activity.

Yarloop is highly susceptible to clover scorch and will suffer substantial losses in herbage and seed production under favourable conditions for the disease. It is also susceptible to root rot caused by race 0 of Phytophthora and to Pythium and Rhizoctonia damping off, but is highly resistant to Cercospora leaf spot and to subterranean clover mottle virus. Yarloop is susceptible to bean yellow mosaic virus and appears to be more susceptible to seedling damage by redlegged earth mite and to bluegreen aphid than most cultivars.

As a result of both its high oestrogenicity and its susceptibility to clover scorch, Yarloop is no longer recommended for sowing. The low formononetin ssp. yanninicum cultivar, Trikkala, has replaced Yarloop in new sowings.

Distinctive features
Cream to amber seeds. Hairless runners, petioles, peduncles and leaf upper surfaces. Leaf mark of narrow A, arms, which fade late in the season. Tendency for brown anthocyanin flush along midrib, but under very cold conditions, whole leaflet can be pigmented. Calyx lobes elongated. Extent of calyx tube pigmentation variable, from nil to about 1/4, when shaded, through to almost totally pigmented when exposed to sunlight. Calyx pigmentation pale brownish pink. Strong reddish purple stipule pigmentation.
Seaton Park (ssp. subterraneum)

The original naturalised strain known as Seaton Park was found in 1929 by Dr H.C. Trumble on the Royal Adelaide Golf Course in the Adelaide suburb of Seaton. During the 1960s, when it was realised that many of the existing cultivars were high in formononetin, and thus likely to cause clover disease, a search began for suitable ‘safe’ replacement cultivars. Seaton Park was selected and released in Western Australia in 1967, mainly on the basis of its low formononetin content and good performance in the long-term mixture trials of Dr Reg Rossiter at the CSIRO Research Station near Kojonup.

In more recent years, it became apparent that more than one strain of Seaton Park existed and that a proportion of certified Seaton Park seed crops in Western Australia and other States were moderately oestrogenic. Following a selection program conducted by Dr Bill Collins (then with the University of Western Australia) and Dr Reg Rossiter (CSIRO), a re-release of low-formononetin Seaton Park was made in 1988.

Seaton Park commences flowering in Perth about four weeks later than Dwalganup and two weeks later than Dalik and Dalkeith. It is highly susceptible to clover scorch and to Pythium damping off. It is susceptible to bean yellow mosaic virus. It is also susceptible to leaf rust and Cercospora leaf spot but, except in disease epidemic years, will not usually suffer large losses to these diseases. The low formononetin strain of Seaton Park is resistant to race 0 of Phytophthora root rot, as well as to the other races found in the other States. It has good burr burial and a moderate level of hard-seededness. Some of the moderately oestrogenic strains of Seaton Park have been found to be more soft-seeded and more susceptible to each of the races of Phytophthora root rot than the low formononetin version.

Seaton Park has been sown very widely in medium rainfall (450–600 mm) areas, except on the south coast, where its susceptibility to clover scorch is a major limitation.

**Distinctive features**

Heart-shaped leaves with strong indentation. Prominent C.A. leaf mark, with arms sliding underneath crescent. Generally no pigmentation of calyx tube, although calyces exposed to sunlight under cold conditions sometimes have a trace of red pigmentation below the calyx hairs. Very weak stipule pigmentation. Very weak flushing tendency, with a narrow strip of brown anthocyanin along the midrib and sometimes outlining the leaf mark.
York (ssp. subterraneum)

York was collected from Sardinia in 1977 by Dr Clive Francis and Mr Dennis Gillespie and selected for field evaluation, under the code-name CPI 89846B, by Dr Bill Collins and Dr John Gladstones, all of the Department of Agriculture Western Australia. It is the first subterranean clover cultivar to be released by the ASCALIP. It was selected for registration jointly by Mr Phil Nichols (Department of Agriculture Western Australia), Mr Brian Dear (New South Wales Department of Agriculture), Dr Carolyn de Koning (South Australian Research and Development Institute), Mr David Lloyd (Queensland Department of Primary Industry) and Mr Stephen Clark (Vicotorian Department of Agriculture). It was registered as a new cultivar in March 1995 and granted Plant Breeder’s Rights protection in May 1995.

In Perth, York commences flowering at the same time as Seaton Park. It has only a trace level of formononetin. It is hard-seeded, having a similar level to Dalkeith and is much more hard-seeded than Seaton Park. Seed size is relatively small. York is susceptible to clover scorch. It is also susceptible to leaf rust, Cercospora leaf spot, and subterranean clover mottle virus. Apart from Cercospora, these diseases are of limited significance in most of the areas suited to York. It is highly resistant to race 0 of Phytophthora root rot and has greater resistance to Rhizoctonia damping off than most other cultivars.

In trials over several years in Western Australia, York has been more persistent than Seaton Park. It has a prostrate growth habit similar to Daliak and individual plants are smaller than Seaton Park. However, York is a better seed producer, regenerates much more densely, and has better early season herbage production than Seaton Park. Spring production of York, however, is no better than Seaton Park.

York is expected to become an important cultivar in areas where Seaton Park has previously been sown, except along the south coast, where its clover scorch resistance is not sufficient. Its higher hard-seededness and better seed production capacity should enable it to persist more strongly than Seaton Park, particularly when grown in rotation with crops.

Distinctive Features

Moderately broad leaflets with only a slight indentation. Leaf mark of C₄ with crescent somewhat flattened. Weak branching tendency with purplish brown anthocyanin usually forming a partial bar along the lower crescent edge but sometimes outlining the leaf mark. No flecking tendency. Much of calyx tube with red pigmentation. Most similar morphologically to Dinninup and Goulburn. Can be distinguished from Goulburn by its earlier maturity, much smaller leaflet indentation and hairiness of runners. Can only be reliably distinguished from Dinninup by its low formononetin content.
Trikkala (ssp. yanninicum)

Trikkala was developed by Dr Clive Francis and Dr John Gladstones of the Department of Agriculture Western Australia from a cross (made by Dr Fred Morley at CSIRO, Canberra) between Larisa and Neuchatel, a highly oestrogenic, early flowering mutant of Yarloop. It was originally known as Y26.

Bred as a low formononetin replacement for Yarloop, Trikkala was registered in 1975. It flowers a few days later than Yarloop and about four weeks earlier than Larisa. Its winter growth, total herbage production and seed yield are at least equal to those of Yarloop. It is also as soft-seeded as Yarloop.

Trikkala has inherited from its parent, Larisa, a degree of tolerance to clover scorch disease. Although not as resistant as Daliak, it is considerably less susceptible than Yarloop. It is highly resistant to race 0 of Phytophthora root rot and to leaf rust. It is also highly resistant to subterranean clover mottle virus, in common with other ssp. yanninicum cultivars but is susceptible to bean yellow mosaic virus. It is resistant to Fusarium damping off but susceptible to Rhizoctonia damping off. Trikkala is more susceptible to bluegreen aphid damage than most other cultivars.

Trikkala has become a very popular cultivar. Generally it has been grown in the medium and high rainfall areas south of Perth, where it has proved to be very widely adapted. Trikkala is suited to winter waterlogged soils, but has also been grown successfully in better drained medium and heavy textured soils with good water holding capacity.

Distinctive features
Cream to amber seeds. Hairless runners and hairless to weakly hairy petioles, peduncles and leaf upper surfaces. Moderately strong tendency to produce flushing, with purplish brown pigmentation often covering the entire basal area below the leaf mark. No flecking tendency. Elongated calyx lobes. No calyx tube pigmentation. Has inherited the C, A, leaf marking of its parent, Larisa. Can only be distinguished from Larisa by its earlier maturity.
Rosedale (ssp. *brachycaulycinum*)

Rosedale was collected near Izmir in Turkey by Dr Clive Francis of the Department of Agriculture Western Australia and Dr Bill Collins of the University of Western Australia in 1974. It was selected for registration in 1988 by Dr Philip Beale of the South Australian Department of Agriculture, following testing under the code name CPI 70124B.

Rosedale is the earliest maturing cultivar of the three ssp. *brachycaulycinum* cultivars. In Perth, it flowers about two weeks earlier than Clare and a few days later than Seaton Park. Rosedale is considerably more hard-seeded than Clare, having a similar level to Geraldton. It has moderate resistance to clover scorch and good resistance to leaf rust, and to bean yellow mosaic and subterranean clover mottle viruses. However, it is susceptible to all known races of Phytophthora root rot. It is also highly susceptible to Cercospora leaf spot. In common with most other members of ssp. *brachycaulycinum*, Rosedale is low in formononetin.

Rosedale is not likely to have a great role in Western Australia, as there are limited soils suited to ssp. *brachycaulycinum*. It has been tested in the neutral to alkaline mallee soils north of Esperance, but did not persist under grazing as well as ssp. *subterraneum* cultivars. There may be a limited role for Rosedale on the alkaline tuart sands along the Swan coastal plain.

**Distinctive features**

Readily distinguished from the other two ssp. *brachycaulycinum* cultivars in having cream to amber coloured seeds. More prostrate than Clare and Nuba, having a growth habit more similar to ssp. *subterraneum* varieties. Leaf mark of C,A, with arms being pale green. Has no tendency to produce fleck or flush patterns. Runners hairless and calyx tubes with no pigmentation. Flowers small. As with other members of ssp. *brachycaulycinum*, peduncles are long, thin and twisting with no active burr burial.
**Dinninup (ssp. subterraneum)**

Dinninup was found in 1956 by Dr Brian Quinlivan of the Department of Agriculture Western Australia, growing on the property of Mr E.A. Miller at Boyup Brook. It was also found to be common in paddocks close to the township. Mr C. Sumner of Dinninup helped popularise it and for a few years it was known as 'Sumners'. Certified seed of Dinninup was first produced in 1962 directly from a pasture with high varietal purity on Mr Miller's property.

In Perth, Dinninup flowers a few days later than Seaton Park. However, its maturity ranking varies considerably between locations. In warmer areas, such as in the northern agricultural districts, it flowers up to two weeks earlier than Seaton Park, whereas at cooler locations such as around Mount Barker and Boyup Brook, it can be as much as 10 days later. Dinninup is a prolific seed-setter, has good burr burial and high levels of hard-seededness and embryo dormancy. It is susceptible to clover scorch and highly susceptible to subterranean clover mottle virus. However, it is very resistant to race 0 of Phytophthora root rot. Dinninup has resistance to Fusarium damping off and has greater resistance than most cultivars to Pythium damping off, but is susceptible to Rhizoctonia damping off.

Dinninup became very popular during the 1960s because of its tendency to become dominant in pastures. It was found subsequently that this dominance was due, in part, to its poor palatability, with sheep tending to select any other clover, grass, or herb in preference. So unpalatable is the cultivar, that sheep grazing Dinninup-dominant pastures in winter often achieve only very slight gains in weight. Later, Dinninup was found to have very high levels of formononetin and total isoflavones, which may account for its low palatability, in addition to making it highly oestrogenic.

Although Dinninup is undoubtedly one of the better cultivars for total production and adaptability, it cannot be recommended for general planting because of its high oestrogenic activity and susceptibility to clover scorch.

**Distinctive features**

Moderately broad leaves with little or no indentation. Strong tendency to produce a distinctive flush pattern, consisting of brown anthocyanin along the midrib and a thin line surrounding the leaf mark which reaches a sharp peak close to the leaf margin. Leaf mark classified as C_{3}A_{1}, although arms difficult to observe both early and late in the season. Crescent appears more flattened once flush disappears. No flecking tendency. Calyx tubes with red pigmentation along about half their length. Most similar morphologically to Goulburn and York. Can be distinguished from Goulburn in having hairy runners and leaflets with little or no indentation and from York by its high formononetin content.
Enfield (ssp. subterraneum)

Enfield was collected in 1973 by Dr Gerald Halloran and colleagues of the Faculty of Agriculture and Forestry, University of Melbourne. It was found growing on the roadside near Kilmore, Victoria, on the Kilmore-Bendigo Road. It was originally known as C26. Following selection by Ms Gwen Hotton of the Victorian Department of Agriculture, it was registered in 1982 as a clover scorch-resistant replacement in Victoria for Woogenellup.

In Perth, Enfield begins flowering about 12 days earlier than Woogenellup and about one week after Seaton Park. It is moderately resistant to clover scorch, being less susceptible than Woogenellup, but is not as resistant as Junee, Green Range and Esperance. It is highly resistant to leaf rust and is also resistant to race 0 of Phytophthora root rot. Enfield has resistance to Fusarium damping off and is more resistant than most cultivars to Pythium damping off. However, it is susceptible to Rhizoctonia damping off.

Because of its low to moderate formononetin content, Enfield could cause clover disease in sheep grazing clover-dominant pastures. Enfield has weak burr burial, a very low level of hard-seededness (less than that of Woogenellup) and very weak embryo dormancy.

Commercial sowings of Enfield in Western Australia have been negligible and it does not appear to have the characters required for persistence in this State. In medium to high rainfall areas where Enfield might be considered, its very low level of hard-seededness would be a disadvantage, particularly if cropping is part of the farm enterprise. Junee is a much better option for medium to high rainfall areas, owing to its higher hard-seededness and greater clover scorch resistance. However, in Victoria and Tasmania, Enfield has proved highly productive in the autumn-winter period, largely because of its good seed production capacity and high seedling density at the break of the season.

Distinctive features

Leaf mark consisting of a large triangular C₃₄ crescent, but occasionally very narrow, white arms can be seen. No calyx pigmentation. A weak tendency to produce a narrow strip of purplish brown anthocyanin flushing along the midrib and outlining the leaf mark. A moderately strong tendency to produce leaf flecks.
Riverina (ssp. yanninicum)

Riverina is the most recent of the subterranean clover cultivars, being registered in 1995. Plant Breeder’s Rights protection has also been granted.

Riverina is a crossbred, derived from a cross between Meteor and Trikkala made in 1976. The breeders were Dr John Gladstones and Dr Bill Collins of the Department of Agriculture Western Australia. It was selected for registration as a new cultivar by Mr Brian Dear of New South Wales Agriculture, following field evaluation throughout southern Australia under the code-name 76Y51-31. It has been released by the ASCALIP.

In Perth, Riverina commences flowering a week later than Trikkala and a week earlier than Gosse. It has a low level of formononetin and will not cause clover disease. It has a similar degree of hard-seededness to Gosse and is more hard-seeded than Trikkala. Riverina has moderate resistance to clover scorch, being similar to Trikkala, but is less resistant than Gosse and Meteor. It is resistant to all known races of Phytophthora root rot and is also highly resistant to leaf rust and Cercospora leaf spot. Riverina has resistance to Fusarium damping off and is one of the more resistant cultivars to Pythium damping off. It is susceptible to Rhizoctonia damping off.

In trials in Western Australia, Riverina has performed well, but does not appear to offer major advantages over Trikkala and Gosse. It is likely to be recommended as an alternative to these cultivars in this State. However, Riverina is likely to become an important cultivar in eastern Australia on waterlogged soils, where its resistance to recently discovered races of Phytophthora confers a major advantage over the other ssp. yanninicum cultivars.

Distinctive features
Cream to amber seeds. Hairless runners and leaf upper surfaces and hairless to weakly hairy petioles and peduncles. Leaf mark consisting of a C1, crescent, which can become flatter in spring to look like a B band. Moderately strong flecking tendency. Weak flushing tendency, with brown anthocyanin mainly along the midrib. A reddish brown pigmentation is sometimes seen beyond the crescent. Calyx lobes elongated. Calyx tubes with no pigmentation when shaded, but with a pale brownish pink pigmentation covering much of their surface when exposed to sunlight. Riverina, along with Gosse, closely resembles Meteor in appearance, both having inherited their leaf mark from that cultivar. Cannot be readily distinguished from Gosse, due to their flowering time being only one week apart. Can be distinguished from Meteor by flowering four weeks earlier and its low formononetin content.
**Esperance (ssp. subterraneum)**

Esperance was registered as a cultivar in 1978. It was selected by Dr Clive Francis and Dr David Chatel of the Department of Agriculture Western Australia from a cross between Bacchus Marsh and Daliak. It was the first cultivar selected specifically for resistance to clover scorch.

Esperance is at least three weeks later in flowering than Daliak and is intermediate in maturity between Seaton Park and Woogenellup. The level of hard-seededness in Esperance is lower than that in Daliak, Seaton Park and Junee but much higher than that in Woogenellup. It is a good seed yielder, generally producing greater seed yields than Woogenellup and Seaton Park, even in the absence of clover scorch. Esperance has a low to moderate level of formononetin and is therefore slightly suspect as a cause of clover disease.

Esperance, along with Daliak, is the most resistant of all cultivars to clover scorch. It also has good resistance to powdery mildew. However, Esperance is highly susceptible to Cercospora leaf spot and can suffer large losses in herbage and seed production under conditions favourable for the disease. It is also susceptible to all known races of Phytophthora root rot and to bean yellow mosaic virus.

Esperance was initially recommended as an interim cultivar for most of the clover scorch-affected south coast areas. Most seed sales of Esperance occurred in the first two years after its release. Since then, limited quantities of Esperance have been sown. A common reason cited for its lack of popularity is its prostrate habit and lack of 'farmer appeal'. Junee has largely taken the place of Esperance in new sowings.

**Distinctive features**

Small C leaf mark which is often not readily apparent. Broad leaflets with little or no indentation, a purplish brown flush occasionally seen along the midrib and surrounding the crescent and moderate flecking tendency. Deep reddish purple pigmentation along whole of calyx tube. Strong stipule pigmentation. Strong resemblance to Daliak. Can only be distinguished from it on the basis of its later maturity. Also has a tendency to produce the occasional leaf with four or five leaflets.
Gosse (ssp. yanninicum)

Gosse originates from a complex cross made at the University of Western Australia in 1980, involving Trikkala, Meteora, CPI 39314YB (an introduction from Greece) and Neuchatel (an early flowering mutant of Yarloop). The breeder was Dr Philip Beale and the selector was Mr Greg Mitchell, both of the South Australian Department of Agriculture. Originally known as FS-24, Gosse was registered as a cultivar in 1992 and granted Plant Variety Rights protection. Certified seed of Gosse first became available in 1994.

In Perth, Gosse starts flowering about two weeks later than Trikkala and Yarloop and two weeks earlier than Larisa. It has only a low level of formononetin. It is more hard-seeded than Trikkala and Larisa, but less hard-seeded than Meteora. Gosse is resistant to clover scorch, leaf rust, Cercospora leaf spot and to race 0 of Phytophthora root rot. As with the other ssp. yanninicum cultivars, Gosse is resistant to subterranean clover mottle virus, the most important virus in high rainfall pastures, but is susceptible to bean yellow mosaic virus. It also has some susceptibility to powdery mildew. Gosse is highly susceptible to both Pythium and Rhizoctonia damping off and moderately susceptible to Fusarium damping off and may suffer seedling losses where these diseases are present.

In Western Australia, Gosse has performed well in field trials over several years. It is a good seed producer, usually producing similar seed yields to Trikkala, and markedly more than Larisa. Regeneration densities of Gosse are usually similar to or lower than Trikkala, but much greater than Larisa. Gosse has large, upright seedlings and vigorous winter growth, and is similar to Yarloop in its growth habit. Gosse appears suited to the wetter margins where Trikkala and Yarloop have been grown. Its good clover scorch resistance makes it suited to south coastal regions in mixtures with later maturing cultivars. Its upright growth habit makes Gosse suitable for grazing by cattle and for hay-making.

Distinctive features

Cream to amber seeds. Hairless runners, petioles and leaf upper surfaces and hairless to weakly hairy peduncles. Leaf mark consisting of a C₄ crescent, which becomes flatter in spring to look more like a B₂ band. Moderately strong flecking tendency. Moderately strong flushing tendency with brown anthocyanin mainly along the midrib, although the area beyond the crescent can also have a reddish brown pigmentation. Calyx lobes elongated. When shaded, calyx tubes generally have no pigmentation, but when exposed to sunlight, a pale brownish pink pigmentation can cover much of their surface. Gosse, along with Riverina, closely resembles Meteora in appearance, both having inherited their leaf mark from that cultivar. Can be distinguished from Meteora by its earlier maturity and low formononetin content. Cannot be readily distinguished from Riverina, due to its closeness in flowering time.
Junee (ssp. subterraneum)

Junee was first registered as a cultivar in 1985 by the National Subterranean Clover Improvement Program. It originates from an initial cross between Howard and the Western Australian naturalised strain, Midland B, made in 1967 by the CSIRO Division of Plant Industries, Canberra. This initial parent was then crossed with Daliak in 1973. Bred by Dr John Gladstones and Dr Clive Francis, of the Department of Agriculture Western Australia, field testing was conducted under the code-name DA20.19.2.1.

Junee was initially selected by Dr Ted Wolfe of the New South Wales Department of Agriculture, and Mr Donald Nicholas of the Department of Agriculture Western Australia for registration as a more hard-seeded, clover scorch-resistant cultivar for areas where Woogenellup and Esperance had previously been recommended. In Perth, Junee flowers two to three days earlier than Woogenellup and Green Range when sown in early May. However, seed development is faster than in Woogenellup. Its final maturity is a week or more earlier than and comparable to that of Esperance.

Formononetin level of Junee is low, unlike the moderately high level in Esperance, and will not cause clover disease. Junee has a moderate level of hard-seededness, being similar to Seaton Park and Goulburn, slightly more hard-seeded than Esperance, and much more hard-seeded than Woogenellup. It has moderately strong burr burial. Junee has good clover scorch resistance, but is highly susceptible to powdery mildew when left ungrazed in spring. It is very susceptible to both Pythium and Rhizoctonia damping off, but has some resistance to Fusarium damping off. It is also highly susceptible to subterranean clover mottle virus.

Individual plants of Junee are not as vigorous as those of Woogenellup. However, its persistence and herbage production in established pastures has generally been at least as great. This has particularly been the case along the south coast, where Junee's clover scorch resistance is a considerable advantage. Junee has also been found to persist more strongly than Woogenellup in rotation with cropping. Its slightly earlier maturity, coupled with its higher hard-seededness and greater seed production, means that Junee can be recommended in slightly lower rainfall areas than Woogenellup.

Distinctive features

No anthocyanin pigmentation of stipule. Generally no calyx tube pigmentation, although occasional calyces have a trace of red-pink pigmentation below the calyx hairs when exposed to sunlight under cold conditions. Strong purplish brown flush covering most or all of basal area below leaf mark early in the season. Leaflets moderately broad and rounded with moderate indentation. C,A, leaf mark with intense white arms. Has inherited its leaf mark directly from Howard, which in turn is derived from Tallarook. Consequently, Junee is morphologically very similar to both Howard and Tallarook. Distinguishable from Tallarook by being four to five weeks earlier flowering. Distinguishable from Howard by its low formononetin content, its almost glabrous peduncles and lesser hairiness of leaves, petioles and runners. In Western Australia Junee is more likely to be found in pastures than Tallarook and Howard, due to the very limited areas sown to these cultivars.
Green Range (ssp. subterraneum)

Green Range originated from the initial cross in 1969 of Nungeela to the West Australian naturalised strain. It was bred by Dr Clive Francis and Dr John Gladstones of the Department of Agriculture. Field tested under the name of GD17.30.4.5, Green Range was registered as a cultivar in 1985 by the National Subterranean Clover Improvement Program.

In Perth, Green Range has a similar flowering time to Woogenellup, but is about 10 days earlier flowering than Karridale. It is moderately hard-seeded, being much harder-seeded than Woogenellup, but is less hard-seeded than Junee and Seaton Park. It has a low formononetin content.

Green Range has good resistance to clover scorch and in this respect, is a major improvement over Woogenellup. However, it is highly susceptible to leaf rust. When swards are undergrazed in spring or closed up for hay or seed production, very large losses of herbage and seed production can result from rust infection. Its extreme susceptibility to leaf rust first became apparent in the initial stands grown for basic and certified seed production along the south coast. In fact, total loss of seed production has occurred in some seed crops. Its rust susceptibility has resulted in poor farmer acceptance of Green Range. Consequently, only small areas of Green Range have been sown in Western Australia and in other States. Green Range is also susceptible to all known races of Phytophthora root rot, to both Pythium and Rhizoctonia damping off and to bean yellow mosaic and subterranean clover mottle viruses. It has some resistance to Fusarium damping off.

Distinctive features
Slightly indented, moderately broad leaflets with a prominent C₃A₃ leaf mark, inherited from its Nungeela parentage. The crescent rises to a point close to the leaflet margin. Arms are cream and slide underneath the crescent. Moderate tendency for flecking. Weak tendency to form a purplish brown flush outlining the leaf mark or as a partial bar along the lower crescent edge. Calyx tubes generally with no pigmentation, although calyces exposed to sunlight under cold conditions can sometimes have a trace of red-pink pigmentation below the calyx hairs. Stipules strongly pigmented. Cannot be readily distinguished morphologically from Karridale and Nungeela, apart from its slightly earlier maturity.
Woogenellup (ssp. subterraneum)

Woogenellup was first noticed by Dr Brian Quinlivan of the Department of Agriculture Western Australia growing in pastures of cultivar Mount Barker on a property at Manjimup about 1951 and shortly after on the property of Mr L. Pearson at Benger. Some of the pasture seed on these properties originated from the property of Mr W. Scott at Elgin, where Woogenellup was subsequently found growing. This may be the site of its first establishment in Western Australia. It was originally known as ‘Pearson’s’ but was renamed ‘Woogenellup’ by Quinlivan in 1957. Certified seed of Woogenellup first became available in 1959. A strain identical to Woogenellup was independently collected in New South Wales in 1955 on a property at Marrar. It was first certified in 1960 in New South Wales under the name ‘Marrar’. In later years, the name Woogenellup was adopted by all States. It is likely that Woogenellup was introduced into Western Australia and other States in the 1920s, as an impurity of cultivar Mount Barker seed from South Australia. Another naturalised strain found in Victoria, Burnley, is very similar morphologically to Woogenellup, although its nodulation response to a range of *Rhizobium* strains differs.

Woogenellup first gained prominence in the 1950s, due to its high winter vigour. It became the basic pasture cultivar in much of the medium and high rainfall zone, particularly on the south coast. During the 1960s over one million hectares were sown in Western Australia to Woogenellup.

Woogenellup flowers about three weeks later than Seaton Park and one week earlier than Mount Barker. Individual plants have very vigorous growth but it is not a prolific seed-setting cultivar. It has quite weak burr burial strength with most burrs forming above the soil surface. Woogenellup produces relatively large seeds. It has a low level of hard-seededness and a low level of embryo dormancy. It is very susceptible to several diseases, including clover scorch, leaf rust, *Phytophthora* root rot, *Fusarium* damping off and subterranean clover mottle and bean yellow mosaic viruses. The formononetin content of Woogenellup is generally low from mid-winter onwards, although early in the season, particularly when grown under stress, levels can be moderate. However, it has never been associated with clover disease. Woogenellup has a different *Rhizobium* inoculation specificity to other subterranean clovers and is not effectively nodulated with some commercial inoculum strains.

Since 1970, following severe outbreaks of clover scorch disease, Woogenellup has lost its popularity. Certified seed of Woogenellup has not been produced in Western Australia since 1983. Junee and the newly released cultivar, Goulburn, are now being recommended in place of Woogenellup.

**Distinctive features**

Heart-shaped leaflets with strong indentation. $C_A^1$ leaf mark. Arms are pale green. Later in the season, the crescent becomes flattened to look more like a $B_2$ band and dips downward in the centre. No flush pattern, but flecking commonly seen early in the season. Calyx tube not pigmented. Runners hairless, while petioles and leaf upper surfaces weakly hairy. Stipules quite large and often strongly pigmented. Most similar to Bacchus Marsh, Mount Barker and Denmark. Can be distinguished from Bacchus Marsh by its hairless runners and pigmented stipule. Can be distinguished from Mount Barker by its non-pigmented calyx tubes and hairless runners. Distinguishable from Denmark by its strong leaflet indentation.
Clare (ssp. brachycalyicum)

This cultivar originated from South Australia, where it was reported to have been growing on the property of Mr J.E. Butler near the township of Clare since about 1921. The first commercial seed was certified in South Australia in 1950 and Western Australia in 1958.

Clare is one of only two members of the subspecies brachycalyicum to have become naturalised in Australia. The other one, Wenilup, has not been commercialised. More recently, Rosedale and Nuba, have been released as new ssp. brachycalyicum cultivars.

Clare commences flowering about the same time as Woogenellup, but takes one to two weeks longer to complete seed formation. As with most members of ssp. brachycalyicum, its oestrogenic potency is low. Clare is soft-seeded, having a similar level of hard-seededness to Trikkala and is slightly more hard-seeded than Woogenellup. It has some tolerance to clover scorch and is resistant to Cercospora leaf spot, leaf rust, powdery mildew and subterranean clover mottle virus. It also suffers less seedling damage to redlegged earth mite than most other cultivars. However, it is highly susceptible to all known races of Phytophthora root rot and is susceptible to bean yellow mosaic virus.

The performance of Clare under heavy grazing in Western Australia has generally been poor and it has always been a minor cultivar in this State. However, Clare can grow well on neutral and slightly alkaline soils, making it suitable for the west coast tuart sands south of Perth, where it is sometimes found as a volunteer.

During the late 1960s Clare was in strong demand on the seed export market and most of the limited Clare pastures in Western Australia were originally established specifically to service that market.

Distinctive features
Prominent leaf mark of $C_A^3$, with arms sliding underneath the crescent. Very strong flush tendency with entire basal area below leaf mark commonly covered with purplish brown anthocyanin. No flecking tendency. Leaflets rounded with little indentation. Hairless runners and leaf upper surfaces. Calyx tubes with no pigmentation. Flowers small. Stipules small, rounded and moderately pigmented. Typical of ssp. brachycalyicum, peduncles are long, thin and twisting, with no active burr burial. Seeds purplish black and flattened.
Bacchus Marsh (ssp. subterraneum)

Bacchus Marsh was first observed growing in fields at Myrning near Bacchus Marsh, Victoria in 1929. It was first certified in Victoria in 1937 and in Western Australia in 1947.

Bacchus Marsh normally flowers a few days later than Woogenellup. It gives good growth in the spring and is very palatable, both in the green and dry stage. It is not a prolific seed-setting cultivar. It has very poor burr burying ability and usually all its burrs form above the soil surface. Formononetin level is low and it has never been associated with infertility in sheep.

Bacchus Marsh is moderately susceptible to clover scorch disease and is susceptible to Pythium, Rhizoctonia and Fusarium damping off. It is also susceptible to powdery mildew, and is highly susceptible to bean yellow mosaic virus. However, it is resistant to race 0 of Phytophthora root rot. It also suffers less seedling damage from redlegged earth mite than most other cultivars.

Bacchus Marsh was extensively planted in the late 1950s, particularly at Esperance, but in many instances proved disappointing. It has a major disadvantage in being extremely soft-seeded, with most of the seeds being capable of germination by February each year. This resulted in many regeneration failures following 'false breaks' and led to a decrease in the area sown. Because of this disadvantage, Bacchus Marsh is no longer an important cultivar in this State. Seed supplies are rarely, if ever, available.

Distinctive features

Leaflets triangular with moderate indentation. Leaf mark of C sat with a tendency for the crescent later in the season to become flatter and dip downwards in the centre. This sometimes makes the leaf mark look more like a B band. Strong flecking tendency but no flushing. Stipules not pigmented. Calyx tubes generally with no pigmentation, although, when exposed to sunlight under cold conditions, they sometimes have a trace of pink pigmentation below the calyx hairs. Hairy runners, petioles and peduncles. Most similar to Woogenellup and Mount Barker. Can be distinguished from Woogenellup by its hairy runners and non-pigmented stipules. Can be distinguished from Mount Barker by its non-pigmented calyx tubes and stipules.
Mount Barker (ssp. subterraneum)

This cultivar was first observed at Mount Barker, South Australia in 1889 by Mr Amos Howard. It subsequently became the first subterranean clover to become commercialised. Mount Barker was first introduced into Western Australia in the early 1900s. During the 1920s it was first extensively planted in the high rainfall areas of the south-west. It was also widely sown in adjacent drier districts, until the commercial release of the earlier maturing Dwalganup in the 1930s. Mount Barker is still perhaps the most widely distributed pasture legume in the lower south-west, although many pastures originally sown to it are now dominated by other subterranean clovers.

Formononetin level is very low in Mount Barker and it has never been associated with infertility in sheep. It is among the most soft-seeded of the cultivars of subterranean clover and is a poor burr burier. It is susceptible to all known races of Phytophthora root rot and to Rhizoctonia damping off. It is also susceptible to leaf rust, Cercospora leaf spot and to bean yellow mosaic and subterranean clover mottle viruses. However, it has a moderate field resistance to clover scorch and some resistance to Fusarium and Pythium damping off.

Mount Barker flowers and matures a week or so after Woogenellup, some five to seven weeks later than Dwalganup, and about four weeks earlier than Tallarook. It makes excellent growth in spring but its winter growth appears to be rather poor. For this reason it tended to be less popular than the more vigorous Woogenellup in the 1960s, but regained some popularity in the 1970s because of its better tolerance to clover scorch disease.

Certified seed of Mount Barker is now difficult to obtain. It has not been certified in Western Australia for several years. Karridale, and more recently, Denmark, have been released as improved cultivars for areas where Mount Barker was originally grown.

Distinctive features
Triangular C, leaf mark, with the crescent rising to a point close to the leaflet margin. Most of calyx tube with purplish red pigmentation. Leaflets broad and rounded with little indentation. Moderate tendency to produce a brown flush pattern along the midrib. Leaf flecking common. Runners and peduncles hairy. Stipules commonly strongly pigmented. Seeds purplish black. Most similar to Bacchus Marsh and Woogenellup. Can be distinguished from both by its strongly pigmented calyx tubes.
Karridale (ssp. subterraneum)

Karridale was bred by Dr Clive Francis and Dr John Gladstones and selected by Mr Donald Nicholas, all of the Department of Agriculture Western Australia. It originates from the cross made in 1973 of Dinnup to a parent derived from a previous cross of Nangeela to Midland B (a Western Australian naturalised strain). It was field-tested under the code-name MND.7.2.2. It was registered as a cultivar in 1985 by the National Subterranean Clover Improvement Program.

In Perth, Karridale flowers two to three days later than Mount Barker and more than a week later than Green Range and Woogenellup. It was released as a more productive, clover scorch-resistant replacement for Mount Barker. However, its resistance to clover scorch in farmers' paddocks has not always been as strong as first indicated in experimental plots. This has particularly been the case in some paddocks on south coast farms closed up in spring for hay or seed production. It is now classed as having only moderate resistance to clover scorch.

Karridale has resistance to race 0 of Phytophthora root rot. It has the best resistance of all cultivars to Pythium damping off and also has resistance to Fusarium damping off. However, it is susceptible to several diseases including leaf rust, powdery mildew and bean yellow mosaic virus. Karridale is generally low in fromononetin content, although it sometimes has moderate levels early in the season and when growing under stress. It is soft-seeded, having similar levels to Denmark and Leura, but is more hard-seeded than Mount Barker and Woogenellup.

After an initial poor acceptance of Karridale in Western Australia it has gained in popularity, largely due to favourable reports from farmers in eastern Australia. Karridale has generally been regarded as a more productive and persistent cultivar than Mount Barker. It is much more erect, particularly in winter, and is a better seed producer. However, the more recently released cultivars, Denmark and Goulburn, have better clover scorch resistance and greater persistence than Karridale and are being recommended in place of it.

Distinctive features
Leaflets broad and rounded with only a slight indentation. Prominent C₃A₂₃ leaf mark, inherited from its Nangeela parentage. Arms are cream and slide underneath the crescent. Weak tendency to form a purplish brown flush as a partial bar along the lower crescent edge or outlining the leaf mark. Leaf flecking is sometimes seen. Calyx tubes generally with no pigmentation. However, under cold conditions, calyces exposed to sunlight sometimes have a trace of pink-red pigmentation below the calyx hairs. Stipules commonly strongly pigmented. Cannot be readily distinguished morphologically from Green Range and Nangeela.
Larisa (ssp. yanninicum)

Larisa was collected in northern Greece in 1965 by Dr Sephi Katznelson of Israel, as part of a CSIRO program to produce a low formononetin cultivar suitable for waterlogged situations. It was selected by Dr Clive Francis and Dr John Gladstones as part of the joint breeding program of the University of Western Australia and the Department of Agriculture Western Australia. It was originally known as CPI 39313Y. Registered in 1975, Larisa was first released to farmers in 1977.

Larisa is about four weeks later in maturity than Trikkala and Yarloop. It commences flowering a few days after Mount Barker and produces mature seeds a week or two later. It is soft-seeded, having a similar level of hard-seededness to Trikkala, but is more hard-seeded than Woogenellup and Mount Barker. Larisa has moderate field resistance to clover scorch. It is highly resistant to race 0 of Phytophthora root rot and to leaf rust, Cercospora leaf spot and subterranean clover mottle virus and is resistant to Fusarium damping off. However, it is susceptible to Pythium and Rhizoctonia damping off and to bean yellow mosaic virus and is more susceptible to bluegreen aphid damage than most other cultivars.

Larisa's winter growth, like Mount Barker, appears to be slow, but spring growth is excellent. It has low oestrogenic activity and has performed satisfactorily under grazing. However, because of its late maturity, use of Larisa is restricted to the very long growing season areas along the south coast or to irrigation districts, where late spring irrigation can be applied.

Distinctive features

Cream to amber seeds. Hairless runners, petioles, peduncles and leaf upper surfaces. C₃A₃ leaf mark. Moderately strong tendency to produce flushing, with purplish brown pigmentation often covering the entire basal area below the leaf mark. No flecking tendency. Elongated calyx lobes. No calyx tube pigmentation. Very similar morphologically to Trikkala. Can only be distinguished from it by its later maturity.
Denmark (ssp. subterraneum)

Denmark was collected in Sardinia by Dr Clive Francis and Mr Dennis Gillespie in 1977 and selected for field testing in 1982 by Dr John Gladstones and Dr Bill Collins, all of the Department of Agriculture Western Australia. It was tested under the code-name \[\text{CPI 89774F,} \] as part of the National Subterranean Clover Improvement Program, and selected by Mr Donald Nicholas and Mr Phil Nichols of the Department of Agriculture Western Australia and Mr Pedro Evans of the Tasmanian Department of Primary Industry. It was registered as a cultivar and granted Plant Variety Rights protection in 1992.

Denmark is of late maturity, flowering in Perth a few days later than Mount Barker and Karridale and a few days earlier than Leura. It contains only a trace amount of formononetin. It is relatively soft-seeded, having a similar level of hard-seededness to Karridale and Leura, but is more hard-seeded than Mount Barker and Woogenellup. Denmark has good resistance to clover scorch and to race 0 of Phytophthora root rot. It is susceptible to Pythium, Rhizoctonia and Fusarium damping off. It is also susceptible to leaf rust and highly susceptible to bean yellow mosaic virus.

In field trials conducted over several years, Denmark has persisted much better in Western Australia than Karridale and Mount Barker. Its most outstanding feature has been its high seedling regeneration densities, which have translated into higher herbage production, particularly early in the season. Denmark is also an excellent seed producer, consistently yielding more than Mount Barker and usually more than Karridale. Seed size is relatively small. Its dense, prostrate growth habit, makes it well suited to heavy grazing. It also appears better able to compete with background Dinninup than other late maturing cultivars. Denmark is viewed as a direct replacement for Mount Barker and Karridale.

Distinctive features

Broad, rounded leaflets, often overlapping, with slight indentation. Leaf mark of \([C_{A_{1/3}}]\) with crescent diamond-shaped, and arms very diffuse and often faint. No flushing and only very occasional flecking. Calyx tubes have no pigmentation. Corollas sometimes have a pink flush prior to opening. Runners, petioles and peduncles are hairless, while leaf upper surfaces have sparse hairs. Most similar to Woogenellup. Can be distinguished from it by its broad leaflets with little indentation.
Goulburn (ssp. subterraneum)

Goulburn was collected from Sardinia by Dr Clive Francis and Mr Dennis Gillespie in 1977 and selected in 1982 for field-testing, under the code-name CPI 89830F, by Dr John Gladstones and Dr Bill Collins, all of the Department of Agriculture Western Australia. Goulburn was registered as a cultivar by the collaborating organisations of the National Subterranean Clover Improvement Program and granted Plant Variety Rights protection in 1992. This followed its selection by Mr Brian Dear of the New South Wales Department of Agriculture and Mr Donald Nicholas and Mr Phil Nichols of the Department of Agriculture Western Australia.

In Perth, Goulburn flowers at about the same time as Denmark, about one week later than Mount Barker and two weeks later than Woogenellup and Green Range. However, in more southerly locations it flowers a few days earlier than Mount Barker and Denmark and a week or so later than Woogenellup and Green Range. Its rate of seed maturation appears to be more rapid than Woogenellup, and so its time to maturity in southern parts of Western Australia is probably similar to Woogenellup. The seeds of Goulburn are the smallest of all the registered cultivars. Goulburn is quite hard-seeded for its maturity, having a level similar to Junee and Seaton Park, and is much more hard-seeded than Woogenellup. It contains only a trace level of formononetin.

Goulburn was selected as a replacement for Green Range, largely on the basis of its resistance to leaf rust, and as a clover scorch-resistant replacement for Woogenellup. It also has good resistance to race 0 of Phytophthora root rot and has some resistance to both Rhizoctonia and Fusarium damping off. It is susceptible to bean yellow mosaic virus.

Goulburn has performed very well in field trials conducted over several years in Western Australia. It is a much better seed producer than Woogenellup. Its regeneration densities have been as high as Denmark and far superior to the other late maturing cultivars. Although individual seedlings tend to be small, their high density provides good early season production. Goulburn is likely to become an important cultivar in the southern agricultural areas where Woogenellup has previously been widely sown.

Distinctive features

Narrow, triangular, widely-spaced leaflets with a strong indentation. Leaf mark of $C_{3}A_{2}$ with the crescent somewhat flattened and tending to dip downwards at the centre. Weak flushing tendency, with purplish brown anthocyanin forming a partial bar along the lower crescent edge, but sometimes outlining the leaf mark. No flecking tendency. Calyx tubes have red anthocyanin along half their length. Runners are hairless, while petioles, peduncles and leaf upper surfaces have sparse hairs. Similar...
Nangeela (ssp. subterraneum)

This cultivar originated from Victoria, where it was first discovered near the township of Nangeela in the early 1930s. It has been commercialised to a limited extent in both Victoria and South Australia and was first certified in the early 1960s. Nangeela has also been sown in Oregon and California in the United States of America. In Western Australia, so far as is known, it has been deliberately sown on only a few hectares east of Donnybrook. However, there are some Nangeela pastures in the Manjimup district which appear to have been established for many years. None of the present owners have any knowledge of the origin of these pastures.

Nangeela is late maturing, with flowering commencing about a week later than Mount Barker. It has low oestrogenic activity, is very soft-seeded and has weak burr burial. It is susceptible to clover scorch disease and to both Rhizoctonia and Fusarium damping off. Nangeela is also highly susceptible to bean yellow mosaic virus, is moderately susceptible to leaf rust, and moderately resistant to subterranean clover mottle virus.

Nangeela has little potential for direct use in Western Australia. However, because of its distinctive leaf markings and vigorous growth, it has been used as a parent in a number of crosses made in Perth. It is a parent of Karridale and Green Range, both of which look identical to it. Seed of Nangeela is no longer commercially available in Australia.

Distinctive features

Moderately broad, rounded leaflets with only a slight indentation. Prominent C₅A₁₃ leaf mark. Arms cream coloured, sliding underneath crescent. Weak tendency to form a purplish brown flush along the midrib or outlining leaf mark. Flecking sometimes seen. Calyx tubes generally with no pigmentation, although under cold conditions, calyces exposed to sunlight sometimes have a trace of red-pink pigmentation below the calyx hairs. Stipules often strongly pigmented. Cannot be readily distinguished morphologically from Karridale and Green Range. However, in Western Australia Nangeela is unlikely to be encountered, due to its very limited sowing in this State.
Nuba (ssp. brachycalyicum)

Nuba is the third cultivar of ssp. brachycalyicum to be released in Australia. It was bred by Dr S. Morgner in Germany and results from a cross between Clare and a Spanish introduction. It has been released in Australia by the South Australian Seedgrowers Cooperative Limited and was granted Plant Variety Rights protection in 1991.

In Perth, Nuba is about two weeks later flowering than Clare and four weeks later flowering than Rosedale. It is more hard-seeded than Clare, but is not as hard-seeded as Rosedale. It also has smaller seeds than Clare. It is susceptible to clover scorch and highly susceptible to all known races of Phytophthora root rot. However, it has the highest level of resistance of all cultivars to Rhizoctonia damping off and also has some resistance to Fusarium damping off and to subterranean clover mottle virus. Nuba is also more susceptible to seedling damage by redlegged earth mite than most other cultivars. Its reactions to important leaf diseases have not yet been determined. In common with most other members of ssp. brachycalyicum, Nuba has a low level of formononetin.

Nuba has had very limited field testing in Western Australia. Most information has come from breeding rows in Perth, where it has shown outstanding vigour. However, there appears to be very little scope for Nuba in Western Australia, due to the limited areas suited to ssp. brachycalyicum and its late maturity. The only possible role for it may be on any alkaline to neutral soils either along the south coast or where late spring irrigation can be applied.

Distinctive features

Moderately broad, rounded leaflets with little indentation. Leaf mark of C.A.A., with pale green arms. For much of the season, only the arms are visible. No flushing or flecking tendencies. Calyx pigmentation absent. Flowers small. Belonging to ssp. brachycalyicum, peduncles are long, thin and twisting, with no active burr burial.
Leura (ssp. subterraneum)

Leura is another cultivar collected from Sardinia in 1977 by Dr Clive Francis and Mr Dennis Gillespie of the Department of Agriculture Western Australia. It was selected for field evaluation, under the code-name CPI 89822H, by Dr Bill Collins and Dr John Gladstones of the Department of Agriculture Western Australia in 1982. Leura was registered as a cultivar by the collaborating organisations of the National Subterranean Clover Improvement Program in 1992, following selection by Dr Kevin Reed and Mr Stephen Clark of the Victorian Department of Agriculture. It was also granted Plant Variety Rights protection in 1992.

In Perth, Leura flowers a few days later than Denmark and Goulburn, seven to ten days later than Mount Barker and Karridale, but about two weeks earlier than Tallarook. Leura is relatively soft-seeded, having a similar level to Denmark and Karridale, but is more hard-seeded than Mount Barker. It contains only a trace level of formononetin.

Leura is moderately susceptible to clover scorch, having slightly less resistance than Mount Barker and Karridale. For this reason, the resistant cultivars Denmark and Goulburn have a major advantage over Leura in the clover scorch-prone areas of the south coast. Leura has good resistance to race 0 of Phytophthora root rot and also has resistance to Cercospora leaf spot and leaf rust. It is highly susceptible to bean yellow mosaic virus and is susceptible to Pythium damping off. Leura is also more susceptible than most other cultivars to seedling damage from redlegged earth mites.

Leura has performed well in trials in the high rainfall regions across southern Australia. In Western Australia, it has persisted better than Mount Barker and Karridale, although not as well as Denmark and Goulburn. The major feature of Leura is its excellent late spring production. Under favourable conditions, Leura will continue growing into late December, at least two weeks longer than Denmark. However, Denmark and Goulburn regenerate more densely and produce more early-season herbage.

Leura is likely to be a more important cultivar in the high rainfall areas of eastern Australia than in Western Australia, where its inadequate clover scorch resistance and late maturity will limit its use.

Distinctive features

Leaflets heart-shaped with a moderate indentation. Leaf mark of C₃A₁, with arms tending to fade late in the season. A weak brown flush can occasionally be seen as a narrow line along the midrib and outlining the leaf mark. Flecking is absent. Calyx tubes have no pigmentation. Most similar morphologically to Dalkeith and Dwalganup, although its maturity is much later. Can be distinguished from Dwalganup by its moderately indented leaflets and from both by its absence of any calyx pigmentation.
**Meteora (ssp. yanninicium)**

Meteora originated from northern Greece and is the second subspecies *yanninicium* cultivar, following Larisa, to come from the collection made by Dr Sephi Katznelson of Israel in 1965. It was tested under the name CPI 39327YB and selected as a new cultivar by Mr Donald Nicholas and Mr Dennis Gillespie of the Department of Agriculture Western Australia. It was registered and released in 1981 by the National Subterranean Clover Improvement Program.

Meteora is the latest maturing of currently recommended cultivars, flowering about 10 days later than Mount Barker and a week or so later than Larisa. In Western Australia, Meteora needs a growing season of at least 8½ months for satisfactory persistence. It has an unusually high level of hardseededness for its maturity. Under mild summer conditions, particularly when dense herbage residues are carried into the summer, limited seed softening can occur, which may result in thin stands in the second year after sowing. Like the other ssp. *yanninicium* cultivars, Meteora is tolerant of waterlogging.

Formononetin level is a little higher than that considered desirable and Meteora should be regarded as slightly suspect as a cause of clover infertility in sheep. Meteora has resistance to clover scorch, leaf rust, Cercospora leaf spot, subterranean clover mottle virus and to race 0 of Phytophthora root rot. It is very susceptible to bean yellow mosaic virus and is also susceptible to Pythium, Rhizoctonia and Fusarium damping off.

Meteora's outstanding attribute is its exceptional spring growth and this, together with its tall habit and resistance to clover scorch, makes it particularly useful for hay production. Meteora is well suited to the high rainfall areas on the south coast where cattle production and fodder conservation are part of the farming system. It is also suited to irrigation districts where late spring irrigations can be applied.

**Distinctive features**

Cream to amber seeds. Hairless runners, petioles, peduncles and leaf upper surfaces. Very broad, rounded leaflets, which tend to overlap. Slight indentation. Leaf mark consisting of a Cc crescent, which becomes flatter later in the season to look more like a Bb band. Moderately strong flushing tendency with brown anthocyanin mainly along the midrib, although the area beyond the crescent can also have reddish brown pigmentation. Calyx lobes elongated. Calyx tubes, when shaded, generally have no pigmentation, but when exposed to sunlight, much of their surface can be a pale brownish pink. Closely resembles both Gosse and Riverina in appearance, being a common parent to both of them. Can be distinguished from Gosse and Riverina by its broader leaflets, which tend to overlap, and by its later maturity and moderately high formononetin content.
Tallarook (ssp. subterraneum)

This naturalised strain was discovered on the property of Mr A.C. Head near Tallarook, Victoria in 1928. It is the latest maturing of the commercial cultivars, flowering some three to four weeks later than Mount Barker. It was first certified in 1935 in Tasmania and in 1943 in Western Australia.

Since its introduction into Western Australia, Tallarook has been grown only to a very limited extent, mainly in the very high rainfall districts of the lower south-west. It is a leafy cultivar which appears to make little growth until spring and has been used mainly in combination with earlier maturing types such as Woogennellup or Yarloop. It is very soft-seeded and has weak burr burial. Tallarook has moderate resistance to clover scorch and is the most resistant of the cultivars to powdery mildew. It is highly susceptible to race 0 of Phytophthora root rot and to bean yellow mosaic virus. Tallarook is also susceptible to Pythium and Rhizoctonia damping off.

Tallarook contains a high level of formononetin and is likely to cause infertility in sheep. However, this has been of little consequence in the past as dairying and beef cattle production have been the main enterprises in districts where Tallarook has been grown.

Distinctive features

Very late maturity, with flowering not commencing until mid-October. No anthocyanin pigmentation of calyx tube and stipule. Moderately strong tendency to produce a purplish brown flush covering most or all of basal area below the leaf mark. Leaflets moderately broad with slight indentation. Leaf mark of C_12 A_1, with arms tending to fade late in the season. Hairy runners and peduncles. An ancestor of both Junee and Howard and very similar morphologically to them. Can be distinguished from Junee by its very hairy peduncles, more hairy runners and its high formononetin content. Distinguishable from both cultivars by its much later maturity.
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Further reading
