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Developing improved varieties of subterranean clover

By Phil Nichols, Plant Breeder1, Bill Collins, Manager1, Dennis Gillespie, Senior Research Officer1, and Martin Barbetti, Senior Plant Pathologist2

Subterranean clover is widely recognised as the most important pasture legume species in southern Australia, having been sown over about 20 million hectares.

Together with superphosphate and trace elements, it has been a key factor in improving and maintaining soil fertility, and has resulted in dramatic increases in crop, livestock and wool production.

While the value of subterranean clover is well established, it does have some shortcomings. Many varieties grown today are not sufficiently adapted to the environments and management systems in use. Others lack sufficient pest and disease resistance.

Improved subterranean clovers are being bred with better adaptation and greater productivity for a range of environments and farming systems across southern Australia and in New Zealand.

This article outlines the breeding and selection processes and highlights recent developments.

ASCALIP

Subterranean clover breeding and selection began in Western Australia in 1950 with Dr A.J. Millington at the University of Western Australia. The Department of Agriculture became involved from 1967, while other States participated in field evaluation from 1970.

In 1983, a formalised structure was adopted and the program became known as the National Subterranean Clover Improvement Program.

This structure was extended in 1992 to include New Zealand, and became part of a larger structure known as the Australasian Subterranean Clover and Alternative Legumes Improvement Program (ASCALIP).

The subterranean clover program of the ASCALIP is operated jointly by the Department of Agriculture and the University of Western Australia. It also forms part of the Cooperative Research Centre for Legumes in Mediterranean Agriculture. Departments of Agriculture in each State and New Zealand test promising breeding material in the field (see map).

Fourteen varieties have been released to farmers from the Perth-based program (see Table). A further variety, York, is currently undergoing seed increase for release in 1996.

The program also contributed to the registration of the varieties Rosedale and Gosse, released by the South Australian Research and Development Institute.

Grouping of breeding material

Subterranean clover is grown over a wide range of environments. Its use in Western Australia extends from wheatbelt areas, with low and unreliable rainfall, to the high rainfall south coast with long growing seasons. Over such diversity, it is unreasonable to expect any one variety to suit all environments.

The aim of the subterranean clover program of the ASCALIP is to breed a range of varieties to cover the major environments in which subterranean clover is grown. Breeding material is divided into broad groups, so that field testing can be done in suitable target environments. These groups are based on maturity and subspecies.

Maturity groups

Early maturity – covers low to medium rainfall wheatbelt environments, where frequent cropping is common.

Medium maturity – represents medium to high rainfall environments, where farming is mixed, with some cropping.

Late maturity – covers high rainfall areas with long growing seasons and permanent or semi-permanent pastures.
Subspecies
Breeding material is also divided into three subspecies, each with its own adaptation features:
- *subterraneum* — adapted to medium to well drained soils of neutral to acid pH; most commercial varieties belong to this subspecies;
- *yanninicum* — prefers neutral to acid soils; also grows well in winter-waterlogged areas;
- *brachycalycinum* — adapted to neutral to alkaline soils, also prefers cracking or stony soils. This subspecies is suited to very limited areas in Western Australia and is more important in other States.

Selection of early generation breeding lines
The first phase of the breeding program involves selecting breeding lines with characteristics known to be important for reliable production and persistence. These include disease and insect resistance, low oestrogen content, and hard-seededness to aid persistence.

Breeding lines can come from two sources: crosses between different parents (crossbreds) or accessions, plants collected from overseas or within Australia.

Crosses are made between breeding lines that contain genes for the required characters and those that have demonstrated good field adaptation. Up to seven generations are needed to produce advanced cross-breds that are both genetically uniform and contain all desired characteristics.

The breeding program also evaluates new accessions. These are tested alongside advanced cross-breds. Selected breeding lines from both sources then enter the field testing phase where they are evaluated under farming conditions.

Much of the early generation selection work is conducted on irrigated short rows or single plants grown at the University of Western Australia Field Station in Shenton Park. Some selection for adaptation to farming conditions also takes place. Following preliminary screening, breeding lines are sown in target environments and allowed to regenerate for at least three seasons under grazing. Seed is then collected from the most promising breeding lines for further screening and selection.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Year released</th>
<th>Maturity</th>
<th>Subspecies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geraldton</td>
<td>1959</td>
<td>1</td>
<td><em>subterraneum</em></td>
</tr>
<tr>
<td>Uniwager</td>
<td>1967</td>
<td>1</td>
<td><em>subterraneum</em></td>
</tr>
<tr>
<td>Trikkala</td>
<td>1975</td>
<td>2</td>
<td><em>yanninicum</em></td>
</tr>
<tr>
<td>Larisa</td>
<td>1975</td>
<td>3</td>
<td><em>yanninicum</em></td>
</tr>
<tr>
<td>Nungarin</td>
<td>1976</td>
<td>1</td>
<td><em>subterraneum</em></td>
</tr>
<tr>
<td>Esperance</td>
<td>1976</td>
<td>2</td>
<td><em>subterraneum</em></td>
</tr>
<tr>
<td>Meteora</td>
<td>1981</td>
<td>3</td>
<td><em>yanninicum</em></td>
</tr>
<tr>
<td>Dalkeith</td>
<td>1983</td>
<td>1</td>
<td><em>subterraneum</em></td>
</tr>
<tr>
<td>Junee</td>
<td>1985</td>
<td>2</td>
<td><em>subterraneum</em></td>
</tr>
<tr>
<td>Green Range</td>
<td>1985</td>
<td>2</td>
<td><em>subterraneum</em></td>
</tr>
<tr>
<td>Karridale</td>
<td>1985</td>
<td>3</td>
<td><em>subterraneum</em></td>
</tr>
<tr>
<td>Rosedale*</td>
<td>1988</td>
<td>2</td>
<td><em>brachycalycinum</em></td>
</tr>
<tr>
<td>Denmark</td>
<td>1992</td>
<td>3</td>
<td><em>subterraneum</em></td>
</tr>
<tr>
<td>Lura</td>
<td>1992</td>
<td>3</td>
<td><em>subterraneum</em></td>
</tr>
<tr>
<td>Goulburn</td>
<td>1992</td>
<td>3</td>
<td><em>subterraneum</em></td>
</tr>
<tr>
<td>Gosse*</td>
<td>1993</td>
<td>2</td>
<td><em>yanninicum</em></td>
</tr>
<tr>
<td>York</td>
<td>1996</td>
<td>2</td>
<td><em>subterraneum</em></td>
</tr>
</tbody>
</table>

* In collaboration with the South Australian Research and Development Institute.
Selection criteria

Low oestrogen levels
Several of the older varieties of subterranean clover, including Yarloop, Dwalganup, Dinninup, Geraldton and Tallarook, contain high levels of the oestrogenic compound, formononetin. Ewes grazing green pastures of these varieties can suffer from 'clover disease', symptoms of which include reduced fertility, difficult lambing and prolapse of the uterus. All breeding material is screened for low levels of formononetin and lines containing more than 0.2 per cent of dry matter are culled. No severe clover disease symptoms have been attributed to varieties containing less than this level. Advanced breeding lines are also screened for two other less potent oestrogenic compounds, genistein and biochanin A.

Disease resistance
Disease resistance, particularly resistance to clover scorch (Kabatiella caulivora), the most important disease of subterranean clover, is given high priority in medium and late maturing material. This work is conducted in the field at Denmark, Western Australia. In addition, the clover scorch resistance of all lines approaching cultivar status is confirmed in glasshouse experiments. New varieties must have at least moderate resistance to clover scorch to be commercially acceptable.

Another major program screens for resistance to root rot caused by Phytophthora clandestina. This is a collaborative project with the Victorian Department of Agriculture. All new medium and late maturing varieties should have resistance to this root rot.

Smaller programs also select for resistance to other diseases; the leaf diseases, leaf rust (Uromyces trifolii-repentis), powdery mildew (Erysiphe polygonii), and cercospora leafspot (Cercospora zebrina); and damping off and root rots caused by Pythium irregulare and Rhizoctonia solani.

Pest resistance
Redlegged earth mite (RLEM) is the major pest of subterranean clover in all districts. Across Australia, annual pasture losses attributed to RLEM, bluegreen aphid and lucerne flea have been estimated at $228 million, with a further $10 million being spent on insecticides (Sloane et al., 1988).

All current commercial varieties of subterranean clover are susceptible to RLEM, particularly at the seedling stage. The development and subsequent use of resistant varieties is the most cost-effective solution to controlling this damage. The breeding program is now placing major emphasis on breeding subterranean clover varieties with resistance to RLEM. A wide range of accessions is being tested to identify those with better resistance.

Seedling resistance is being sought first, since clover plants are most susceptible to damage at this stage. Fortunately, some accessions have been identified with much better seedling resistance than current commercial varieties. These are being evaluated as possible varieties in their own right. They are also being crossed with other varieties and advanced breeding lines to transfer their genes for resistance.

A small program concerns resistance to bluegreen aphid. This pest is mainly a problem in spring, causing premature 'hayin-off' and reducing seed set. No fully resistant varieties are known.

No breeding work has been attempted for resistance to lucerne flea.
Rosemary Lugg is processing leaf samples to determine oestrogen content.

Technician John Titterington cross-pollinating clover parent plants.

Variety identification

In the past, considerable attention was directed at selecting subterranean clovers with distinctive visible features. This was considered necessary to readily identify a variety, and was particularly important for seed certification. Distinctive leaf marks, in particular, were sought. Other markers included pigmentation of the flower tube and hairiness of runners, petioles and leaf upper surfaces.

We no longer emphasise this. With the introduction of the limited generation seed certification scheme, it is no longer essential for each variety to be visibly distinct. Breeding now concentrates on characters of agronomic importance. However, where two breeding lines of equal performance are being considered for commercialisation, the more distinctive will most likely be chosen as the new variety.

Hard-seededness

Insufficient hard-seededness is a major limitation to persistence of subterranean clover, particularly when it is grown in rotation with field crops. Subterranean clover sets virtually no seed during the year in which a paddock is cropped. To regenerate satisfactorily in the following year, seed produced in the previous pasture phase must germinate.

Seeds that do not germinate after germinating rains are termed 'hard seeds'. At the beginning of summer more than 80 per cent of the seeds of all varieties are hard. Seeds soften in the field during summer and early autumn owing to fluctuating temperatures, and soft seeds germinate at the break of the season. However, the rate of seed softening varies between varieties.

Soft-seeded varieties have a higher proportion of seed ready to germinate in the first summer or autumn. Hard-seeded clovers have a high proportion of seed able to survive the following growing season without germinating. These varieties are more likely to produce a dense regenerating pasture in the year following cropping.

Hard-seededness is also important in areas with frequent false breaks and unreliable springs. With either occurrence, good regeneration in following seasons depends on hard seeds remaining in the soil from previous seasons.

Early and medium maturing varieties are being bred with higher hard seed levels. Hard-seededness is not important in late maturing varieties.
Field testing

Once genetically uniform breeding lines with the desired characters have been selected, they are tested in the field by collaborators in each State Department of Agriculture and in New Zealand. Breeding lines are tested in small swards under farming conditions and compared with recommended commercial varieties.

Field evaluation consists of two stages, each lasting three to four years. The most promising breeding lines from Stage I trials are selected for Stage II trials. The short list of breeding lines is decided by consensus among the collaborating Departments of Agriculture. Stage II is more intensive than Stage I and involves fewer breeding lines, more sites, larger plots and more measurements.

Characters measured in the field evaluation phase include:
- herbage production and clover dominance in autumn, winter and spring,
- seed production and seedling regeneration density, and
- reaction to local pests and diseases.
Commercialisation of new varieties

To be considered for commercial release, a breeding line must be as good as existing recommended varieties in most aspects and have a significant improvement in at least one character.

Future breeding

Resistance to redlegged earth mite

A major effort is being devoted to developing varieties with resistance to RLEM. We aim to release several RLEM-resistant varieties to cover the full range of environments in which subterranean clover is grown.

Hard-seededness

Varieties with increased levels of hard-seededness are being developed for low and medium rainfall environments. A very promising group of 104 early maturing breeding lines is undergoing Stage I field evaluation trials.

Field and laboratory tests have indicated that many are significantly more hard-seeded than Nungarin and Dalkeith, the two most hard-seeded varieties.

Resistance to fungal diseases

Varieties with resistance to a wide range of fungal pathogens including clover scorch, root rots, leaf rust, cercospora leaf spot and powdery mildew will be developed for medium and high rainfall regions. New strains of clover scorch in Western Australia and phytophthora root rot in eastern Australia have been identified. New varieties will need to be resistant to all major strains of these pathogens.

In addition, resistance will be sought to fungi that cause damping-off and root rot, particularly *Pythium irregulare* and *Rhizoctonia solani*.

Work in the early stages will primarily involve searching among accessions for sources of resistance.

Resistance to viruses

Plant viruses are posing an increasing problem in subterranean clover pastures. Subterranean clover mottle virus and bean yellow mosaic virus, in particular, are of major concern in higher rainfall zones. Some screening for resistance has been conducted and it is hoped this work will continue.

Low oestrogen levels

All future varieties will be selected for low levels of oestrogens as an insurance against clover disease.

Acknowledgements

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Further reading


Reference


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