1984

Naturalised subterranean clover strains of Western Australia

W J. Collins

John S. Gladstones

Western Australian
Department of Agriculture

ISSN 0083-8675
Agdex No. 137/33

Technical Bulletin

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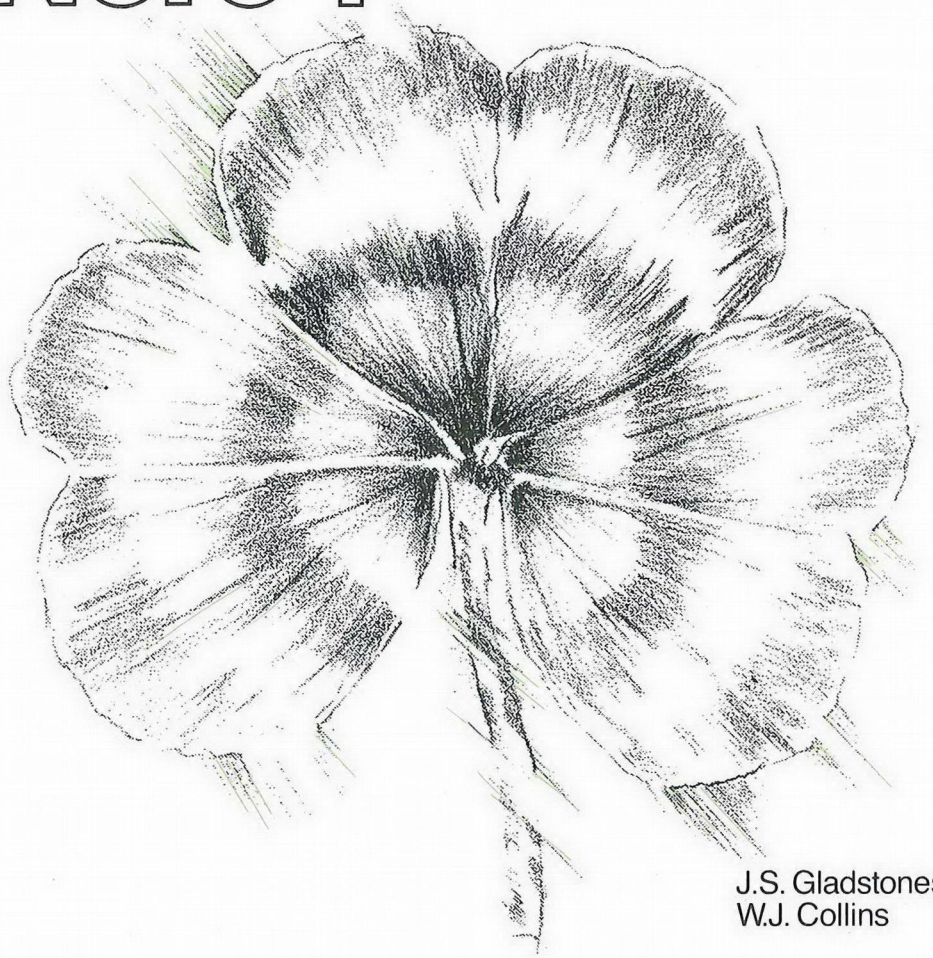
No. 64



J.S. Gladstones
W.J. Collins

The authors

J. S. Gladstones, Principal Plant Breeder, and W. J. Collins, Senior Research Officer, Division of Plant Production, Western Australian Department of Agriculture.

The study formed part of the National Subterranean Clover Improvement Programme. Most of the work was done at the University of Western Australia Field Station, Shenton Park, during periods when both authors were members of staff of the University.

Gladstones, J. S. (John Sylvester), 1932-.

Naturalized subterranean clover strains of Western Australia.

ISBN 0 7244 8862 6.

1. Subterranean clover—Western Australia—Varieties. I. Collins, W. J. (William John), 1943-. II. Western Australia. Dept. of Agriculture. III. Title (Series: Technical Bulletin (Western Australia. Dept. of Agriculture); No. 64).

633.3'2

Manuscript received June, 1982.

Introduction

Other papers (Gladstones 1966, 1967; Gladstones and Collins 1983) have discussed the history of subterranean clover (*Trifolium subterraneum* L.) as a naturalized plant in Western Australia. The two earlier papers tabulated some of the morphological and agronomic characteristics of strains collected up to 1962. Following the collection of further naturalized strains during 1966-1970 by Gladstones (then of the University of Western Australia) and by C. M. Francis and colleagues in the Western Australian Department of Agriculture, the expanded collection of strains was examined and rationalized. This bulletin describes the reorganized Western Australian naturalized collection as it now exists. It does not purport to be complete, because some districts which are possible sources of naturalized strains have not as yet been explored; while others have been explored only incompletely.

A number of lines previously described by Gladstones (1966, 1967) have been deleted as being probably the products of recent mutation or natural crossing, and unlikely to be of direct or indirect agronomic use. They are listed in a later section. A few of the apparent mutants and recent crossbreds were retained on the ground of possible agronomic merit. The final collection comprises 115 strains, of which 13 are, or have been, commercial cultivars. Of these, six were introduced commercially from other States, but are here assumed to have become naturalized in Western Australia to some extent. Recent cultivars developed by breeding are omitted: for their descriptions see Quinlivan and Francis (1977); Collins, Francis and Quinlivan (1984).

We define as *primary naturalized strains* those which, from their distributions and extents of spread as more or less uniform populations, appear to have been originally introduced in their present forms. *Secondary naturalized strains* are those which have evolved by natural crossing or major mutation since introduction. They have become established over sufficient areas, as well-defined genetic forms, to be recognised as distinct naturalized entities. Recombinants derived from recent crossing, present only as components of hybrid swarms or mixed populations, are not recognised as yet being true naturalized strains. However, individual component genotypes could eventually become so under the influence of natural selection or genetic drift.

A primary naturalization site is the putative site of initial establishment of a primary naturalized strain, while a *secondary naturalization site* is one to which an established primary naturalized strain has been secondarily transported; or alternatively, the site of evolution of a secondary naturalized strain.

For definitions of the terms strain, sub-strain and cultivar, and for a fuller discussion of the terms associated with plant naturalization, see appendix 1.

Strain characteristics

Recorded strain characteristics are set out in table 1. Categorizations for the individual diagnostic characters are explained in the following section.

All data, other than those for resistance to clover scorch (*Kabatiella caulivora*), were obtained from rows or plots grown at the University of Western Australia Field Station at Shenton Park, with a minimum of two years observations or measurements for any one item. The ratings for clover scorch resistance were based on published data of Chatel, Francis and Devitt (1973) and of Chatel and Francis (1974, 1977, 1978), mainly from tests at the Western Australian Department of Agriculture Research Station at Denmark. Ratings for hard-seededness and physiological seed dormancy were derived from varying numbers of tests, with at least two for any strain, carried out between 1966-67 and 1973-74. Those for hard-seededness reflect relative rates of impermeability breakdown in seeds from buried burrs, harvested soon after maturity and held under controlled temperatures alternating daily between 15°C and 60°C to simulate summer soil surface conditions (Quinlivan and Millington 1962).

Tests of physiological seed dormancy were mainly confined to strains considered at the time to be of agronomic or genetic interest. We have categorized seed development rate only for those strains which have been under fairly constant observation, or on which direct experimental measurements have been made (Tennant 1965; Walton 1966; Francis and Gladstones 1974). Ratings of burr burial were based partly on previously published measurements (Quinlivan and Francis 1971; Collins, Francis and Quinlivan 1976), but chiefly on our direct observations on rows at Shenton Park. The figures for floret number per inflorescence came from two complete series of counts made in 1972 and 1973.

The cited figures for isoflavones are representative averages for fully developed leaves of healthy undefoliated plants at about early flowering, and are based on measurements at Shenton Park over a number of years using the technique of Francis and Millington (1965).

The practical significance of some of the agronomic and biochemical characteristics recorded has been discussed elsewhere (Gladstones 1975; Francis *et al.* 1976). Remarks on potential agronomic value are included where relevant in the commentaries on individual strains, while in the final section some of the more important agronomic observations are discussed.

Key to ratings of seed and plant characteristics

Seeds

Colour:

P = purple
B = black
pB = purplish black
C = cream
A = amber

Size:

\+ = small
++ = medium
+++ = large

Seedlings

Growth habit:

(1) S = short petioles
M = medium length petioles
L = long petioles

(2) E = erect habit
N = intermediate habit
P = prostrate habit

Cotyledon flecks:

— = always absent
(—) = slight flecking occasionally present
(+) = slight flecking often present
\+ = slight to moderate flecking on all cotyledons
++ = prominent flecking on all cotyledons

Hypocotyl pigmentation:

\+ = pale pigmentation of exposed surfaces only
++ = light pigmentation, mainly on the exposed surfaces
+++ = moderate to fairly strong pigmentation covering most of the hypocotyl
++++ = strong pigmentation of the whole hypocotyl

Unifoliate crescent:

— = crescent marking always absent
(—) = faint central spot only occasionally visible
(+) = faint central spot often visible
\+ = small central spot always visible
++ = moderate spot or crescent, covering about one-half the width of the unifoliate
+++ = prominent, fully developed crescent, extending over most or all the width of the unifoliate
++++ = whole of area below the crescent white or greenish white

Unifoliate upper surface hairs:

— = more or less glabrous
\+ = sparse hairs, mainly around the leaf margin
++ = moderately hairy, hairs often sparse or absent in the centre of the leaf
+++ = densely or coarsely hairy, hairs covering the whole leaf

(Superscripts: a = hairs moderately appressed; aa = hairs strongly appressed.)

Trifoliate leaves

Colour (depth of green):

\+ = conspicuously light green
++ = moderately light green
+++ = moderately dark green
++++ = conspicuously dark green

Size (as attained in spring):

\+ = small
++ = moderate
+++ = large
++++ = very large

Leaflet shape (ratings only on leaves formed up to early flowering):

First digit describes breadth
1 = narrow
2 = medium
3 = broad

Second digit describes roundness
1 = triangular
2 = intermediate
3 = rounded

Third digit describes indentation of distal margin
1. Convex with little or no indent.
2. Moderately indented
3. Strongly indented

Crescent markings (ratings only on leaves formed from third trifoliate leaf to early flowering):

* Light green area in the centre of the leaflet

C1 = a small central spot
C2 = large spot, or a moderately small angular or crescent-shaped area extending across about half the width of the leaflet
C3 = moderately prominent angular or crescent-shaped area, extending up to three-quarters of the way across the leaflet
C4 = very prominent angular or crescent-shaped area, extending more than three-quarters of the way across the leaflet.

* Pale green or white "arms" extending laterally from the central light green area (if any) to the leaflet margin:

A1 = arms narrow, not prominent
A2 = arms moderately broad and prominent
A3 = arms very broad and prominent
A4 = whitish area extending downwards to cover the whole leaflet surface below the central light green area.

* Band of more or less uniform width and colour extending right across the leaflet:

B1 = band narrow, often faint
B2 = band moderately broad and/or prominent
B3 = band very broad and/or prominent.

Red flecking:

— = no red flecking under any conditions
\+ = fine and/or sparse red flecking only under conducive conditions
++ = moderately prominent flecking under conducive conditions, disappearing partly or completely under non-conducive conditions (see following section)
+++ = very prominent red flecking under conducive conditions, tending to persist under non-conducive conditions.

Anthocyanin flushing:

— = no flushing under any conditions
\+ = slight flushing under conducive conditions only
++ = moderate flushing under conducive conditions, usually disappearing under non-conducive conditions (see following section)
+++ = strong flushing under conducive conditions, often persisting to some extent under non-conducive conditions.

Colour of anthocyanin flushing:

B = brown
pB = purplish brown
bP = brownish purple
P = purple.

Pattern of anthocyanin flushing:

M = a clearly defined bar along the midrib, usually below the crescent
MF = mainly along the midrib, but under conducive conditions extending outwards along the veins and/or as a diffused flush
F = a more or less diffused flush over most or all of the area below the crescent, sometimes extending above it
B = pigmentation at extreme base of the leaflet only
S = forming a border surrounding the crescent

Hairiness of upper surface (ratings pre-flowering):

Key as for unifoliate leaves.

Petioles

Length (as attained in spring at the beginning of flowering):

\+ = short
++ = moderate
+++ = long
++++ = very long

Thickness (as attained in spring at the beginning of flowering):

\+ = thin
++ = moderate
+++ = thick
++++ = very thick

Hairiness

— = petioles more or less glabrous
\+ = sparsely and/or finely hairy
++ = moderately hairy
+++ = fairly densely or coarsely hairy
++++ = very densely and/or coarsely hairy

(Superscripts: a = hairs moderately appressed aa = hairs strongly appressed)

Stipules

Pigmentation:

— = no pigmentation
\+ = some or all veins pink to red
++ = veins red, plus a narrow but more or less solid bar across the centre of the stipule
+++ = broad, solid red or purple transverse bar or flush, normally covering about half the stipule or more

Stems (Runners)

Thickness:

\+ = thin
++ = moderate
+++ = thick
++++ = very thick

Internode length (average of internodes distal to the first flower):

\+ = very short
++ = moderately short
+++ = moderately long
++++ = long

Hairiness:

As for petiole hairs

Pigmentation:

\+ = weak, only on surfaces directly exposed to the sun
++ = moderate on exposed stems, little or none on shaded stems
+++ = moderately strong on exposed stems, usually some on shaded stems
++++ = very strong on exposed stems, moderate or stronger on shaded stems.

Colour of pigmentation:

B = brown
piB = pinkish brown
pB = purplish brown
bPi = brownish pink
bP = brownish purple
P = purple.

Flowers

Pigmentation of standard:

\+ = faint reddening of some veins
++ = reddening of most or all veins
+++ = vein reddening plus diffuse pink tinge at tip of standard
++++ = whole standard and flower pink.

Pigmentation of calyx:

— = no pigmentation, whole calyx pale green
\+ = calyx teeth and usually tip of calyx tube lightly pigmented
++ = upper one-quarter to one-third of calyx lightly to moderately pigmented
+++ = upper about one-half of calyx tube moderately to strongly pigmented
++++ = upper about two-thirds of calyx tube strongly pigmented
+++++ = three-quarters to whole of calyx tube very strongly pigmented

Colour of calyx pigmentation:

pB = purplish brown
bP = brownish purple
bPi = brownish pink
Pi = pink
rPi = reddish pink
piR = pinkish red
R = red
pPi = purplish pink
pR = purplish red
rP = reddish purple
P = purple

Peduncles

Length:

\+ = short
++ = moderate
+++ = long
++++ = very long

Thickness:

\+ = thin
\+ + = moderate
\+ + + = thick
\+ + + + = very thick

Hairiness:

As for petioles

Burrs

Coarseness:

\+ = fine
\+ + = moderate
\+ + + = coarse

Strength of burial:

\+ = weak, usually little burial
\+ + = moderately weak
\+ + + = moderately strong
\+ + + + = strong

Seed physiology

Rate of seed development:

\+ = slow
\+ + = moderate
\+ + + = rapid

Hard-seededness (seed coat impermeability):

\+ = very low, breaking down rapidly and more or less completely under Mediterranean summer field temperatures
\+ + = low
\+ + + = moderate
\+ + + + = moderately high
\+ + + + + = high

Physiological domancy:

\+ = very weak
\+ + = weak
\+ + + = moderate
\+ + + + = strong
\+ + + + + = very strong

Disease

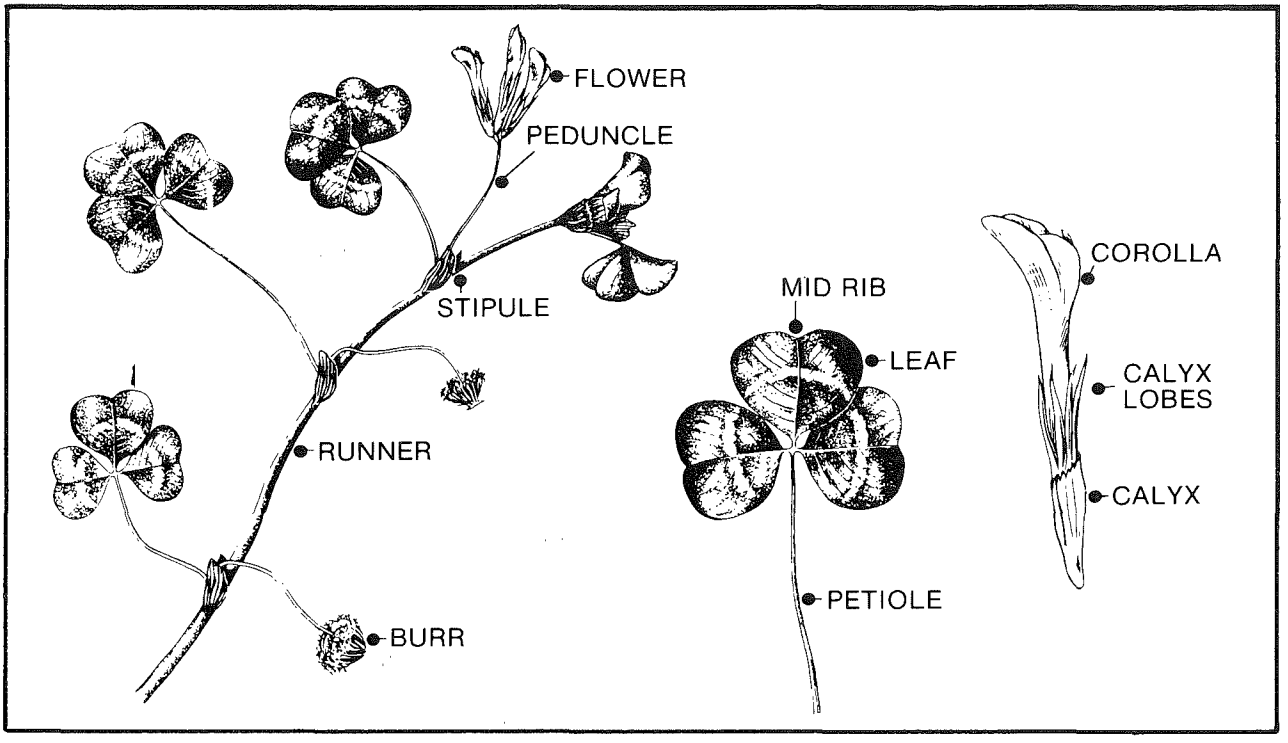
Resistance to clover scorch (caused by the fungus *Kabatiella caulivora*):

\+ = highly susceptible
\+ + = slightly tolerant
\+ + + = tolerant
\+ + + + = resistant

The plant parts and rated morphological characters are illustrated graphically in figures 3 and 4, from Collins, Francis and Quinlivan (1984).

Figure 3 of that publication is repeated here as figure 1.

Figure 1—Illustration of the botanical terms used in the text.



Effects of growth stage and environment on certain plant characteristics

Because growth stage and environment modify the expression of some plant characteristics, their value for descriptive and diagnostic purposes is reduced. Nevertheless they can still be useful where the nature of the influence is known.

Leaf size, petiole length and petiole thickness all change with stage and vigour of growth. They are substantially correlated amongst themselves (Gladstones 1967). In ungrazed plants, leaf size, petiole length and petiole thickness increase with each successive node up to about the beginning of flowering, then progressively decrease further out along the runner. As a consequence, mid-season and late-flowering genotypes attain greater leaf and petiole sizes in spring than early-flowering genotypes. The ratings refer to size attained in spring at the beginning of flowering, and therefore substantially reflect maturity differences. However, differences do exist among lines of the same flowering time, which are best seen early in growth while all strains are still vegetative. They are reflected in the ratings as differences within maturity groups.

Leaflet shape varies according to the physiological age of the plant when the leaves are formed. The leaflets produced after flowering has started not only become progressively smaller with increasing node number, but also tend to become narrower, more triangular, and less indented at the distal margin. The ratings refer to leaflets produced up to early flowering.

Upper surface hairiness of the trifoliate leaves changes with physiological age in many strains, being relatively much greater on leaves produced after the onset of flowering than on those produced pre-flowering. The hairs also tend to become more appressed. It should be noted that apparent hairiness is less under conditions conducive to lush growth and large leaves, probably because with larger epidermal cells the same number of hairs is spread over a larger surface area.

Trifoliate crescent markings are weakly expressed in seedlings on the first and, to a lesser extent, the second trifoliate leaves. They also vary to some extent in sympathy with the changed shape of leaflets produced in mid to late-flowering, becoming flatter as the successive leaflets are more triangular. Finally, the markings fade on all leaves at high temperatures or as they approach senescence. The ratings apply to fully developed, but non-senescent, leaflets under normal field conditions, from about the third trifoliate to those produced in early flowering.

Red flecking of the leaves is highly dependent on environment, being most strongly expressed before early to mid-flowering, and under low temperatures and phosphate deficiency. By contrast, deficiency of potassium, or of other elements whose deficiency leads to chlorosis, generally causes fading of the flecks; as does moisture stress. The ratings refer only to tendencies, and are best observed no later than early flowering.

Anthocyanin flushing of the leaves reacts to environment in much the same way as red flecking, and should likewise be observed only up to early flowering.

Stipule pigmentation is fully expressed only under almost complete shading, such as in a dense vigorous sward, and before mid-flowering. It fades to varying degrees on exposed runners; under moisture stress; and as plants approach maturity.

Stem pigmentation in most strains depends on exposure to direct sunlight, and must be judged accordingly. The apparent colour of the pigmentation is influenced by its intensity. The green background colour where pigmentation is weak tends to give a brown impression, as compared with a more strongly purple impression where pigmentation is strong.

Pigmentation of the calyx is fully expressed on runners of at least normal vigour and in early to mid-flowering. It is weaker on very weak runners and towards the end of flowering.

Isoflavone content of the leaves is influenced by environment in a number of ways, which closely parallel those of environment on anthocyanin flecking and flushing (Rossiter and Beck 1966a, 1966b, 1967a, 1967b; Rossiter 1967, 1969a, 1969b; Rossiter and Barrow 1972). The parallels are thought to be based on a common dependence of isoflavone and anthocyanin synthesis on the concentration of available sugar substrates (Rossiter 1970, 1972).

Thus, isoflavone (and in particular formononetin) content is increased by low temperature and deficiencies of phosphorus, sulphur, nitrogen or zinc; and decreased by low

Table 1. Characteristics of naturalized and introduced commercial subterranean clover strains in Western Australia. (For detailed description of ratings, see text)

		1 Carnarmah	2 Northam	3 Northam A2	4 Gingin Brook	5 Daglish	6 Jolimont	7 Williams	8 Midland A	9 Swanbourne	10 Dwalganup	11 Crawley	12 Bridgetown A	13 Pink Flower	14 Geraldton
Seeds	Colour	B	pB	pB	B	B	B	P-pB	pB	B	B	B	B	B	B
	Size	+++	++	++	++	++	++	+(+)	++	++	+++	+++	+++	+++	+
Seedlings	Growth habit	I.E	MN	MN	LN	MP	MP	LN	LN	MN	LN	LN	LN	LN	MP
	Cotyledon flecks	—	—	—	+	—	—	—	—	—	—	—	—	—	—
	Hypocotyl pigmentation	+++	++	++	++(+)	+++	+++(+)	++(+)	++(+)	++(+)	++(+)	+++	+++	++++	+++
	Unifoliate crescent	(+)	—	(+)		+	(—)	+	+	+	+	+++	—	—	—
	Unifoliate upper surface hairs	+++	++	++	—	++	++	(+)	(+)	++(+)	++(+)	++(+)	++(+)	++(+)	++
Trifoliate leaves	Colour: depth of green	+++	+	+(+)	++	+++	+++	++	++	+++	+++	+++	+++	++++	++
	Size	+	++	++	+(+)	+	+	++	++	+	+	+	+	+	+
	Leaflet shape	121	322	322	212	221	231	112	332	221	221	221	221	231	112
	Crescent markings	C1(A1)	B1	B2	C3-4(A1)	C2A1	C1A1	C4A1	B3A1	C2A1	C2A1	C2A4	—	—	B1
	Red flecking	(+)	—	—	—	(+)	(+)	—	—	+	+	+	+	(—)	+
	Flushing	+	—	—	+	(+)	(+)	+	+(+)	++	++	(+)	—	—	+
	Colour of flushing	pB	—	—	pB	bP	bP	pB	pB	bP	pB	pB	—	—	pB
	Pattern of flushing	MF	—	—	MF	(M)F	(M)F	M	MF	MF	MF	F	—	—	M(F)
	Upper surface hairs	+++	+++[a]	+++[a]	—	(+)	(+)	—	—	++(+)[a]	++	++	++	++	++
Petioles	Length	+	+(+)	+(+)	++	+	+	++	++	+	+	+	+	+	+
	Thickness	++	++	++	++	+	+	++	++	+	++	++	++	++	+
	Hairs	++	+	+	+(+)	+	+	+[a]	+[a]	+	++	++	++	++	++
Stipules	Pigmentation	+	+	+	++	+	+	+	(—)	(+)	+	+	+	—	+
Stems	Thickness	+	++	++	+++	+	+	+++	+++	+	++	++	++	++	++
	Internode length	++++	++(+)	++(+)	+++	++	++	++	+++	++	+++	+++	+++	+++	++
	Hairs	++	++	++	+(+)[a]	++	++	++[a]	++[a]	++	++	++	++	++	++(+)
	Pigmentation	++	++++	++++	+++	++++	++++	+++	++	+++(+)	++	++	++	++	++
	Colour of pigmentation	pB	bPi	bPi	bPi	P	P	pB	pB	bP	pB	pB	pB	pB	bP
Flowers	Number of florets/inflorescence		4	4	4	4	4	4	4	4	4	4	4	4	4
	Pigmentation of standard	++	+	+	+	+	+(+)	+(+)	++	++	++	++	++	++++	++
	Pigmentation of calyx	+	++++	++++	++++	+	+	++++	++++	++	+	+	+	+	+++
	Colour of calyx pigmentation	bPi	pR	pR	(p)R	bPi	bPi	pR	pR	pPi	bPi	bPi	bPi	bPi	pR
Peduncles	Length	+++	++	++	++	++	++	++	+++	++	+++	+++	+++	+++	+++
	Thickness	+(+)	++	++	++	++	++	+++	+++	+	++	++	++	++	++
	Hairs	+++	++	++	++	++	++	++aa	++[a]	++(+)	+++	+++	+++	+++	++
Burrs	Coarseness	++	++	++	+++	++		+++	+++	+	++	++	++	++	+
	Strength of burial	++(+)	++	++	++	++++	++++	+++	+++	+(+)	+++	+++	+++	+++	+++
Seed physiology	Rate of seed development		+(+)	+(+)	++	+++	+++	++			++	++	++	++	+++
	Hard-seededness	+++	+++(+)	++++(+)	++++	+++++	++++	+++++	+++++	++++	++++(+)			++++	++++(+)
	Physiological dormancy	++	++++	++++	+++	+++		++++			++				+++
Isoflavones (leaves)	Av. Formononetin, % of d.m.	1.60	0.12	0.12	1.30	0.10	0.10	0.70	0.60	0.10	1.30	1.30	1.30	1.40	1.00
	Av. Genistein, % of d.m.	1.20	1.80	1.80	0.60	0.70	0.70	1.00	0.80	1.20	1.20	1.20	1.20	1.20	0.40
	Av. Biochanin A, % of d.m.	0.40	0.50	0.50	0.60	1.00	1.10	1.00	0.80	1.40	0.50	0.50	0.50	0.50	0.60
Disease	Resistance to Kabatiella	+	+	+	+	+		+	+	+	+	+	+	+	+

		15 Darkan A	16 Blackboy Hill	17 Gillingarra	18 Northam E	19 Pinjarra A	20 Mundijong	21 Williams B	22 Williams C	23 Hollywood A	24 Hollywood B	25 Greenmount A	26 Bellevue	27 Northam B	28 Northam C
Seeds	Colour	B	B	pB	pB	pB-B	B	B	pB	B	B	B	B	B	pB-B
	Size	++	+++	++	+(+)	++	+++	++	++	+++	+(+)	++	+(+)	++	++
Seedlings	Growth habit	MN	MN	LE	MP	MP	LN	MN	MN	LN	MN	SP	MN	MN	MN
	Cotyledon flecks	(—)	(+)	—	(+)	—	+	—	(—)	—	—	(—)	+	—	—
	Hypocotyl pigmentation	+++	++(+)	+++	++	+++	++(+)	++	++	+++	++	+++	+++(+)	++++	+++(+)
	Unifoliate crescent	—	+(+)	—	++	—	++	+	—	+	—	—	—	—	(+)
	Unifoliate upper surface hairs	+++[a]	++	++(+)	++	++	++	++	++(+)[a]	++(+)	++[a]	++(+)	+++	+	++
Trifoliate leaves	Colour: depth of green	+++	++++	++	++	++	++			+++	+	++++	+++	++++	++(+)
	Size	+	+	++	++	++	++	++	++	+	+(+)	+	+	+	++
	Leaflet shape	221	231	222	222	112	221	213	221	221	321	112	221	112	221
	Crescent markings	C3	C2A2	C3	C3A3	(B1)	C2A1	C3A1	C1	C3A1	(B1)	C3	C2-3	C2-B1	C3-4(A1)
	Red flecking	+	+	—	+	—	++	+	+	+	+	+	+	—	(—)
	Flushing	+	+++	+	++(+)	+	++	+	—	++	—	++(+)	(—)	(—)	+++
	Colour of flushing	pB	P	bP	pB	bP	bP	pB	—	pB	—	bP	(bP)	(pB)	bP
	Pattern of flushing	M	MF	B	(M)F	MF	(M)F	M	—	MF	—	MS	(M)	(M)	MF
	Upper surface hairs	+(+)[a]	+	++	+	+	+	(—)	++(+)[a]	++	++[a]	+(+)	(+)[a]	(+)[a]	+
Petioles	Length	+	+(+)	++	++	++	++(+)	++	+	+	++	+	+(+)	+(+)	++
	Thickness	+	++	++	++	++	++	++	+	++	+	+(+)	+(+)	+(+)	++(+)
	Hairs	+(+)[a]	++[a]	+[a]	—	+	+(+)	+	+	++	+	+(+)	+	+	+
Stipules	Pigmentation	+	+(+)	++	+	+(+)	+	(+)	++(+)	+	+	++	+	(—)	++
Stems	Thickness	++	++	++	++(+)	+(+)	++(+)	+++	++	++	++	+	+(+)	++	++
	Internode Length	+++	++	++++	+++	+++	++++	+++	++	+++	++(+)	++	++	++	++
	Hairs	++[a]	+++	++	(+)	++(+)	++	+++	++(+)	++	++	++[a]	++	++	++
	Pigmentation	++	++	+++	+++(+)	+++	++(+)	+++	+++	++	+++(+)	++	+++	+++	+++
	Colour of pigmentation	pB	bPi	P	bPi	bP	bPi	pB .	pB	pB	bP	bP	bP	bPi	bP
Flowers	Number of florets/inflorescence	4	4	4	4	3-4	4-5	4(-5)	4	4	3	4	4-5	4	(4-)5
	Pigmentation of standard	++	++	++	+	+++	+	++	++	++	++	++	+	++	++
	Pigmentation of calyx	++	(—)	++(+)	+++	++++	++	+++	+++(+)	+	++++	+++	++	+(+)	++(+)
	Colour of calyx pigmentation	pPi	—	pPi	pR	deep pR	pale bP	pR	deep P	bPi	pR	R	pPi	bPi	pPi
Peduncles	Length	++	++	+++	++(+)	++	+++(+)	++	++	+++	+++(+)	++	++	++	++
	Thickness	+(+)	++	++	+	+	++	+++	++	++	+	+(+)	++	+(+)	+++
	Hairs	++[a]	+++	++	(+)	++++	++	+++	++(+)[a]	+++	++	++(+)[a]	++[a]	++	++(+)
Burrs	Coarseness	++	++		++	+	++			++	+	++	++	++	++
	Strength of burial	++	++++	++	+(+)	+	++	+++	++	+++	+	++	++++	+(+)	++++
Seed physiology	Rate of seed development		++	+	+	+	+			++	+	++	+++		++(+)
	Hard seededness	++++	++++	++	++	+++++	++++	+++	+++		++++(+)	+++(+)	++++	+++	+++
	Physiological dormancy	+++			+++	++						+++	++(+)	++++	+++
Insoflavones (leaves)	Av. Formononetin, % of d.m.	1.00	1.20	0.90	0.20	0.05	1.00	1.20	0.20	0.90	0.60	1.10	0.18	0.60	0.18
	Av. Genistein, % of d.m.	0.60	0.90	1.00	1.80	1.50	1.00	0.70	0.80	1.00	0.90	0.60	1.10	0.80	1.00
	Av. Biochanin A, % of d.m.	0.50	0.70	0.50	0.25	0.60	0.70	0.50	0.80	0.60	0.30	0.50	1.20	0.80	1.00
Disease	Resistance to Kabatiella	+	+			++	+			+	+	+	+	+	+

		29 Northam F	30 Spencers Brook	31 Toodyay A	32 Cannington A	33 Dwellingup A	34 Quindanning A	35 Neuchatel	36 Shenton Park A	37 Shenton Park B	38 Shenton Park C	39 Lake Claremont	40 Mt. Helena A	41 Daliak	42 Hollywood C
Seeds	Colour	B	pB	pB-B	B	pB	B	C-A	pB	pB	pB	pB-B	pB	pB-B	pB
	Size	++	++(+)	++	+++	++	++	+++	++	++	++	++	+	+	++
Seedlings	Growth habit	MP	MN	MN	MP	LN	LN	LE	LP	MP	MP	MP	SN	SE	LP
	Cotyledon flecks	+	—	—	+	—	—	—	(+)	(—)	(+)	—	—	—	—
	Hypocotyl pigmentation	+++(+)	++++	++++	+++	+(+)	++	+	++	++	++	++	+++	++	++
	Unifoliate crescent	(+)	++	(+)	(—)	++(+)	+	—	—	(+)	(—)	+	—	—	+++
	Unifoliate upper surface hairs	++	++	++(+)[a]	++(+)	++	++	+(+)[a]	++	++	++	+(+)	++	++	++
Trifoliate leaves	Colour: depth of green	++	+++	+++	++			+	++	++(+)	++	++	+	++	++
	Size	++	+	++	+(+)	+(+)	++	+++	+	+	+	++	++	+	++
	Leaflet shape	212	112	221	213	213	212	112	212	212	212	331	313	212	212
	Crescent markings	C3(A1)	C3A1-2	C3(A1)	C3	C3A2	C3-4(A2)	(A1)	—	C2(A1)	(C2A1)	C2A1	—	(C1)	C2A2
	Red flecking	+	—	+	+(+)	+	+	—	++	+(+)	+(+)	+	—	+	—
	Flushing	+	++	++	++	+	+	++	—	+	—	+	—	—	(+)
	Colour of flushing	bP	P	bP	bP	P	pB	B	—	pB	—	bP	—	—	pB
	Pattern of flushing	M	F	M	M	M	M	(B)MF	—	MF	—	M	—	—	(M)F
	Upper surface hairs	+	—	+[a]	+	+(+)[a]	—	—	( )	(—)	(—)	+[a]	+	++[a]	—
Petioles	Length	++	+(+)	++	+	++	++(+)	++	+(+)	++	+(+)	++	+	+	+
	Thickness	+(+)	++	++	++	++	++	+++	+(+)	+	+(+)	++	++	+	++
	Hairs	+(+)	+	+[a]	+(+)	+	+	—	—	—	—	+	+(+)	+	+
Stipules	Pigmentation	++(+)	++	+(+)	++(+)	(+)	(—)	++	+	+	+	+	++	+++	++(+)
Stems	Thickness	++(+)	++	+++	+++	++	++(+)	++	+	+	+	++	+++	+	++
	Internode length	++	++	+++	++(+)	++	+++	+++(+)	++(+)	+++	++(+)	++(+)	+(+)	+(+)	+++
	Hairs	++(+)	++	+(+)[a]	++	++	++(+)	—	(—)	(—)	(—)	++	+++[a]	++	++
	Pigmentation	++	++++	++++	++	+++	++	++	++	++	++	++	+++	+++	++
	Colour of pigmentation	bP	bP	P	bPi	bP	pB	bP	piB	bPi	piB	bPi	bP	bPi	pB
Flowers	Number of florets/inflorescence	4	4	4	4	4	4		4	4	4	4	3-4	4	4
	Pigmentation of standard	+	++(+)	++	++	+	++	++	+(+)	++	++	+	++	+	+
	Pigmentation of calyx	(++)	(+)	+++	++++	+++(+)	+++	(++)	+++	+	+	+(+)	+++	++++++	—
	Colour of calyx pigmentation	pale Pi	bPi	pPi	pR	P	pR	pale pB	pR	bPi		bPi	pR	deep R	—
Peduncles	Length	++	+++	++(+)	+	++	++(+)	++++	++(+)	++(+)	++(+)	++	+	+(+)	+++
	Thickness	++	++	++	++(+)	++	+++	++	+	+	+	+	+++	+(+)	++
	Hairs	+++	++[a]	++[a]	++(+)	++[a]	++(+)	(—)	—	—	—	++	+++[a]	++	+++
Burrs	Coarseness	++		++	++			+	+	+		++	++	+	++
	Strength of burial	++	+++	+++	++++	+++	++(+)	++	++	+(+)	++	++	++	+++	++
Seed physiology	Rate of seed development	++	+++	++	++(+)			++	++	+	++	+	++	++(+)	+
	Hard-seededness	++	++++	+++	+++	++++	+++++	++(+)	++++	+++	++++	+++++	+++	++++	++++
	Physiological dormancy	+++						+++	+++(+)	+++	+++(+)	++	+++(+)	+++	
Isoflavones (leaves)	Av. Formononetin, % of d.m.	0.18	0.03	0.80	1.30	0.40	0.70	1.40	0.03	0.10	0.05	0.12	0.04	0.25	1.20
	Av. Genistein, % of d.m.	0.80	0.60	1.20	1.40	0.25	0.80	1.40	1.00	1.30	1.00	1.20	1.50	0.30	0.70
	Av. Biochanin A, % of d.m.	1.00	1.00	0.15	0.50	0.08	0.80	0.25	0.15	0.35	0.15	0.20	1.00	0.25	0.70
Disease	Resistance to Kabatiella	+	+	+	+	+		+	+	+		+	++	++++	+

		43 Darkan C	44 Rocky Gully	45 Dwellingup B	46 Mogumber A	47 Boyup A	48 Northam D	49 Nedlands	50 Chidlows A	51 Dalkeith	52 Williams D	53 Collie A	54 Darlington	55 Toodyay B	56 Woorooloo
Seeds	Colour	pB	B	B	B	PB	B	B	pB	pB	B	B	pB	B	B
	Size	++	++	++	+++	++	++	+	+	+++	++	+	+	+(+)	+
Seedlings	Growth habit		MN	MN	LP	LE	MP	SN	SE	MP	MN	SN	SN	SP	SN
	Cotyledon flecks	—	—	—	—	—	—	—	—	(—)	—	(+)	(—)	—	—
	Hypocotyl pigmentation	+++	+++	+	+	++	++	++	++(+)	++	+++	++(+)	++(+)	++	+(+)
	Unifoliate crescent	(+)	++(+)	+(+)	(+)	(+)	—	++	+(+)	+	++(+)	—	+	+	—
	Unifoliate upper surface hairs	++	++(+)	+(+)	++	+++	+++aa	++	+++	++	++(+)a	++a	++	++	+(+)a
Trifoliate leaves	Colour: depth of green	+++	+++	++	++	+++	+++	++	++	+++		+++	+++	+++	
	Size	+	+(+)	++	+++	++	+	+	++	++	+(+)	+	+(+)	++	++
	Leaflet shape	221	221	213	231	231	211	212	222	222	221	111	112	212	212
	Crescent markings	C2	C3A3	C3A1	C3(A1)	C2(A1)	C2	C2A2	C2A1	C2A1	C3A3	C3-4	C2A2	C2A1	C2
	Red flecking	+	+	—	++	(—)	+++	—	—	(+)	(+)	+	(+)	(+)	—
	Flushing	++	++(+)	+	++	—	++	+++	—	—	++	+(+)	++	—	+
	Colour of flushing	bP	P	P	pB	—	bP	bP	—	—	pB	bP	bP	—	bP
	Pattern of flushing	M	F	M	M	—	M	(M)F	—	—	F	M	F	—	B
	Upper surface hairs	++	+(+)	—	(—)	—	+++aa	++a	+++a	++a	+a	+++a	+a	(—)	+a
Petioles	Length	+(+)	++	++	++(+)	++	+(+)	+	++	+(+)	+(+)	+	+(+)	++	++
	Thickness	+	++	+(+)	+++	++(+)	+	+	++	+(+)	+(+)	+	+(+)	+	++
	Hairs	++	+(+)	+	++	++	++a	+	++a	+a	(+)	(+)	+	—	(+)
Stipules	Pigmentation	++	+	(—)	++	++	+	+	+(+)	+	+	++	+	++	+(+)
Stems	Thickness	+	+++	+	++(+)	+++	++	++	++(+)	++(+)	++	+	++	+	++
	Internode length	++	+++	++	++(+)	+	++	++(+)	++	+++	+++(+)	+++	++	+++	++
	Hairs	++	++	+++	+++	++++	++a	+(+)	+++	++(+)a	++	+	++	—	+++
	Pigmentation	+	+++	++(+)	+	++++	+(+)	++(+)	++(+)	++(+)	++++	++	++(+)	++	++
	Colour of pigmentation	pB	pB	bPi	pB	P	bP	bP	bP	bP	bPi	pB	bP	pB	bP
Flowers	Number of florets/inflorescence	4-5	4	4	4-5	4	4	4	4	4	4	3	4-5	4	4
	Pigmentation of standard	++	++	+(+)	+(+)	++	+	+	+	+	+(+)	++	++	++	+(+)
	Pigmentation of calyx	+++	—	++++	+++	(+)	+++(+)	—	(—)	(+)	—	++++	++	+	—
	Colour of calyx pigmentation	pR	—	pR	pR	rPi	rPi	—	—	bPi	—	pR	pPi	pale P	—
Peduncles	Length	+++	+++	++	++(+)	+	++	++(+)	++(+)	++	+++	+++	+++	+++	+++
	Thickness	+	+++	+	++(+)	++++	++	+	++	+++	++	+	++	+	+
	Hairs	++	++	+++a	++++	++++	++a	++(+)a	+++aa	++(+)a	++	(+)a	++	(+)	++a
Burrs	Coarseness	++	++				++	+				++	+	+	
	Strength of burial	++	++++	+	+(+)	++(+)	++(+)	+(+)	++	+++	+++	+	++	+	+
Seed physiology	Rate of seed development		++		+					++			++	+	
	Hard-seededness	+++	++++	++(+)	+++	+++	++++	++++	+++++	+++++	+++	++++	+++++	++++	+++
	Physiological dormancy		++			++	+++			++(+)		+++++	++++	++++	
Isoflavones (leaves)	Av. Formononetin, % of d.m.	1.30	1.10	0.80	0.50	0.05	1.40	0.40	0.25	0.05	0.80	0.20	0.10	0.04	0.35
	Av. Genistein, % of d.m.	1.00	1.10	0.80	0.90	1.20	0.90	1.20	1.30	0.70	1.10	1.00	0.90	0.90	0.80
	Av. Biochanin A, % of d.m.	0.50	0.50	0.60	0.20	1.00	1.00	0.25	0.25	0.05	0.80	0.30	0.20	0.10	0.60
Disease	Resistance to Kabatiella	+	+			+	+	+	+(+)	+		+	+	+	

		57 Northam G	58 Blackwood	59 New Norcia A	60 New Norcia B	61 Kojonup	62 Chidlows B	63 Collie B	64 Yarloop	65 Nedlands B	66 Cannington B	67 Williams E	68 Clackline	69 Seaton Park	70 Quindanning B
Seeds	Colour	B	pB	B	pB	pB	B	B	C-A	B	B	B	pB	B	B
	Size	++	++	+++	++	++	+++	+	+++	++	+++	+(+)	++	++	++
Seedlings	Growth habit	ME	LE	MN	MP	LP	LP	LN	LE	MN	MN	MN	MP	LP	LP
	Cotyledon flecks	—	—	(+)	+	—	(+)	—	—	—	—	—	+	—	—
	Hypocotyl pigmentation	+++	+	++	+++	++(+)	++	++	+	++++	++(+)	+	+++	+	++
	Unifoliate crescent	—	—	—	—	++	+	++	—	—	++	--	—	+++	++(+)
	Unifoliate upper surface hairs	++[a]	++(+)	++(+)	++[a]	++[a]	++	++[a]	+(+)[a]	++	++[a]	+(+)[a]	+++[a]	++[a]	++[a]
Trifoliate leaves	Colour: depth of green	++(+)	+	++		++++		++	+	+++	++++		+++	+++	
	Size	++	++	++	++	++	++	++	+++	+++	+++	++(+)	++	+++	++(+)
	Leaflet shape	212	231	222	212	212	112	223	112	221	212	212	223	213	122
	Crescent markings	C2	C1-2	C2-3	C2A1	C2A2	C2A2	C3A1	A1	C3(A1)	C2A3	—	C2A2	C3A2	C3A2-3
	Red flecking	—	+	+++	+++	—	(+)	+(+)	--	—	+	—	+	—	—
	Flushing	—	+	+	+(+)	(+)	—	+(+)	++	+++	+++	—	+	—	(+)
	Colour of flushing	—	B	bP	bP	pB	—	bP	B	bP	bP	—	pB	—	pB
	Pattern of flushing	—	M	B	M	MF	—	F	(B)MF	MF	(M)F	—	MF	—	MF
	Upper surface hairs	++	++	+[a]	—	(+)[a]	—	—	—	(—)	(+)	(—)	+(+)	(—)	(+)[a]
Petioles	Length	++	++	+(+)	+(+)	++	+(+)	++(+)	+++	++	++	+(+)	++	++(+)	++
	Thickness	++	++	++	+(+)	++	++(+)	+++	+++	++	++	++	++	+++	++(+)
	Hairs	+	+++	+(+)	(+)[a]	+	+	—	—	++	++	(+)	++	+	+(+)
Stipules	Pigmentation	++(+)	(++)	+	++(+)	++	++	++(+)	+++	++(+)	++	+	++(+)	(+)	++
Stems	Thickness	++	++	++	+(+)	++(+)	++(+)	++	++	+++	+++	+(+)	++	+++	++(+)
	Internode length	+++	++++	+++	+++	++++	+++	+++	+++	++(+)	+++	++(+)	++	+++	++++
	Hairs	++	+++	++(+)	++[a]	++(+)	++(+)	—	—	+++	++(+)	++	+++	+++	++
	Pigmentation	++(+)	+	++	+(+)	++	+(+)	+(+)	++	+++	++	+	++	+	++
	Colour of pigmentation	pB	bP	pB	pB	pB	pB	bPi	bP	bP	bP	piB	pB	pB	pB
Flowers	Number of florets/inflorescence	4	4	4	4-5	4-5	4	4	3(-4)	4	4	4	5	4-5	4(-5)
	Pigmentation of standard	++	++	++(+)	+(+)	++	++	++	+(+)	+++	++	+(+)	+	++	+(+)
	Pigmentation of calyx	+++	+++	+(+)	+++(+)	—	(—)	(—)	(++)	++	—	++++(+)	+(+)	—	—
	Colour of calyx pigmentation	pR	pR	rPi	pR	—	—	—	pale pB	pale P	—	pR	light bP	—	—
Peduncles	Length	+++	++	++(+)	++	+++	+++(+)	++++	++++	++	+++	+(+)	+++	++	+++
	Thickness	++	+	+	++	++	+++	++	++(+)	++(+)	+	+(+)	+++	++	++
	Hairs	+++[a]	++++	+++	++[a]	++[a]	+++	(+)[a]	(—)	+++	++	++[aa]	+++	+++	++[a]
Burrs	Coarseness	++	++			++++		++	+		+++		++		
	Strength of burial	++	+	+	++	++	+++	+	++	+++	++	++(+)	++	+++	++
Seed physiology	Rate of seed development		+	+				+(+)	++				++	++	
	Hard-seededness	++++	+	++++	++(+)	+++	++	+++++	++(+)	+++	+++(+)	++	++++	+++	+++
	Pysiological dormancy	++++				+++		++	+++		+		+++++	+++	
Isoflavones	Av. Formononetin, % of d.m.	0.80	0.08	0.70	1.00	0.70	0.60	0.10	1.40	0.05	0.90	0.15	0.40	0.12	0.60
(leaves)	Av. Genistein, % of d.m.	0.80	0.60	0.50	1.50	1.00	1.00	1.10	1.40	0.40	1.20	0.60	0.40	0.70	0.70
	Av. Biochanin A, % of d.m.	0.20	1.50	0.60	0.50	0.80	0.60	0.20	0.25	1.30	1.20	1.00	0.50	1.40	1.00
Disease	Resistance to Kabatiella	+	+			+(+)		+	+		++	+++	++	+	

		71 Gingin	72 Mahogany Creek	73 Dinninup C	74 Mogumber B	75 Pinjarra B	76 Mundaring	77 Wembley	78 Graylands	79 Belmont	80 Byford	81 Jarrahdale A	82 Pinjarra C	83 Bindoon	84 Dinninup
Seeds	Colour	B	B	pB-B	B	B	B	B	B	B	B	pB	B	B	B
	Size	++(+)	+(++)	++	++	+++	++	++	+++	+++	+++	++	++	+++	+
Seedlings	Growth habit	MP	LN	MN	MP	MN	MP	MN	MN	MP	MN	LE	MN	MN	MN
	Cotyledon flecks	—	++	—	—	+	(—)	(—)	+	+	—	—	—	—	—
	Hypocotyl pigmentation	+++	++(+)	++	++	+++(+)	++	+++(+)	+(+)	+++	+++	++	++	++	++
	Unifoliate crescent	+++	—	—	—	+	—	++	+	+	+	+(+)	(+)	+	(+)
	Unifoliate upper surface hairs	++[a]	++	++	++[aa]	++[a]	+[a]	++	++	++	++	+(+)	++	++	++[a]
Trifoliate leaves	Colour: depth of green	++++	++	++		+++	++	++	++	+++	+++	+(+)		+++	++
	Size	+++	++	++	++	+++	+(+)	+++	++	+++	+++	+++(+)	++(+)	++(+)	+++
	Leaflet shape	322	222	231	212	221	321	111	121	221	321	321	321	221	221
	Crescent markings	C3A3	C2A2	C2-3	C1-2A1	C2A2	C2-3	C2A2-3	C2A2	C2A1-2	C2-3A1	C2A1	C2A1	C2A1	C3-4(A1)
	Red flecking	—	+	+++	—	+	—	—	+	+	++	+++	++	+++	—
	Flushing	(+)	(+)	+	—	(—)	(+)	++	+	+	+++	++	++	+(+)	++
	Colour of flushing	bP	B	B	—	—	pB	pB	bP	pB	bP	pB	pB	pB	B
	Patterns of flushing	M	(M)F	M	—	—	M	MF	MF	MF	(M)F	F	F	MF	M(S)
	Upper surface hairs	+[a]	+	+(+)	+++[aa]	+[a]	(+)	—	++	+	+	+	+	+	—
Petioles	Length	+++	+++	++	++	++(+)	+(+)	++	++	++(+)	++	++	++	++	+++
	Thickness	+++	++	++	++	++(+)	+(+)	++	++	++	++	+++	++(+)	+++	+++
	Hairs	++	++	+	+	++	+	+(+)	++	++	++	+	+(+)	+	++
Stipules	Pigmentation	(—)	+++	+	+(+)	+(+)	++	+	+	+	++(+)	(+)	+++	++	+(+)
Stems	Thickness	++++	++	++	++	++	++	+++	+++	+++	+++	+++	+++	+++	+++
	Internode length	+++	+++	+++	++++	+++	++	+++(+)	+++	+++	+++	+++	+++	+++	+++(+)
	Hairs	+++	++	++	++(+)	+++	++	+++	++(+)	+++	++	+++	+++	++(+)	++(+)
	Pigmentation	+++	+(+)	+	++	+++	++	+++	++(+)	+++	++	++	+++	++++	++
	Colour of pigmentation	bP	pB	pB	piB	P	bP	P	bP	bP	pB	bPi	P	bP	bP
Flowers	Number of florets/inflorescence	(4—)5	4	4	4	4—5	4	4(—5)	4—5	4(—5)	4	4	4	4	4(—5)
	Pigmentation of standard	++	++	++	+	+(+)	+	++	++	+	++	+	++	++	++
	Pigmentation of calyx	(+)	+	+++	+++(+)	—	++	—	+	(+)	(+)	—	+	+	++
	Colour of calyx pigmentation	bPi	pale P	pR	pR	—	light pR	—	pale bPi	pale P	pale bP	—	piR	rPi	light P
Peduncles	Length	++++	+++	++	+++	++++	++	+++	+++	+++	++(+)	+++	+++	++	++
	Thickness	+++	+	+(+)	++	++	+	++(+)	++	++	++	+(+)	++(+)	++	++
	Hairs	+++	+++	++++	+++	++	++	+++	+++	+++	++	+++	+++	+++	+++(+)
Burrs	Coarseness	+++	+++	++		+++	+++		++	+++	+++				++
	Strength of burial	+++	+(+)	+(+)	+++	++	+++	++	+++	+++	++++	++	++	+++	+++
Seed physiology	Rate of seed development	++	+						++						+++
	Hard-seededness	+++	+++	+++	+++	+(+)	++	+++	++++	++++	+++	+(+)	+++	+++	++++
	Physiological dormancy	+++	++	+++	++	++		+++(+)	++(+)						++++
Isoflavones (leaves)	Av. Formononetin, % of d.m.	0.40	0.70	0.10	0.15	1.20	0.40	0.10	0.40	0.50	1.10	0.30	1.20	1.10	1.60
	Av. Genistein, % of d.m.	0.70	1.30	0.35	1.10	1.20	1.60	1.00	0.60	0.70	0.90	0.60	1.00	0.90	1.00
	Av. Biochanin A, % of d.m.	1.20	1.30	1.40	0.10	0.60	1.40	1.20	1.10	0.70	0.40	1.00	0.70	0.60	1.20
Disease	Resistance to Kabatiella	+	+	+(+)	+(+)	+	+		+(+)	+(+)	+	+			+

		85 South Perth	86 Guildford D	87 Gidgegannup	88 Mt. Helena B	89 Ravenswood	90 Marradong	91 Ludlow	92 Collie C	93 Midland B	94 Walebing	95 Lake Leschenault	96 Helena Vale	97 Guildford E	98 Mayanup
Seeds	Colour	B	pB-B	B	pB-B	B	B	B	pB	pB-B	pB	B	pB-B	B	B
	Size	+	+	+++	++	+	+++	++	++	+	+(+)	++	++	+	++
Seedlings	Growth habit	MN	MN	MP	MP	MN	MN	MP	MP	MP	SP	ME	LP	MN	MN
	Cotyledon flecks	—	—	(—)	—	—	—	—	+	—	—	—	—	—	—
	Hypocotyl pigmentation	++	++	++(+)	++(+)	++	+	++	++(+)	+++	++	+++	+++	+++	++
	Unifoliate crescent	(+)	—	+++	++	(+)	++	—	(+)	(+)	+	+	—	+	+(+)
	Unifoliate upper surface hairs	++[a]	++	++[a]	++(+)[a]	++	++	++	++(+)[a]	+(+)	++[a]	++	++[a]	++	++
Trifoliate leaves	Colour: depth of green	+(+)	+++	++++	++(+)	++	+++	++	++	+(+)	++	++	++	++(+)	
	Size	++	++	++(+)	++	+++(+)	+++	++	+++	++(+)	+(+)	+(+)	++	+++	+++
	Leaflet shape	222	212	221	112	332	212	222	232	113	223	312	212	321	321
	Crescent markings	C3-4(A1)	(C1)	C3A3	C3A1	B3A1	C3A2	C1-2A1	C2A1	C3(A1)	C2A1	C2A1	C3	C2A1	C2-3A1
	Red flecking	—	+++	+	—	+++	+++	+	+	+++	++	+++	(+)	+	++
	Flushing	++	—	(—)	+	+	++	+	+	+	+	+(+)	++	+	+(+)
	Colour of flushing	B	—	—	pB	bP	bP	bP	pB	pB	pB	pB	B	pB	pB
	Pattern of flushing	M(S)	—	—	MF	MF	MF	M	M(F)	M	F	F	M	F	F
	Upper surface hairs	—	++	+	+(+)[a]	++	—	—	+(+)[a]	—	—	+	++	+	+
Petioles	Length	++	++	++	+++	++	+++	++	+(+)	++	++	++	++(+)	++	++
	Thickness	++(+)	++	++	+++	+++	+++	++	+(+)	++	++	++	++(+)	+++	+++
	Hairs	++	+(+)	++	+	+(+)	++	+	(+)	(+)	(—)	+	++	+	+(+)
Stipules	Pigmentation	+	+++	+	+++	+++	+	++(+)	++	++	+(+)	+++	++	++	+(+)
Stems	Thickness	+++	++	++	++++	++	+++	++	++	++	+	++	++	+++	+++
	Internode length	+++	++(+)	++	+++	+++	+++	++	++(+)	++(+)	++	+++	++++	+++	++(+)
	Hairs	+++	++	+++	++	+++	+++	—	—	+	++	+++	++	++	+++
	Pigmentation	++	++	++	+++	+++	++	++	++	+(+)	++	+++	++	++(+)	++
	Colour of pigmentation	bP	pB	pB	pB	P	bP	bP	bPi	pB	bPi	pB	pB	pB	piB
Flowers	Number of florets/inflorescence	4(-5)		4	4-5	4	4	4-5	4-5	5	4	4	4(-5)	4	4
	Pigmentation of standard	++	++	++	+	+(+)	++	+	+(+)	++	++	++	+	++	++
	Pigmentation of calyx	++	++++	—	++	(—)	—	+++(+)	+++	++(+)	(+)	+	+++	(+)	(+)
	Colour of calyx pigmentation	light P	deep R	—	pPi	—	—	pR	pPi	light P	rP	rP	deep pR	bPi	rPi
Peduncles	Length	+++	++	++	+++	+++	++	++	+++	+++	++	+++	++++	++	+++
	Thickness	++	++	++	++++	++	+	+	+	++	+	+	++	++	+(+)
	Hairs	+++(+)[a]	+++	+++	++	+++	+++	++[a]	+(+)[a]	(+)	++	+++	++	+++	++++
Burrs	Coarseness	++	++	+++	+++				++	+++			++	++	
	Strength of burial	++(+)	+++	+	+++	++	+(+)	++	+	++	++	+(+)	++	+++	++
Seed physiology	Rate of seed development	+++								+++	+++		+		
	Hard-seededness	+++(+)	+++	++	++(+)	+++	+++	+++	++++	+++++	+++(+)	+++	++	+++	++
	Pysiological dormancy				+		++++	+++	+++	++++	+++		+		
Insoflavones (leaves)	Av. formononetin, % of d.m.	1.60	1.00	1.00	0.80	0.80	0.25	0.20	0.25	0.04	0.30	0.70	1.50	1.20	0.80
	Av. Genistein, % of d.m.	0.60	0.80	0.70	0.60	0.80	1.00	1.40	1.30	1.60	1.10	0.50	0.80	1.20	0.60
	Av. Biochanin A, % of d.m.	0.60	0.60	0.60	0.50	0.80	0.80	0.30	0.35	0.60	0.25	1.00	0.60	0.70	0.90
Diseases	Resistance to Kabaticlla	+	++++	++	+		+++	+	+	+(+)			+	++	

		99 Dingup	100 Koongamia	101 Albany	102 Clare	103 Bassendean H	104 Boyup B	105 Jarrahdale B	106 Parkerville A	107 Bacchus Marsh	108 Toodyay C	109 Toodyay D	110 Toodyay E	111 Woogenellup	112 Mt. Barker
Seeds	Colour	B	B	B	pB	pB	B	B	pB	B	B	B	B	B	pB
	Size	++	+++	+(+)	++	++	+++	++	++	++	++	++	++	+++	++
Seedlings	Growth habit	LN	MN	SP	LN	ME	SP	SP	MN	MN	SP	SP	MN	SP	ME
	Cotyledon flecks	—	+	+	—	—	+	—	—	—	—	—	—	—	—
	Hypocotyl pigmentation	+++	++(+)	++	++	++	++++	++	++	++	++	++	+	+(+)	+(+)
	Unifoliate crescent	+	+	(+)	++	—	+	+(+)	—	—	++	+++	(+)	—	—
	Unifoliate upper surface hairs	+	++	++	++[a]	++	+++[a]	++[a]	++	++(+)	++	++	++	++[a]	++(+)
Trifoliate leaves	Colour: depth of green		+++	++	++(+)	+(+)	++++	+(+)	++	+	+++			+(+)	+(+)
	Size	+++	+++	++	++++	+++	+++	++(+)	+++	+++	+++	++(+)	+++(+)	++++	+++
	Leaflet shape	211	312	112	222	322	113	231	322	222	321	222	221	313	322
	Crescent markings	C2A1	C2-3A2	C2A1-2	C3A2-3	C2	C4	C2(A1)	C2-3	C2-B2	C2A2	C2A2-3	C2A2	A1-B1	C2-3
	Red flecking	+++	+	+++	—	++	(+)	(+)	++	+++	(—)	+++	+++	+	+++
	Flushing	++(+)	+++	+	+++	+	++(+)	(+)	+	+	(—)	++(+)	(—)	—	+
	Colour of flushing	bP	pB	pB	pB	B	P	pB	B	B	—	P	—	—	pB
	Pattern of flushing	F	MF	MF	F	M	M	MF	M	MF	—	(M)F	—	—	M
	Upper surface hairs	+	++[a]	+++[a]	—	+	+[a]	++[a]	+(+)	+	+[a]	(+)	+	(+)	+
Petioles	Length	++	+++	++	+++(+)	+++	++	+(+)	++	+++	++	++	++	+++(+)	+++
	Thickness	+++	+++	++	+++	+++	+++	+(+)	+++	+++	++(+)	++	+++	+++	+++
	Hairs	++	++	++	+	++	+	+	++	++	++	++	++	+	++(+)
Stipules	Pigmentation	+++	+++	++	++	+++	++	(—)	+++	—	+	++	++	+++	+++
Stems	Thickness	+++	+++	++	++	++	+++	+	+++	+++	++	++	++	+++	++(+)
	Internode length	+++	+++	+	+++	+++	++++	+(+)	+++	++++	++(+)	++(+)	+++	+++	+++
	Hairs	+++	++	+++	(—)	++	+++	—	++	++(+)	+++	+++	+++	—	+++(+)
	Pigmentation	+++	+++	++	+++	+	++	+	+	++	++	++	++	+	+
	Colour of pigmentation	bP	pB	B	pB	pB	bP	þB	pB	bPi	bP	bP	P	pB	pB
Flowers	Number of florets/inflorescence	4	4	4-5	4-5	4	4-5	4(-5)	4	4(-5)	3-4	(3-)4	4	4	4
	Pigmentation of standard	++	++	+	+	+	+(+)	+	+	+	+	+(+)	+	+	+
	Pigmentation of calyx	(+)	+	—	—	+++(+)	+++(+)	—	+++(+)	—	—	—	—	—	+++(+)
	Colour of calyx pigmentation	rPi	bPi	—	—	pR	deep pR	—	pR	—	—	—	—	—	pR
Peduncles	Length	+++(+)	+++	+	++++	++	+++	++	++	+++	+	++	+++	+++	++
	Thickness	+(+)	+++	++	+	+	+++	+	+	+	+	++	++	+	+
	Hairs	++++	++(+)	++[a]	+	++++	+++	++[a]	++++	+++	+++	++++	++++	++	++++
Burrs	Coarseness		+++		++	++			++	+				++	++
	Strength of burial	+	+++	+++	+	+	+++	+(+)	+	+	++	+	++	+	+
Seed physiology	Rate of seed development		+		+	++			++	+(+)	++			+	++
	Hard-seededness	+++	++	+(+)	++	+	++(+)	++++	+	+	+	+++	++	++	+
	Physiological dormancy				+	+++			++(+)	+++	+++			+	+++
Isoflavones (leaves)	Av. Formononetin, % of d.m.	0.60	1.40	0.05	0.10	0.04	1.00	1.00	0.04	0.10	0.10	0.40	0.05	0.25	0.04
	Av. Genistein, % of d.m.	1.00	0.70	0.80	1.80	0.40	0.90	0.80	0.30	0.40	1.00	0.70	0.50	1.80	0.30
	Av. Biochanin A, % of d.m.	0.90	0.40	0.70	0.15	1.40	0.60	0.15	1.40	1.60	0.70	0.70	1.20	0.70	1.40
Disease	Resistance to Kabatiella		+	++	++(+)	++	+++		++	+	+++			+	++

		113 Nangeela	114 Wenjup	115 Tallarook
Seeds	Colour	pB	B	B
	Size	++	++	+
Seedlings	Growth habit	MP	LN	SP
	Cotyledon flecks	—	—	—
	Hypocotyl pigmentation	+	++	+
	Unifoliate crescent	(+)	—	+
	Unifoliate upper surface hairs	++(+)	++	++
Trifoliate leaves	Colour: depth of green	++	++	++
	Size	++++	++++	+++
	Leaflet shape	222	122	212
	Crescent markings	C3A2	—	C1A1
	Red flecking	+++	+++	++
	Flushing	—	—	++
	Colour of flushing	—	—	pB
	Pattern of flushing	—	—	F
	Upper surface hairs	+	—	+
Petioles	Length	+++	++++	++(+)
	Thickness	+++	++++	+++(+)
	Hairs	++	+	+++
Stipules	Pigmentation	++	+	—
Stems	Thickness	++	++	++
	Internode length	++	+++	++
	Hairs	+++	(—)	++++
	Pigmentation	++	+++	++
	Colour of pigmentation	P	pB	bP
Flowers	Number of florets/inflorescence	4	4	4
	Pigmentation of standard	+	+	+
	Pigmentation of calyx	—	—	—
	Colour of calyx pigmentaton	—	—	—
Peduncles	Length	++	++++	++
	Thickness	+(+)	+	+
	Hairs	++++	+	++++
Burrs	Coarseness			+++
	Strength of burial	+	+	+
Seed physiology	Rate of seed development		+	
	Hard-seededness	+	++	+
	Physiological dormancy	+++	++(+)	+++
Isoflavones (leaves)	Av. Formononetin, % of d.m.	0.15	0.20	1.30
	Av. Genistein, % of d.m.	0.30	1.80	0.80
	Av. Biochanin A, % of d.m.	1.80	0.40	1.00
Disease	Resistance to Kabatiella	+		+

light intensity, excessively severe defoliation, and senescence. Our figures are representative of reasonably healthy, well-nourished ungrazed plants, growing in field rows under normal winter-spring conditions in a mild environment (Perth), and sampled up to mid-flowering.

Burr burial has been established as being encouraged by defoliation (Rossiter 1961; Rossiter and Pack 1972; Walton 1975; Collins 1978). Opportunity for burial also depends on soil type and soil surface conditions, such as moisture status. Our observations are mainly for undefoliated rows with watering as needed.

From general comparisons with field swards we believe that the ratings, which are strictly relative, have a fair degree of general validity. However, we acknowledge that they must be taken with caution.

Some groupings among strains

Certain of the putative primary naturalized strains appeared to fall into groups which suggested closer-than-average genetic relationships. Assuming, by definition, that these strains were introduced into Western Australia in their present forms, it may be suspected that most strains within groups came from the same part of the species' natural range. Some may even have been members of particular hybrid swarms in their original environment, and have been introduced simultaneously. Provisional comments on origin are included here where the available evidence seems strong enough.

- The "Shenton Park A" group. Typical members are Shenton Park A, B and C, Toodyay B, Northam E, Collie B and C, and Ludlow. With a slightly wider definition, Collie A, Midland B and Walebing might be included. An obvious feature is a relative smoothness of the leaves and petioles and especially of the stems, giving a *yanninicum*-like appearance, although these strains undoubtedly belong to subspecies *subterraneum*. [In this bulletin we retain the convention of Katznelson and Morley (1965), which divides *Trifolium subterraneum* into the three subspecies *subterraneum, yanninicum* and *brachycalycinum*, rather than elevating all three to species status as suggested later by Katznelson (1974). Throughout the text and tables all strains are of subsp. *subterraneum* unless otherwise stated.]

  A second feature of the Shenton Park A group is a distinctive isoflavone pattern, with low to very low contents of formononetin, high genistein, and fairly low levels of biochanin A. Maturities of the Western Australian strains of the group range from early to early mid-season, and in general the plants are fine-textured. Burr burial is fair to poor. Hard-seededness and physiological dormancy range from medium to very high. We have noted that similar strains are reasonably common among those collected from medium to low altitudes in Portugal, western Spain and Sardinia, but are absent or very rare elsewhere. Taking historical probability into account as well (Gladstones and

Collins 1983), an Iberian origin for Western Australian members of the group seems likely.

- The "Late Dwalganup" group. Members typically have the Dwalganup pattern of leaf crescent markings (C2A1 or C3A1) and its substantial lack of calyx pigmentation, and are at least moderately hairy. Burr burial is usually strong and the level of hard-seededness fairly high. Formononetin contents are mostly moderate to high, and many members have the typical Dwalganup isoflavone pattern of high formononetin, high genistein, and only moderate biochanin A. Most strains of this group in Western Australia are of early mid-season to mid-season maturity. They are particularly common along the lower foothills of the Darling Range from Bindoon southwards, extending to the Bridgetown and Manjimup districts. The task of tracing origins and relationships is greatly complicated by the fact that many similar genotypes have undoubtedly originated from natural crosses between Dwalganup and Mt. Barker. We have examined large numbers of such genotypes which have been selected, by C.J.B. Sykes and B.J. Quinlivan, as impurities in rows of Western Australian commercial Dwalganup or Mt. Barker being grown for cultivar certification purposes. Nevertheless, the occurrence of some of the presently described "Late Dwalganup" types in pure form over significant areas, often in the absence of likely parents or apparently related hybrids, seems to indicate that at least a proportion are true primary naturalized strains. Examples are Graylands, Dwellingup A, Pinjarra C, Guildford E and possibly Dingup. Others retained in the collection, despite a lack of proven extensive distribution, are Belmont, Byford, Bindoon and Mayanup, chosen as being representative of the genetic range in the group and at least not obviously of recent hybrid origin.

  The "Late Dwalganup" type is common among collections from Greece. A Greek origin seems possible, but cannot yet be considered proved because similar plant types have been collected from other Mediterranean parts of the species' natural range. More detailed studies will be needed to settle this point.

  Certain strains with more prominent crescents (C2A2 - C3A3) appear to belong essentially to the Dwalganup-type group. They include Blackboy Hill, Rocky Gully (formerly called Dinninup B), Cannington B, Pinjarra B and Gidgegannup.

  Three strains retained in the collection are probably only Dwalganup variants, but were kept for their distinctive markings for possible use in breeding. These are Bridgetown A, Crawley, and Hollywood A. The highly distinctive Pink Flower may be no more than a Dwalganup variant, but this is less sure. Carnamah is probably an early-flowering natural mutant of Dwalganup.

  Other presumed simple variants are Northam A2 (from Northam A = cv. Northam), and Jolimont (from Daglish). Neuchatel (subsp. *yanninicum*) is almost certainly an early-flowering natural mutant of Yarloop. Shenton Park A, B and C form a closely related group, both in strain characteristics and in their sites of collection.

  South Perth is extremely similar to Dinninup, but in this case their allopatric distributions and the nature of the differences between them suggest that the two are indeed independent introductions, even if closely related. Circumstantial evidence suggests that Guildford D may have originated from a natural cross between South Perth and Daliak; alternatively it could be a direct mutant of Daliak, as suggested originally (Gladstones 1966). The markings of Williams C also suggest Daliak parentage.

  Four of the strains retained (Blackwood, Dinninup C, Bassendean H and Parkerville A), plus a number of those discarded, have typical Mt. Barker leaf and calyx markings and are almost certainly descended from cv. Mt. Barker. Blackwood, Bassendean H and Parkerville A resemble Mt. Barker in all respects other than in their earlier flowering, and could be simple early-flowering mutants.

  As Gladstones (1966) pointed out, the survival of such variants in localities where Mt. Barker is only marginally adapted, because of its late maturity, is one of the examples of current evolution towards better adaptation to Australian environments. Dinninup C has a higher hard seed content, indicating that it probably originated from a cross between Mt. Barker and an unknown other parent. Numerous such hybrids occur in old Mt. Barker/Dwalganup pasture mixtures.

Strains described in 1966—now deleted

Bassendean A, B, C, D, E, F and G were probably all members of a hybrid swarm between Mt. Barker and either Dwalganup or a similar strain (Gladstones 1966). None had any characteristics suggesting agronomic merit, so they were discarded from the collection. Bassendean H from the same site may have had the same origin, but seems more probably to have been a simple early-flowering mutant of Mt. Barker (as already described). As such, it holds sufficient genetic and agronomic interest to warrant retention.

York and Darkan B appeared to be merely minor variants of Dwalganup; no good reason existed for their retention.

Wagin was suspected to have been an early-flowering segregate from a natural cross between Mt. Barker and Dwalganup, having the less desirable characteristics of each. This now seems less certain, but unfortunately the strain has been lost from the collection.

Bridgetown B and Hollywood D had a Mt. Barker-like appearance, but Dwalganup-like isoflavones and intermediate maturity. They were probably natural hybrids between these two, with no apparent agronomic merits.

Greenmount B proved on re-examination to be identical with Nedlands.

Cannington C appeared to be a defective mutant of Cannington B.

Guildford A, B, C and F were collected at a site which was subsequently found to have been used earlier for testing some crossbred lines developed by J. A. Carpenter of the University of Western Australia (crosses 1984 and 1985 of Millington 1960a, p. 76). The highly interesting combination of characters in Guildford B and C stemmed from their origin from an inter-subspecies cross (subsp. *subterraneum* x subsp. *yanninicum*). In view of their origin it is of particular interest that, in our study, they all proved to have fully normal fertility. While deserving to be retained in the permanent genetic collection, the group can hardly be included in the present listing of naturalized strains.

Parkerville B and Hazelmere were classed as late-flowering members of the "Late Dwalganup" group and had no apparent merit. No evidence is available to tell whether they were recent crossbreds or primary naturalized strains. They were discarded in favour of other strains regarded as being more representative, or whose distributions are better defined.

Mulwala is a New South Wales strain which was included by Gladstones (1966) because of the report by Quinlivan (1957) that it had at one time been introduced commercially into the Boyup Brook district. However in the present work we have seen no evidence of its survival as a naturalized plant, nor have we heard of further commercial introductions in recent years.

Strain naturalization sites and modes of introduction.

The range of apparent primary naturalization sites so far documented is shown in figure 2, after Gladstones and Collins (1983). Figures 3 and 4, after Gladstones (1966), show in greater detail the distribution of subterranan clover in the Perth metropolitan area, and its association with low-lying habitats and alluvial soils. For further discussion of the association between naturalized subterranean clover and soil type, see Gladstones and Collins (1983).

As in the 1960/62 collections (Gladstones 1966), later collections of naturalized strains were mainly from in or around old-settled towns, or where stock may have grazed or congregated in the early years before subterranean clover was sown commercially. Few, if any, were found in districts settled after about 1900. The historical and other implications of the observed strain distributions have been discussed elsewhere (Gladstones 1966; Gladstones and Collins 1983).

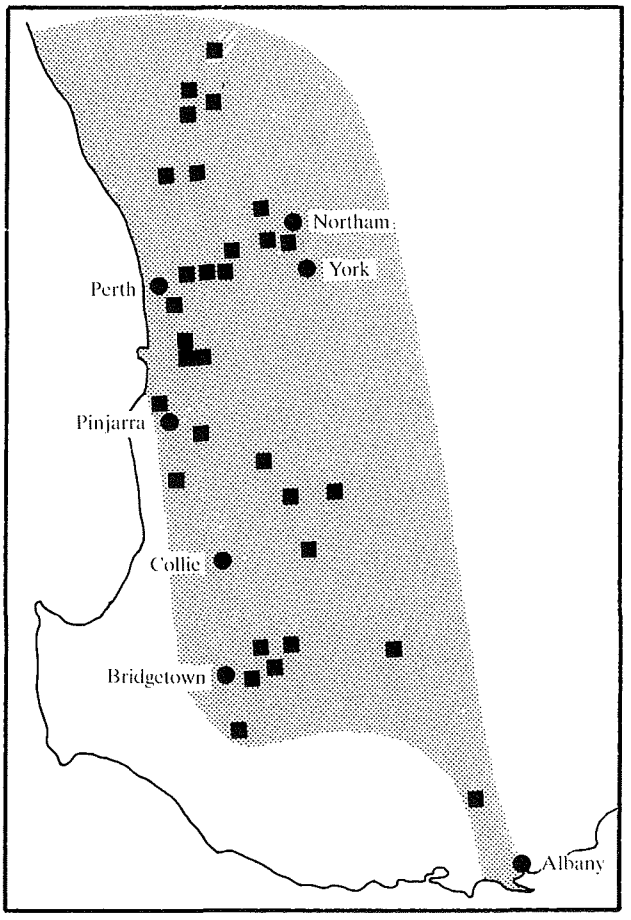
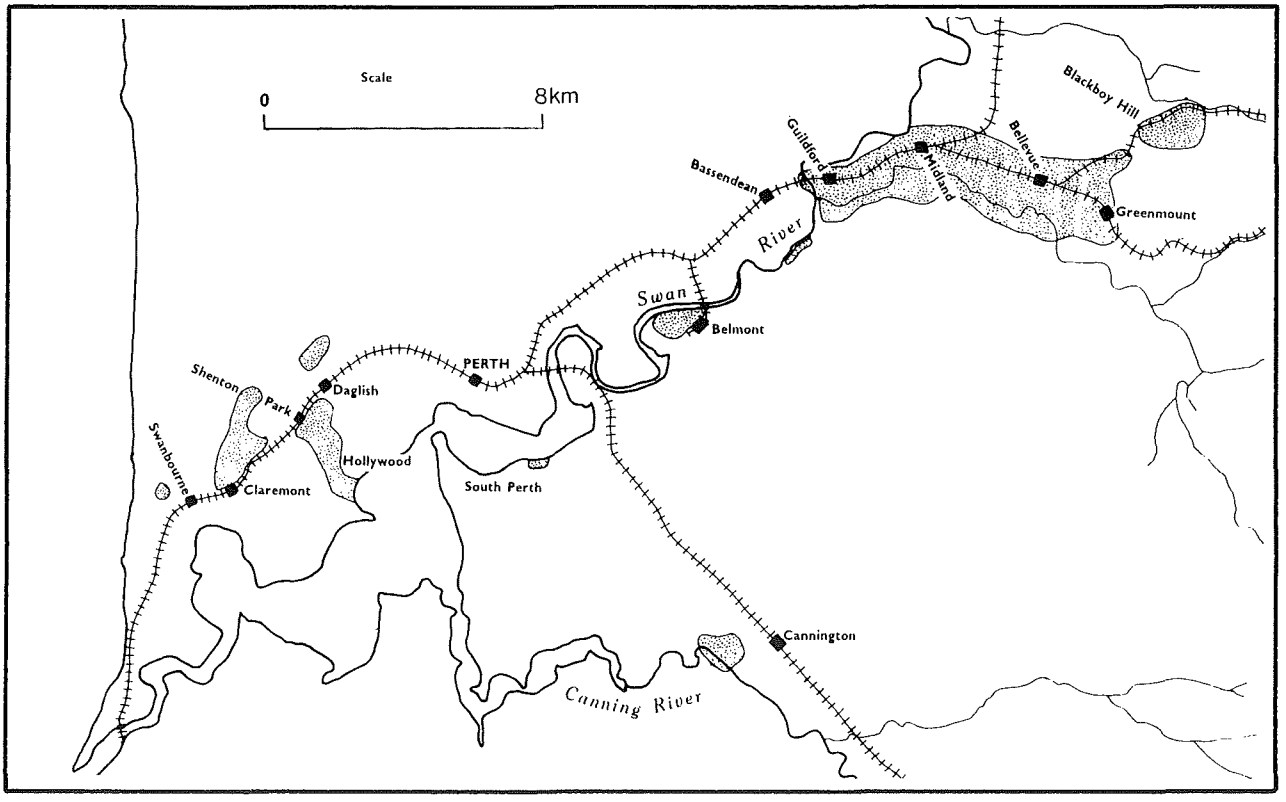


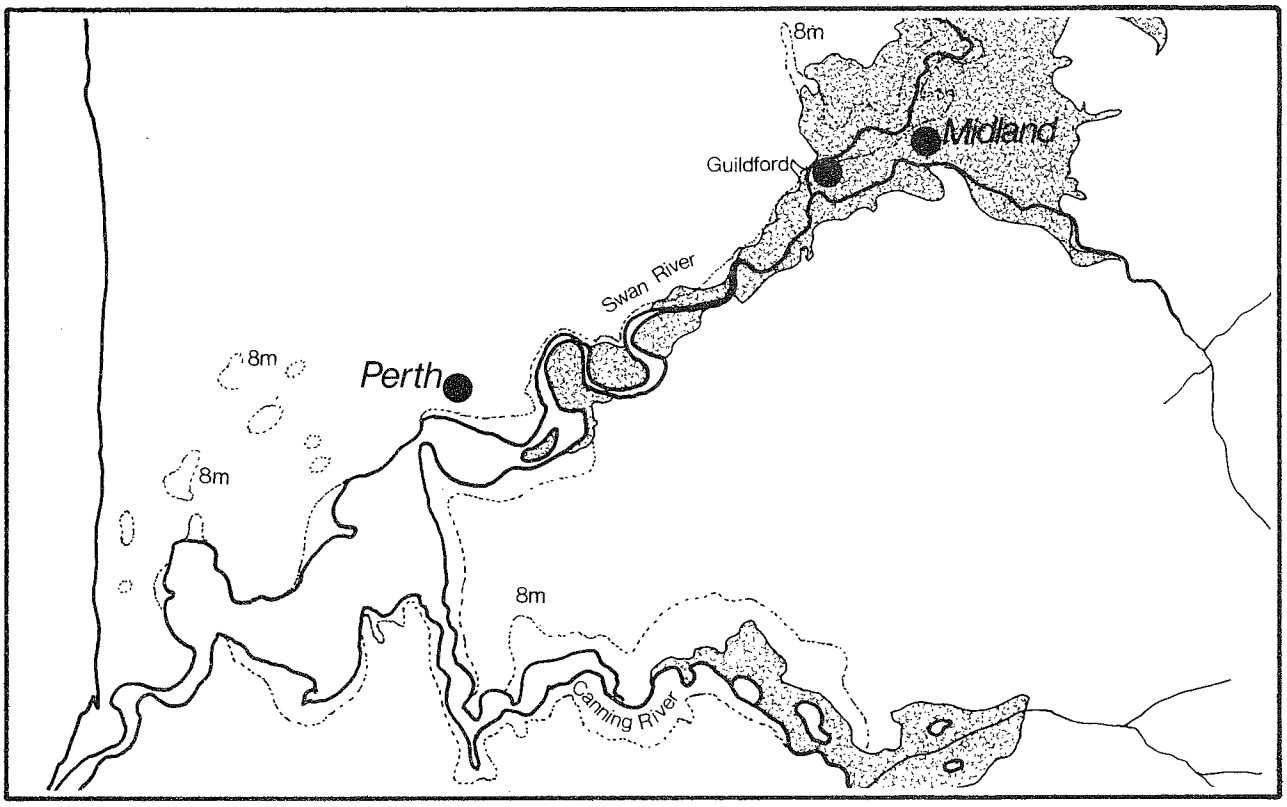
Figure 2—Recorded apparent primary sites of naturalization by subterranean clover strains in Western Australia. Shaded area indicates main area explored to date.

Figure 3—Map of the Perth metropolitan area. Shaded areas show where subterranean clover is naturalized.



Not all early-settled areas where subterranean clover may have become naturalized in south-western Australia have yet been searched, particularly near the south coast and along the west coast south of Perth (see figure 2); nor have the northern agricultural areas around Geraldton been thoroughly searched. Even in the main area explored, coverage has been incomplete. Nevertheless, it seems likely that most of the more common strains naturalized in these areas have by now been detected. This has been achieved by concentrating searches in and around the towns and at points such as railway sidings and showgrounds, whither seeds would have been carried by stock from the surrounding farms.

Figure 4—Map of the Perth metropolitan area showing alluvial soils (shaded) and the eight metre altitude contour.



Commentaries on individual strains

The strains are listed here and in table 1 in their approximate order of maturity as observed in rows at Perth. To a small extent the maturity rankings have been manipulated to keep groups of similar or related strains together for ready comparison.

Strains collected since 1959 are described first by the initials of the discoverer, then by the place and date of first collection. The initials J. G., indicate first discovery and collection by J. S. Gladstones; C. F., first discovery and collection by C. M. Francis, in some cases in association with A. C. Devitt and B. J. Quinlivan.

1. Carnamah. Selected by A. Forrester on his farm at Carnamah, Western Australia, in 1958. Morphological and agronomic characteristics are described by Rossiter and Millington (1961) and by Taylor and Rossiter (1967). It now seems certain—despite earlier views to the contrary—that Carnamah is a simple early-flowering natural mutant of Dwalganup.

2. Northam A. Now cv. Northam, syn. Northam First Early or Burlong Early of Adams 1934b; equivalent to the "earlier strain" of Adams 1932. First discovered in 1931 growing on the Northam Golf Course (Adams 1932): subsequently renamed Northam A by R. C. Rossiter (personal communication) in 1947. Grows fairly extensively on heavy soils around the Northam township, collected also from small patches at two widely separated sites in Nedlands. Before the discovery of Carnamah, it was the earliest-flowering strain known in Australia, although not necessarily the earliest maturing because of its rather slow rate of maturation (Walton 1966; Francis and Gladstones 1974). Northam gave promising results in the agronomic experiments of Taylor and Rossiter (1967) and Rossiter (1974), and later in grazing trials of N. R. McKeown (unpublished data) in eastern wheatbelt areas of Western Australia. It was released commercially in 1977. Important characteristics other than earliness are low formononetin content and high levels of both hard-seededness and physiological seed dormancy.

3. Northam A2. J. G., Northam 1962. Found as a small patch growing in association with Northam A and almost certainly a simple natural mutant of the latter, with which it appears identical in all respects other than in having a B2 rather than a B1 leaflet crescent marking. Together with Daglish, it is one of the parents of the cross-bred cultivar Nungarin, which inherits its broad leaflet crescent band.

4. Gingin Brook. J. G., Gingin 1962. Common within the Gingin townsite; collected also in Moora. An early-flowering, high-oestrogen strain, with distinctive, prominent leaf and calyx markings which fairly closely resemble those of Williams. Early growth is vigorous, but quite prostrate where plant density allows. Hard-seededness and physiological seed dormancy are moderately high, but burr burial appears rather weak for a strain of its early maturity. It has been used in breeding for its earliness and distinctive markings.

5. Daglish. J. G., Daglish 1962. At the time of collection it was common on deep sand along Millington Avenue, Daglish, extending nearby into Jolimont. The area is now largely built upon or grassed over and it has not been sighted elsewhere. Daglish has considerable agronomic merit because of its low oestrogen content, earliness, good burr burial, rapid seed development, high level of hard-seededness, and reasonable physiological seed dormancy. It was among the strains selected by Gladstones (1967) for seed increase and field trial, but suffered from the disability of a morphological resemblance to Dwalganup. Extensively used in cross-breeding, it is one of the parents, with Northam A2, of cv. Nungarin.

6. Jolimont. J. G., Jolimont 1969. Found growing in association with Daglish and probably a rare variant of it, differing only in having a narrower and more faint (C1A1) leaf crescent marking.

7. Williams. The date of discovery is not known, but Quinlivan (1957) recorded it as then being known on a number of farms around Williams, and it was already in the Western Australian CSIRO collection in 1940 (R. C. Rossiter, personal communication). Subsequent collecting has showed Williams to be very common in that district and to be well established in the Narrogin township, with smaller and probably more recently established patches close to the railway at many centres along the Great Southern Railway and westwards; also at Guildford, Gingin and

Toodyay. Williams is a vigorous, high-oestrogen strain, with strong distinctive leaf and calyx markings, triangular leaflets, high hard-seededness and physiological seed dormancy, and quite good burr burial.

8. Midland A. J. G., Midland 1962. Found only in a small patch at one site. Although resembling Dwalganup in many ways, the differences seem too great for it to have originated as a simple mutant. No putative other parent has been found in the vicinity. Midland A is very robust for its early maturity, with thick stems and petioles. Fully exposed stems develop a blackish colour. The leaflets are notably round, broad and overlapping, and have a very distinctive semi-circular B3A1 crescent band high on the leaflet, together with strong calyx pigmentation. Formononetin content is moderately high. Midland A has been used in the cross-breeding programme for its robustness and distinctive markings.

9. Swanbourne. J. G., Swanbourne 1960. Found over a moderate area in the north-east corner of Allen Park reserve, Swanbourne, but nowhere else. Although low in formononetin and reasonably hard-seeded, it has shown little agronomic promise in rows because of its consistenly weak, unhealthy-looking growth.

10. Dwalganup. Well known in the Bridgetown-Boyup Brook area by the 1920s, and thought to have been present there before 1890 (see Underwood and Gladstones 1979; Gladstones and Collins 1983, for further discussion). Extensive cultivation and secondary spread since commercial release in about 1930 have obscured Dwalganup's history as a purely naturalized plant; nevertheless observations during collecting suggested that Bridgetown-Boyup Brook may indeed have been its original area of establishment.

11. Crawley. Found by R. J. Pack, of the CSIRO, at Crawley in 1954 in an area that had previously been sown to Dwalganup. Almost certainly a simple mutant of Dwalganup, having a whitish coloration over the whole leaflet area below the crescent. Otherwise appears identical with Dwalganup.

12. Bridgetown A. J. G., Bridgetown 1962. Found growing in vacant land in the central township, associated with Dwalganup. Appears to be a simple mutant of Dwalganup, identical except that it completely lacks leaflet crescent markings or anthocyanin flushing.

13. Pink Flower. Discovered by A. B. Adams in 1929 as a cluster of identical plants in a paddock of Dwalganup at the Muresk Agricultural College; suggested to be a simple mutant of Dwalganup (Adams 1929b).

Plant characteristics are as for Dwalganup except that it has conspicuously pink flowers, combined with a complete lack of leaflet crescent markings, anthocyanin flushing, or, except very occasionally, red flecking. The leaflets tend to be broader than those of Dwalganup.

14. Geraldton. First discovered by A.J. Millington and G. L. Throssell at Moonyoonooka on the Geraldton-Mullewa road in 1950; released commercially in 1959. Described by Millington (1960b). Subsequent collections (Gladstones 1966) showed Geraldton to be common and clearly long established in much of the Perth metropolitan area and at Toodyay and Katanning, with smaller, but also apparently old-established, patches in several other country towns. It may well have first become established in or near Perth, with subsequent spread from there. Geraldton's agronomic characteristics have been dealt with elsewhere (Millington 1960b; Tennant 1965).

15. Darkan A. J. G., Darkan 1962. Fairly common around the Darkan railway yards, but not sighted elsewhere. A fine-growing, high-oestrogen strain, having reasonably high hard-seededness but no other obvious agronomic merits.

16. Blackboy Hill. J. G., Blackboy Hill 1961. Common around the old Blackboy Hill army camp site at Midland, with scattered other occurrences in Greenmount, Bellevue, Helena Vale, Guildford and West Swan. It is a robust, hairy strain, with conspicuous C2A2 crescent markings on dark green leaves. Its growth habit and isoflavone pattern resemble those of Dwalganup.

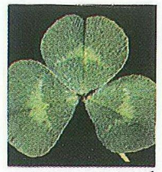
17. Gillingarra. J. G., Gillingarra 1967. Fairly common at the Gillingarra railway siding; not found elsewhere. A distinctive strain of very open, semi-erect but sprawling habit, and high oestrogen content. It has no discernable agronomic merit.

18. Northam E. J. G., Northam 1962. Collected or sighted at several points in the vicinity of St. John's Church, Northam, but nowhere else. It is highly distinctive among the Northam strains for its prominent crescent and anthocyanin flushing, combined with more or less smooth

Key:

Photos: Leaves of subterranean clover strains in Western Australia.

1. Carnamah
2. Northam A
3. Northam A_2
4. Gingin Brook
5. Daglish
7. Williams
8. Midland A
9. Swanbourne
10. Dwalganup
11. Crawley
14. Geraldton
15. Darkan A
16. Blackboy Hill
17. Gillingara
18. Northam E
19. Pinjarra
20. Mundijong
21. Williams B
24. Hollywood B
25. Greenmount A
26. Bellevue
27. Northam B
28. Northam C
29. Northam F
30. Spencers Brook
31. Toodyay A
32. Cannington A
33. Dwellingup A
34. Quindanning A
36. Shenton Park A
37. Shenton Park B
39. Lake Claremont
40. Mt. Helena A
41. Daliak
42. Hollywood C
43. Darkan C
44. Rocky Gully
45. Dwellingup B
46. Mogumber A
47. Boyup A
48. Northam D
49. Nedlands
51. Dalkeith
53. Collie A
54. Darlington
55. Toodyay B
56. Woorooloo
57. Northam G
59. New Norcia A
60. New Norcia B
61. Kojonup
62. Chidlows B
63. Collie B
64. Yarloop
65. Nedlands B
66. Cannington B
67. Williams E
68. Clackline
69. Seaton Park
70. Quindanning B
71. Gingin
72. Mahogany Creek
74. Mogumber B
75. Pinjarra B
76. Mundaring
78. Graylands
79. Belmont
80. Byford
81. Jarrahdale A
82. Pinjarra C
84. Dinninup
85. South Perth
87. Gidgegannup
88. Mt. Helena B
89. Ravenswood
90. Marradong
91. Ludlow
92. Collie C
93. Midland B
94. Walebing
95. Lake Leschenault
96. Helena Vale
97. Guildford E
98. Mayanup
99. Dingup
100. Koongamia
101. Albany
102. Clare
104. Boyup B
107. Bacchus Marsh
108. Toodyay C
110. Toodyay E.
111. Woogenellup
112. Mt. Barker
113. Nangeela
114. Wenijup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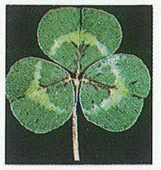
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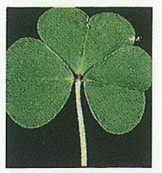
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petioles, stems and peduncles. Despite a reasonably low formononetin content, its straggly growth, weak burr burial, and lack of hard-seededness would appear to preclude direct agronomic usefulness.

19. Pinjarra A. J. G., Pinjarra 1962. Found growing fairly extensively around the Pinjarra railway yards, but not seen elsewhere. It has narrow, triangular leaves with no flecking and at most only a faint, narrow crescent band. The flowers are distinctively tinged pink at the tips and have deep red calyces. Pinjarra A is highly hard-seeded and has a very low formononetin content. Unlike nearly all other early-flowering strains, it has some tolerance of clover scorch. Otherwise it appears to be agronomically an undesirable type of plant, with thin straggly stems and peduncles, weak burr burial, low seed number per burr, and very slow seed development.

20. Mundijong. J. G., Mundijong 1962. Appeared fairly well established in the railway yards. A Dwalganup-type plant, with the typical Dwalganup isoflavone pattern but longer runners, more lanky growth, and some other consistent differences which include a slightly higher seed number per burr than in most Dwalganup-like strains. In the absence of other sightings the possibility of a Mt. Barker/ Dwalganup origin cannot be dismissed.

21. Williams B. C. F., Williams 1969. Collected in the railway yards. A robust, high-oestrogen strain, resembing Williams though clearly different. Burr burial is good, but it lacks the hard-seededness of Williams. Evidence as to its origin is lacking.

22. Williams C. C. F., Williams 1969. collected in the railway yards. Resembles Daliak in leaf and calyx markings and in isoflavone pattern, but the plants are darker green and more robust, with a Williams-like growth habit. Hard-seededness is only moderate. Could have originated from a Daliak/Williams natural cross.

23. Hollywood A. J. G., Hollywood 1962. Found growing as a small patch, almost certainly a natural mutant of Dwalganup. Has a distinctive, curiously compressed and distorted leaflet crescent marking; otherwise apparently identical with Dwalganup.

24. Hollywood B. J.G., Hollywood 1962. Present at several points in Kanimbla Street, Hollywood. A distinctive strain with only a faint, narrow crescent band on the leaflets and a complete lack of leaflet anthocyanin flushing, combined with a strongly pigmented calyx. Resembles Pinjarra A, but differs in having very broad leaflets and a quite different isoflavone pattern with moderately high formononetin. The level of hard-seededness is very high, but growth is open and straggly, and it has very long thin peduncles and poor burr burial. There are regularly, at most, only three seeds per burr.

25. Greenmount A. J.G., Greenmount 1960. Common throughout Greenmount, Bellevue, Helena Vale and Blackboy Hill, collected or sighted in Midland, Guildford, Upper Swan, Darkan, Claremont, and near the lake at the south-east end of King's Park, Perth. An identical strain supplied by R. J. Pack under the name "King's Park" was present in the Western Australian CSIRO collection by 1949, probably from the same site. It is listed under that name by Curnow and Rossiter (1955), but in view of its published detailed description under the name Greenmount A (Gladstones 1966), together with its main distribution around Greenmount, we have retained the latter name. Greenmount A is a relatively fine, compact-growing, prostrate strain, with narrow triangular leaflets and distinctive crescent markings and calyx pigmentation. It has a high formononetin content.

26. Bellevue. J.G., Bellevue 1960. Common around the grain silo at Bellevue railway siding; also collected at Guildford, West Swan, Meltham, Bakers Hill, Toodyay, Northam and Boyanup, mostly in railway yards. The recorded distribution gives no definite indication of the primary naturalization site, all the above occurrences being possibly secondary. In appearance, Bellevue is distinctively different from all present commercial cultivars and has a number of desirable agronomic characteristics: prostrate but quite vigorous growth; a reasonably low formononetin content; very good burr burial; an above average number of seeds per burr; good total seed production; and reasonable hard-seededness. It has been used as a parent in breeding for these characteristics and its distinctive markings.

27 Northam B. The original collection of this strain has not been recorded. It does not seem to correspond to any of the strains mentioned by A. B. Adams up to 1937 or by Aitken and Drake (1941). However, it was thought to have come from material originally collected by Adams and was named Northam B in 1947 by R. C. Rossiter, CSIRO Perth (personal communication). Subsequent collection and observation have shown it to be moderately

common (though less so than Northam A, C or D) in Northam, and that it grows at several points in Toodyay. Northam B has a moderately high formononetin content.

28. Northam C. (syn. Northam Second Early of Adams 1937 and of Aitken and Drake 1941; could equal Northam Early of Donald and Neal Smith 1937). First discovered in 1930, growing and spreading on the Northam golf course (Adams 1930). Named Northam C in 1947 by R. C. Rossiter (personal communication). It is now quite common throughout Northam, and has been found at Spencers Brook, Midland, Guildford, Boyanup and Noggerup. In 1970 C.M. Francis found it to be plentiful around railway sidings at Nanson and Narngulu in the Geraldton district. Northam C is a robust, vigorous strain with very prominent and distinctive leaf markings, and has performed well in long-term strain mixture trials (Rossiter 1966). It has a low formononetin content, good burr burial, and an unusually high number of seeds per burr, which suggests good seed production (Francis and Gladstones 1974). However, its hard-seededness is probably insufficient for an early-maturing strain in a cropping situation. Northam C has been used as a parent in breeding.

29. Northam F. J.G., Northam 1962. Found at the railway yard and at the entrance to the army camp outside the town. This strain bears some resemblance to Northam C, but the crescent is less prominent, while the stipules are unusual and distinctive in being pigmented purple rather than red. It has an attractive vigorous, fairly prostrate, dense growth habit. Formononetin content is reasonably low, but burr burial is only fair. Hard-seededness is still lower than that of Northam C, and clearly insufficient for direct usefulness in most cropping rotations.

30. Spencers Brook. C.F., Spencers Brook 1969, growing in the lawn of the Spencers Brook Hotel. It has a very low formonetin content, together with an attractive growth and seeding habit resembling that of Bellevue, quite good burr burial, and a high level of hard-seededness. Further agronomic testing would seem to be justified.

31. Toodyay A. J.G., Toodyay 1962. Common along the west bank of the Avon River at Toodyay, but not collected or sighted elsewhere. In appearance Toodyay A resembles Northam C and Northam F, but it is much higher in formononetin than either, having an overall isoflavone pattern resembling that of Dwalganup.

32. Cannington A. J.G., Cannington 1961. An uncommon component in mainly Cannington B pastures on the east bank of the Canning River; isolated once as a contaminant of a commercial pasture in the Boyup Brook district (Quinlivan collection, 1968). Cannington A is a very prostrate growing but quite vigorous strain, with conspicuously triangular, strongly-indented leaflets. It is characterized by very strong burr burial but only moderate hard-seededness. Formononetin content is very high.

33. Dwellingup A. C.F., Dwellingup 1967; not sighted elsewhere. A strain with triangular, strongly indented leaflets and distinctive, strong crescent markings, it is unusual among Australian collections in that it combines fairly strong white crescent arms with a pigmented calyx (which is purple rather than the normal purplish red). It is also unusual in combining moderate formononetin with very low genistein and biochanin A contents, resulting in the lowest total isoflavone content in the leaves of any strain we have examined, apart from the artificial mutant Uniwager. Burr burial and hard-seededness are good.

34. Quindanning A. C.F., Quindanning 1969; not sighted elsewhere. Resembles Dwellingup A in having a strong leaflet crescent, though with only indefinite arms and fairly triangular leaflets. Quindanning A is strongly hard-seeded, but its formononetin content is fairly high.

35. Neuchatel. Originally selected by A. J. Plattenier, a farmer at Waroona, some time before 1958. It is undoubtedly an early-flowering natural mutant of cv. Yarloop. Used in breeding as a source of earliness, it was one of the parents of cv. Trikkala. The name Neuchatel was chosen by Plattenier in honour of his home city in Switzerland, and therefore does not follow the usual Australian convention of naming strains after their places of discovery.

36. Shenton Park A. J.G., Shenton Park 1962, growing on street verges in Aberdare and Commercial Roads. It typifies the "Shenton Park A" group of subsp. *subterraneum* strains in being smooth all over (except that the leaflets become hairy from flowering onwards), and in having a characteristic isoflavone pattern of low formononetin, high genistein, and low biochanin A. The formononetin content is consistently among the lowest of all strains. Other favourable agronomic characteristics are fairly high levels of hard-seededness and of physiological seed dormancy. The growth habit is quite prostrate when plant density allows, but reasonably vigorous. Burr burial is only fair.

Results from field experiments and other plantings (G.H. Walton, N.R. McKeown, unpublished data; Gladstones, unpublished observations) have been promising on certain sandy soils, but overall have not been good enough to suggest potential superiority over comparable existing cultivars such as Northam and Daliak.

37. Shenton Park B. J.G., Shenton Park 1962. Collected in Croydon Street, not far from Shenton Park A. It is obviously closely related to Shenton Park A, differing mainly in that it has a definite C2A1 leaflet crescent, but little pigmentation of the calyx. On average, it flowers a little later than Shenton Park A, has a slightly higher formononetin content, buries its burrs still more weakly, and has less hard-seededness and physiological seed dormancy.

38. Shenton Park C. J.G., Shenton Park 1967. Collected in Aberdare Road, in the same general vicinity as Shenton Park A and B. It closely resembles both strains, being possibly an intermediate between them. The markings are as for Shenton Park B except that the leaflet crescent is reduced to a faint "ghost" marking. Agronomic characters more closely resemble those of Shenton Park A.

39. Lake Claremont. J.G., Claremont 1961. Very common in the area east and north-east of Lake Claremont (formerly Butler's Swamp), including the Royal Showgrounds, Claremont, and northwards through Graylands; found once as a contaminant of a commercial pasture in the Boyup Brook district (Quinlivan collection, 1968). In its marking this strain resembles Dwalganup, but the leaflets are broader and rounder, less hairy, and slightly lighter green. Lake Claremont differs from Dwalganup in having a low formononetin content and slender peduncles. Burr burial is poor and the rate of seed development slow. Maturity, as a result, is distinctively later than that of Dwalganup, even though flowering might start at the same time. Observation of rows suggests that the strain is more susceptible than most to mildew. Hard-seededness is high, but physiological seed dormancy low. In field experiments (G.H. Walton, unpublished observations), Lake Claremont has performed promisingly at some sites on sandy soils, where burr burial is presumably not a problem.

40. Mt. Helena A. J.G., Mt. Helena 1961. Collected also on the bank of the Woorooloo Brook at Noble Falls, on the Perth to Toodyay road, suggesting that it may be fairly widely established in the district. Mt. Helena A is a distinctive strain, of robust, but compact, habit. The leaflets are broad-triangular and strongly indented, and light green with no crescent markings or anthocyanin flecking or flushing. There is some resemblance to Daliak, but Mt. Helena A lacks that strain's extent and intensity of calyx pigmentation and its distinctive red flushing of the stipules. Its growth is coarser than that of Daliak, and more prostrate when plant spacing allows. Agronomically, Mt. Helena A is interesting because of its extremely low formononetin content, reasonable levels of hard-seededness and physiological seed dormancy, and short but extremely robust peduncles. Their shortness detracts from what might otherwise be very good burr burial. Crosses with longer-peduncled strains as part of the breeding programme have produced some selections with outstandingly good burr burial. In field trials to date in Western Australia (G.H. Walton, N.R. McKeown, unpublished data) and in New South Wales (O.R. Southwood, E.C. Wolfe, unpublished data), Mt. Helena A has given results generally comparable with those of Daliak.

41. Daliak. This strain was known to have been growing on A.J. Monger's "Daliak" estate at York well before 1920. Adams (1929a) stated that two bags of clover burr from Daliak had been supplied to E.W. Cotton, a previous occupant of the property that became Muresk Agricultural College, in 1921. Collections and observations in 1960-62 (Gladstones 1966) showed that the strain then occurred commonly along nearly all the railways of the Great Southern line and westwards. An interesting peculiarity of its distribution is that Daliak tends to form pure or dominant stands immediately next to the railway track, whereas Dwalganup or other strains tend to predominate in clover-grass mixtures further away from the track. By the 1950s Daliak was common, and appeared to be increasing, in many old Dwalganup pastures in areas west of the Great Southern railway (R.C. Rossiter, personal communication).

Daliak was officially released in 1967, on the basis mainly of its relatively low oestrogenic potency and good results in long-term mixture experiments (Rossiter 1966). It has since been found to have good resistance to clover scorch (Chatel, Francis and Devitt 1973; Chatel and Francis 1974, 1977, 1978). Daliak also has quite good resistance to root rots in Western Australia, but is highly susceptible to blue-green aphids (D.J. Gillespie, personal communication). It has been used extensively in

breeding as a source of resistance to clover scorch (Francis and Gladstones 1980). It is a parent of the cultivars Esperance and Junee.

Daliak is a fine-growing strain, with a compact, almost clumpy growth habit. It is characterized by moderately rapid flowering and seed development (Walton 1966; Francis and Gladstones 1974), together with good burr burial combined with a good capacity to form viable seeds when burial is prevented (Quinlivan and Francis 1971; Collins, Francis and Quinlivan 1976). Hard-seededness and physiological seed dormancy are moderately high. The formononetin content is perhaps higher than desirable for a low-oestrogen cultivar. A peculiarity we have noted (Gladstones and Collins, unpublished data) is that, to a greater degree than in other strains, the formononetin content of Daliak can be relatively high during early growth but falls rapidly to a low level after about the beginning of flowering. This behaviour appears to be inherited by its daughter cultivar Esperance.

42. **Hollywood C.** J.G., Hollywood 1962. Also collected on the Nedlands golf course and at Armadale, and later found growing quite extensively on the lower parts of the Chidley Point golf course at Mosman Park. Hollywood C is a fairly tall-growing strain, though prostrate as a seedling, with prominent leaflet markings, green calyx, and fairly high hard-seededness. Its formononetin content is very high.

43. **Darkan C.** J.G., Darkan 1962. Common around the Darkan railway yard, but not collected or sighted elsewhere. Darkan C is notable for its extreme fineness of growth, which in some seasons has appeared almost aberrant, despite a medium seed size and an above-average number of seeds per burr. It is a high-oestrogen strain with an isoflavone pattern similar to that of Dwalganup. It has no discernable points of agronomic merit.

44. **Rocky Gully.** Some uncertainty exists as to the precise nature and history of this strain. According to B. J. Quinlivan (personal communication), a "Rocky Gully" strain was known for many years as a contaminant of commercial subterranean clover pastures in southern areas of Western Australia, particularly around Rocky Gully. A line collected from Mt. Barker (Western Australia) identified by him as being this strain proved to be identical with one previously collected at Dinninup in 1962, which was described under the name Dinninup B (Gladstones 1966). We have adopted the name Rocky Gully in preference to Dinninup B because of its earlier (if unpublished) currency. Subsequent accessions of the same kind from Albany and Williams are probably identical with these two. Another found by C. M. Francis in the grounds of St. Luke's Church, Gingin and several isolated by Quinlivan as contaminants in certification rows, are very similar although apparently not identical. What we now call Rocky Gully would therefore appear to be either a complex of extremely similar strains, or one main strain with a number of variants. It should be noted further that the Rocky Gully complex constitutes one focal point in a wider series of similar-looking, but clearly distinct strains ranging in maturity from Blackboy Hill to Gidgegannup. This broader grouping is discussed further in the commentary on Gidgegannup.

All the Rocky Gully-type strains or sub-strains are high in formononetin, having an isoflavone pattern similar to that of Dwalganup. Most tend to be highly hard-seeded and have good burr burial. This, together with moderately early maturity would in many districts have given them a long-term selective advantage over cv. Mt. Barker, with which they have often been found mixed. It is quite possible that members of this group were initially introduced into Western Australia as a contaminant of commercial seed imported from interstate, with further variability within the group perhaps arising from natural crossing over the years. The strain retained in the collection under the name Rocky Gully is that previously described as Dinninup B. It is a robust plant, having strong leaflet crescent markings which make it conspicuous in mixtures with other strains.

45. **Dwellingup B.** C.F., Dwellingup 1967, not collected elsewhere. Bears resemblances to Williams and Cannington A, but has finer, laxer growth. It is a high-oestrogen strain, with poor burr burial and a relatively low hard-seededness level.

46. **Mogumber A.** J.G., Mogumber 1967, in an old Dwalganup pasture on the property of D. Purser. At the time it covered a substantial area and was apparently spreading. It has notably rounded, non-indented leaflets and unusually hairy stems and peduncles, but more or less smooth leaves. In general appearance it bears resemblances to Gingin Brook and Mt. Barker.

47. **Boyup A.** C.F., Boyup Brook 1968. Collected at a site identified by B. J. Quinlivan as having a probable hybrid swarm, which proved to be the case; but this one line displays characteristics so far outside the prevailing

range of variability for the site that it would appear to be an independent naturalized strain. Boyup A has exceptionally hairy stems and peduncles and moderately hairy petioles, giving the plant overall a strongly furry appearance. However, the leaflet upper surfaces are smooth. The stems have strong purple pigmentation, but the leaves completely lack anthocyanin flushing. The stems are thick and the peduncles exceptionally so. The latter are nevertheless very short, a combination which in the present collection has been found otherwise only in Mt. Helena A. Boyup A resembles Mt. Helena A in isoflavone pattern, having very low formononetin, but high genistein and biochanin A contents. Hard-seededness and physiological seed dormancy are only moderate.

48. Northam D. (syn. Muresk Early of Adams 1934a, 1937). First named Northam D by R. C. Rossiter in 1947. Until recently the precise origin of Northam D was unknown, although it had always been assumed to have come from material collected by A. B. Adams around Northam in the late 1920s and early 1930s (Rossiter, personal communication). Synonymy with "Muresk Early" seemed possible, but Adams' description was too sketchy to allow adequate comparison, nor was positive identification possible from the published description of a strain under that name by Aitken and Drake (1941).

With the assistance of Yvonne Aitken of the University of Melbourne, we have now had the opportunity of growing out a series of lines which have been held in Melbourne, directly descended from material supplied by Adams in the late 1930s. One labelled "Muresk" proved to be identical with Rossiter's Northam D. We have retained the latter name in preference to the original because of its universal currency in the modern literature, and because it constitutes part of a series of strain names which has now reached Northam G. Northam D is common around the Northam townsite, though less so than Northam A or C. It has also been collected at Mundaring, Collie and Claremont, and is quite common in one of the memorial drives of Kings Park, Perth. Northam D is characterized particularly by the coarse, strongly appressed hairs which cover its leaflet upper surfaces and to a less conspicuous degree all other plant parts, together with very strong dark red flecking of the leaflets. The leaflets are triangular, but not indented. Hard-seededness and physiological seed dormancy are moderately high. Formononetin, genistein and biochanin contents are all high, giving Northam D one of the highest total isoflavone contents of any strain.

49. Nedlands. J. G., Nedlands 1962. Found as a moderate-sized patch on the Crawley foreshore not far from the old Shenton homestead. The Greenmount B strain (Gladstones 1966), orginally thought to differ slightly, later proved to be identical. Nedlands resembles Darlington, but is distinct in several respects, most notably in its lack of calyx pigmentation and its somewhat higher isoflavone content. Nedlands is a fine-growing strain, with fairly high hard seededness but weak burr burial.

50. Chidlows A. J.G., Chidlows 1969; no other collections. In some respects this strain resembles Lake Claremont and Dalkeith, with which it forms a natural group in respect to markings, isoflavone pattern, and high level of hard-seededness. Chidlows A is distinguished in part by its hairiness and the appression of the hairs on all plant parts. Its growth habit is semi-erect and compact, at times bunchy.

51. Dalkeith. J.G., Dalkeith 1967, fairly common immediately west and north of the Dalkeith Bowling Club. A robust strain, having very low formononetin and total isoflavone contents, high hard-seededness but low physiological seed dormancy, and fairly good burr burial. There is some resemblance to Dwalganup, but an experienced observer can usually distinguish Dalkeith by its complete lack of anthocyanin flushing on the leaflets, less rounded and more indented leaflet shape, greater appression of the hairs on leaf, petiole, stem and peduncle, and somewhat later maturity. Dalkeith has been used as a parent in breeding. It has shown promise in field trials in New South Wales (E.C. Wolfe, personal communication) and latterly in Western Australia (D. A. Nicholas, personal communication), and has been registered and is being increased for direct release in both States.

52. Williams D. C. F., Williams 1967. Resembles Rocky Gully, but is probably distinct from that group, as indicated by this strain's darker brown leaf flushing and its strong brownish-pink stem pigmentation. There is a tendency towards the longish petioles but prostrate growth habit characteristic of Kojonup. The internodes and peduncles are long, but relatively slender. Burr burial is quite good. Formononetin content is fairly high, hard-seededness moderate.

53. Collie A. J. G., Collie 1962. Together with the other Collie strains, this belongs in the "Shenton Park A" group characterized by smooth to sparsely hairy petioles, stems and peduncles, and a low formononetin, high

genistein, low biochanin A isoflavone pattern. The leaflet upper surfaces of Collie A are, however, strongly appressed-hairy. Collie A is characterized by its small, narrow-triangular, non-indented leaflets and prostrate, fine growth habit including fine peduncles with very poor burr burial. Hard-seededness is fairly high, and physiological seed dormancy exceptionally high. An apparent lack of vigour, poor burr burial and only moderately low formononetin content have prevented serious consideration of Collie A for direct use or breeding, but it could be a useful genetic source of physiological dormancy.

54. Darlington. J. G., Darlington 1961. Collected from a small patch near the old Darlington railway station, not seen elsewhere. It has marked similarities to Nedlands, but is distinct from that strain. Darlington is relatively fine growing, with narrow, triangular leaflets. Agronomically attractive features include low formononetin content, an above average number of seeds per burr, and high hard-seededness and physiological seed dormancy. Burr burial is only fair. In the seed development trial of Francis and Gladstones (1974), Darlington had a very high seed yield which appeared to be related to its having both rapid and prolonged flowering, resulting in very high total inflorescence and burr numbers. However, performance in field tests (G. H. Walton, N. R. McKeown, O. R. Southwood, E. C. Wolfe, personal communications) has not been encouraging.

55. Toodyay B. J. G., Toodyay 1962. Moderately common, but much less so than Toodyay A or Geraldton, along the west bank of the Avon River at Toodyay. Not seen or collected elsewhere. Toodyay B is a typical member of the "Shenton Park A" group and bears a considerable resemblance to Shenton Park B. The leaves, petioles, stems and peduncles are more or less completely hairless. It is a rather lax-growing strain, having thin petioles, stems and peduncles, and very poor burr burial. Positive agronomic features are a very low formononetin content and fairly high levels of both hard-seededness and physiological seed dormancy.

56. Woorooloo. J. G., Woorooloo 1966; not seen elsewhere. Bears a considerable resemblance to Daliak in the vegetative stage, but is coarser-growing, has a somewhat larger and more definite leaflet crescent, and lacks Daliak's characteristic stipule flushing. At flowering it clearly differs in lacking any calyx pigmentation. Leaf formononetin content is moderately low, but burr burial appears poor.

57. Northam G. J. G., Northam 1962. Collected near the railway station and near the entrance to the army camp outside the town, and later by C. M. Francis at Toodyay. Northam G is the latest-flowering of the Northam strains. It has quite high levels of hard-seededness and physiological seed dormancy, but is high in formononetin.

58. Blackwood, syn. Sumner's Early. Collected by C. Sumner at Dinninup, and supplied to A. J. Millington, University of Western Australia, about 1958. J. G. found a small patch of an apparently identical type growing near the railway in Guildford in 1960. Commercial seed producers attempted unsuccessfully to commercialize the strain in the middle 1960s. Blackwood's characteristics suggest that it is probably a simple early-flowering mutant of Mt. Barker (Gladstones 1966). Unlike those of most strains, Blackwood's internodes usually start extending several nodes before that of first flowering, giving the plants an extremely straggly growth habit. It has its putative parent's isoflavone pattern, poor burr burial, almost complete lack of hard-seededness, and ability to produce viable seeds when burial is prevented (Collins, Francis and Quinlivan 1976).

59. New Norcia A. J. G., New Norcia 1967, on vacant land among the Benedictine Monastery buildings. The same strain was later collected at two places and seen at others in "Inga's paddock" on the monastery farm. It is a moderately high-formononetin strain with a distinctive, low-set C2-3 crescent marking and strong flecking of the leaflets. Although fairly hard-seeded and having a vigorous, sturdy growth habit, New Norcia A has very thin peduncles and poor burr burial.

60. New Norcia B. J.G., New Norcia 1969, near the monastery Farm Superintendant's house. There have been no other collections or sightings. The upper surface of the leaflets is smooth and strongly flecked, with a C2A1 crescent marking which is, unusually for an Australian strain, combined with a fairly strongly pigmented calyx. The petiole, stem and peduncle hairs are moderately appressed. Growth is prostrate, fine and fairly compact, and in rows has tended to lack vigour. New Norcia B is high in formononetin and has only fair burr burial and hard-seededness.

61. Kojonup. J.G., Kojonup 1961. Found at several points in the railway yards; also collected at Brookton, Quindanning and Dinninup. Characterized by its dark green,

triangular leaflet, flat C2A2 crescent marking, and long petioles and runners with a prostrate habit when conditions allow. Kojonup has a moderately high formononetin content, and moderate hard-seededness and physiological seed dormancy.

62. Chidlows B. J.G., Chidlows 1969; not sighted elsewhere. Bears a very considerable resemblance to Hollywood C. Chidlows B is characterized particularly by its narrow-triangular, indented leaflets, C2A2 crescent markings, and lack of leaflet or calyx pigmentation. It has a prostrate, attractive growth habit, long, thick peduncles, and quite good burr burial. However its formononetin content is medium to high and it lacks adequate hard-seededness.

63. Collie B. J.G., Collie 1962. Found growing as a moderately extensive patch, apparently long-established, but not sighted elsewhere. Collie B is a typical member of the "Shenton Park A" group, having completely smooth leaflet upper surfaces, petioles and stems; only very sparsely hairy peduncles; and the low-formononetin, high-genistein, low-biochanin A isoflavone pattern characteristic of the group. It is quite vigorous-growing and highly hard-seeded for its maturity, but physiological seed dormancy is low. One peculiarity of Collie B is the conspicuous thickness of its petioles relative to the rest of the plant. The peduncles are long but thin, and burr burial is fairly weak.

64. Yarloop. This cultivar was discovered by J. M. Riegert at Cookernup (near Yarloop) in 1935. He distributed some seed to other farmers in 1939, and official seed certification started in 1947. Yarloop and its early-flowering derivative Neuchatel are unique in being the only members of the subspecies *yanninicum* (Katznelson and Morley 1965) to have been found growing naturally in Western Australia. Yarloop is very readily distinguished by its vigorous, tall, fairly coarse growth; indented triangular, light green leaflets with variable brown flushing; small A1 markings on the leaflets; smoothness of all plant parts; and its large cream to amber seeds. It has exceptionally high contents of both formononetin and genistein, and is both highly oestrogenic and unpalatable to stock. The latter characteristic makes it frequently more dominant and apparently successful in pastures than would otherwise be the case. Strong susceptibility to clover scorch has contributed to Yarloop's decline in south coastal high rainfall pastures in recent years.

65 Nedlands B. J.G., Nedlands 1969, as a small patch on vacant land between Parkway and the river; not sighted elsewhere. A robust, vigorous strain, with markings and general appearance suggesting a late-flowering Northam C. The leaflet upper surfaces are more or less smooth, but the stems and peduncles are densely and rather coarsely hairy. Nedlands B has a very low formononetin content and an overall isoflavone pattern resembling that of Mt. Barker. With good burr burial and reasonable hard-seededness for its maturity, Nedland B could warrant further agronomic testing.

66. Cannington B. J.G., Cannington 1961. Common and predominant in some pastures along the east bank of the Canning River at Cannington, with scattered patches extending towards Bentley and Manning. It has triangular, dark green leaflets with conspicuous C2A3 crescent markings. Growth is quite vigorous and robust, but the peduncles are thin and burr burial only fair. Cannington B combines moderately high hard-seededness for its maturity with extremely low physiological seed dormancy. It has shown indications of a slight degree of resistance to clover scorch, but has no promise for direct use because of its high formononetin content.

67. Williams E. Collected 1967 by R. R. Fraser on his farm at Williams. One selection by B. J. Quinlivan from commercial material in certification rows proved to be identical. Williams E resembles Pinjarra A in many ways, but is considerably later-flowering. It lacks any leaflet markings, flecking or flushing, and has a strongly pigmented calyx tube. The peduncle hairs are strongly appressed. Although quite low in formononetin and having a significant degree of resistance to clover scorch, Williams E lacks sufficient hard-seededness for its maturity. It has a rather straggly growth habit which suggests that it may lack tolerance to grazing.

68. Clackline. J.G., Clackline 1962, as a small patch in the railway yard; later collected by C. M. Francis at Toodyay, growing in the old cemetery. Clackline is a prostrate, moderately compact-growing strain, with high hard-seededness for its maturity and exceptionally high physiological seed dormancy. The number of seeds per burr is unusually high, averaging five with occasional burrs having six or seven seeds. It has some degree of tolerance to clover scorch. Formononetin content is moderate, while burr burial is only fair. Although probably not directly usable, Clackline could be useful for breeding as a source of physiological seed dormancy and high number of seeds per burr.

69. Seaton Park. A commercial cultivar, first developed as such in Western Australia. The original strain known as Seaton Park was collected by H. C. Trumble in 1929 in the Adelaide suburb of Seaton. However, recent observations (Rossiter, Collins and Haynes 1985) have shown that the variety as currently grown in Western Australia differs slightly but clearly in several characters, from the original strain. The nature of, and possible reasons for, the differences have been discussed by the above authors. Seaton Park was released commercially in Western Australia in 1967, on the principal bases of its low formononetin content and its good performance in the long-term mixture trials of Rossiter (1966). It rates well on all the present agronomic criteria, apart from being highly susceptible to clover scorch.

70. Quindanning B. C.F., Quindanning 1969, collected on the camping ground near the river. Very similar to Kojonup, but having stronger leaflet crescent markings. It resembles Hollywood C and Cannington B. A moderately high-formononetin strain, with long runners but fairly prostrate growth where conditions allow.

71. Gingin. It is not known when this strain was first collected and recognised, but it was present in the Western Australian CSIRO collection in 1947 (R. C. Rossiter, personal communication). A strain called "Northam Midseason" (Adams 1934a) answers well to the description, and could conceivably have been the same; however as this line is not held in any collection, a direct comparison cannot be made. Gingin has since been collected, or sighted, close to railway lines in several districts. It is now common throughout the Gingin townsite and along nearby roads. Other collections or sightings have been at Muchea, Upper Swan, Guildford, Midland, Pinjarra and Dinninup.

Gingin is a highly distinctive strain.
Its very strong C3A3 leaflet crescent marking, on a dark green background, is unique among presently known strains. The plants are unusually robust and vigorous in the reproductive stage, with exceptionally thick and fairly long stems. Growth is nevertheless quite compact and prostrate pre-flowering. The peduncles are long and thick, and burr burial is good though not outstanding. The burrs often contain five seeds. Hard-seededness is quite high and seed physiological dormancy moderate. Gingin performed very well in the long-term mixture trials of Rossiter (1966). However its formononetin content, although moderately low, cannot be considered low enough to be really satisfactory for direct commercial use in the districts to which a strain of its maturity would be adapted. In breeding, Gingin has been used for its distinctive leaf marking and as a source of vigour, which is readily transmitted to offspring which have the same leaf marking.

72. Mahogany Creek. J.G., Mahogany Creek 1960; also collected at Parkerville, Glen Forrest, Darlington, Greenmount, Midland and Guildford. This strain is distinguished by its very large, almost perfectly round seeds (from buried burrs only), strong flecking of the cotyledons, strong stipule pigmentation, and milky-green leaves with a rather flat C2A2 crescent marking. It is rangy in growth, with long petioles and runners, thin peduncles, poor burr burial, and slow seed development. Its formononetin content is fairly high.

73. Dinninup C. J.G., Dinninup 1962, found as a moderately large patch in the Dinninup railway yard. Earlier flowering, but otherwise more or less the same in appearance and general isoflavone pattern as Mt. Barker. However, its higher hard-seededness compared with Mt. Barker, together with perhaps a slightly higher formononetin content, suggest a hybrid origin with Mt. Barker as one parent.

74. Mogumber B. J.G., Mogumber 1967. Found growing extensively, and apparently becoming dominant, in an old hilltop Dwalganup pasture on the property of D. Purser at Mogumber. A rather rangy strain, with long but relatively slender runners. The leaflets are triangular and strongly appressed-hairy, with a thin crescent marking. Burr burial and hard-seededness are moderately good and formononetin and total isoflavone contents fairly low.

75. Pinjarra B. J.G., Pinjarra 1962. Plentiful in the northern half of the railway yards; later collected at Ravenswood, between Pinjarra and Mandurah. Closely resembling, and in various ways intermediate between, Rocky Gully and Cannington B. Pinjarra B has a fairly prominent C2A2 leaflet crescent marking, green calyx, and long internodes, runners and peduncles. Burr burial and hard-seededness are poor, and the oestrogen content very high, with an isoflavone pattern similar to that of Dwalganup.

76. Mundaring. J.G., Mundaring 1961. Found only as a small patch in the Mundaring railway yard. Bears some resemblance to Northam B, but is later flowering and the leaflets are broader and of a peculiar milky bluish green. The plants tend to be compact, with a rather

weak, unhealthy appearance when grown at Perth. Burr burial is good and formononetin moderate, but hard-seededness is fairly low.

77. Wembley. J.G., Wembley 1968. Found growing on a street verge near the corner of Brookdale and Cambridge Streets. It resembles Seaton Park but is clearly distinct in several respects, most notably in its strong seedling hypocotyl pigmentation, lighter green leaf, the presence of flushing on the leaves, and purple rather than purplish brown stem pigmentation. The leaflets are narrower and show little indentation. Wembley is low in formononetin and has moderately high hard-seededness and physiological seed dormancy, but its burr burial appears to be weaker than that of Seaton Park.

78. Graylands. J.G., Graylands 1961. Grows extensively in Claremont and Graylands, particularly east and north of Lake Claremont (Butler's Swamp) and to the east and north of the Swanbourne Hospital, extending on low land northwards through Floreat Park in the vicinity of the Perry Lakes as far as Wembley Downs. Collected and noted as very common in Dwellingup by C. M. Francis in 1967; also collected at Shenton Park, Hollywood, Armadale, Jarrahdale, Mardella, Dardanup, and Australind. Graylands is a strain of the "Late Dwalganup" group, but has some distinctive features. Most notably, the white arms of the otherwise Dwalganup-like crescent markings are a little more prominent than usual and are visibly detached from the central pale green spot. Agronomically, Graylands is characterized by its high seed number per burr, good burr burial, high level of hard-seededness, and moderate formononetin content. Its widespread natural occurrence on infertile sands may have agronomic significance.

It should be noted that Graylands' maturity is somewhat earlier than indicated by its position in this list and table 1, where it is placed for convenient grouping with other members of the "Late Dwalganup" group. Actual flowering time is similar to that of Daliak.

79. Belmont. J.G., Belmont 1960, as a small patch in vacant land near the racecourse. Retained in the collection mainly as a typical representative of the "Late Dwalganup" group and as having relatively attractive agronomic features for that group. It is a robust strain with vigorous but moderately prostrate growth, moderate formononetin content, good burr burial and a high level of hard-seededness.

80. Byford. J.G., Byford 1962. Present in patches in the Byford railway yard. An apparently identical line was also collected at the Serpentine Bridge on the South-West Highway, and several possibly identical lines around Armadale. It is a "Late Dwalgannup" strain, of a general type common between Armadale and Pinjarra. The leaflets are broad and non-indented, and the central crescent spot on the leaflets relatively large and of a distinctively yellowish light green. Under conducive conditions, the leaflets have a strong purplish flushing below the crescent. The plants are robust, with very good burr burial, moderate hard-seededness, and an isoflavone pattern similar to that of Dwalganup.

81. Jarrahdale A. J.G., Jarrahdale 1970. Very common in and around the township. Jarrahdale A differs from other "Late Dwalganup" types found north of Pinjarra in that the leaves are lightish green and strongly flecked. The runners have only moderate pigmentation, of a brownish pink. Burial is only fair and the hard-seededness level low. All these tendencies and its isoflavone pattern might suggest a hybrid origin, with Mt. Barker as one parent, but its extensive distribution in constant form seem to indicate that this is a primary naturalized strain.

82. Pinjarra C. J.G., Pinjarra 1967. Common along the west bank of the Murray River north of the road bridge. This is another typical "Late Dwalganup" type, whose site and extent of occurrence as a pure strain seem to indicate that it could not have originated as a Dwalganup/Mt. Barker hybrid. Types very similar to Pinjarra C, some perhaps identical with it, are common along the foot of the Darling Range between Armadale and Upper Swan. Pinjarra C is notable among the "Late Dwalganup" group for its almost pure purple stem pigmentation. Burr burial is only fair and hard-seededness moderate.

83. Bindoon. J.G., Bindoon 1967, near an old house ruin (since disappeared) at the Chittering road turn-off. It has the Dwalganup isoflavone pattern and is closest to Byford, though distinct from the latter in subtle ways.

84. Dinninup. This strain was identified by B. J. Quinlivan in 1956 as a new strain on the property of E. A. Miller at Boyup Brook, and was commercialized by a group of farmers in that district. It is not the same as the strain called Dinninup by Donald and Neal Smith (1937), which would appear merely to have been a duplicate accession of cv. Mt. Barker. Certified seed of Dinninup first became available in 1962 (Quinlivan 1962). Collections

from 1960 to 1962 showed it to be common and clearly long established in the Boyup Brook township. Other occurences, dating from before commercialization, were at the nearby railway sidings of Dinninup, Newgalup and Asplin, and also at Boyanup and Gingin. Dinninup is a vigorous-growing strain, despite its small seed size, with a prominent, distinctive leaflet crescent marking and smooth leaflet upper surfaces. It has hairy stems and notably hairy peduncles. For its early-midseason maturity burr burial is good, and it is high in both hard-seededness and physiological seed dormancy. Dinninup is one of the strains most resistant to root rots (D. J. Gillespie, personal communication). Formononetin and total isoflavone contents are extremely high, making it very highly oestrogenic and highly unpalatable to stock. As a result, Dinninup is an aggressive cultivar in commercial agriculture and can readily become dominant in pastures. It is markedly susceptible to clover scorch.

85. South Perth. J.G., South Perth 1960. Found growing quite extensively on low-lying land at the foot of Heppingstone Street; subsequently collected at several points in Guildford, Belmont, Welshpool, Maddington and Parkerville. South Perth is extremely similar to Dinninup, but the consistency in the characteristics of the metropolitan collections, as compared with the true Dinninup, shows that the two are different and independently naturalized. South Perth differs in that it is usually a little lighter green and perhaps less vigorous, and its crescent marking tends to be smaller and situated lower on the leaflet. The leaflet margin tends to have some indentation whereas that of Dinninup is almost perfectly convex. Burr burial appears to be a little weaker than that of Dinninup, and hard-seededness a little lower.

86. Guildford D. J.G., Guildford 1960. Found as a small roadside patch associated with Daliak and South Perth. Thought originally to be a natural mutant of Daliak (Gladstones 1966), it may alternatively be a natural hybrid between Daliak and South Perth. The leaflets have the shape and the faint, inconstant, small crescent spot of Daliak, while the calyces and stipules have that strain's characteristic strong anthocyanin pigmentation. Guildford D also has Daliak's high level of resistance to clover scorch and root rots, and a similar level of hard-seededness. However it is higher in formononetin. Guildford D has been retained in the collection and used extensively in breeding because of its multiple disease resistances. It is a parent of cv. Green Range.

87. Gidgegannup. J.G., Gidgegannup 1961, as a common contaminant in an old Mt. Barker/Dwalganup pasture on a property then owned by C. P. Johnson. Its ultimate origin is unknown. One other accession selected by B. J. Quinlivan as a contaminant in a commercial certification line appeared to be identical. Gidgegannup is the latest-flowering of the strain series including Blackboy Hill, Rocky Gully, Cannington B and Pinjarra B, all of which have strong leaflet crescents with prominent white arms, but in other respects closely resemble the "Late Dwalganup" group. Gidgegannup itself is characterized by a prostrate, rather compact growth habit with slow mid-winter growth; relatively smooth leaflets, with little or no anthocyanin flushing; and a Dwalganup-type isoflavone pattern.

88. Mt. Helena B. J.G., Mt. Helena 1961, near the railway station; later collected on a terrace of the Swan River at Maylands. A coarse, robust strain with thick petioles and especially thick stems and peduncles. However the narrow, triangular leaves are of only medium size. Stem pigmentation is distinctively dark purplish brown. Burr burial is quite strong and the burrs often contain five seeds. Formononetin is high, hard-seededness relatively low, and physiological seed dormancy very low.

89. Ravenswood. J.G., Ravenswood 1970; two plants only, on the bank of the Murray River near the bridge. Ravenswood is conspicuous for its very broad, rounded, overlapping leaflets and high, arched B3A1 leaflet crescent marking, similar to that of Midland A. However, in contrast to Midland A, the calyx is more or less pure green. Ravenswood has a high formononetin content and only fair burr burial and hard-seededness.

90. Marradong. C.F., Marradong 1967. Very similar to Gidgegannup, but distinguished by the high, large, rounded central spot of its leaflet crescent, and greater flecking and anthocyanin flushing of the leaflets. Marradong is a fairly robust strain, of prostrate growth habit when plant spacing allows, but only weak burr burial. It has a moderately low formononetin content, moderate hard-seededness, high physiological seed dormancy, and some resistance to clover scorch.

91. Ludlow. J.G. and C.F., Ludlow 1969; small patch near the Capel-Busselton road. Later found also at Wonnerup siding. A smooth-stemmed strain of the "Shenton Park A" group, very similar to Collie C, but having a smooth leaflet upper surface, slightly less rounded leaflets, more purplish stems and

deeper-red calyx tubes. Ludlow's growth is prostrate when plant spacing allows, with stiff petioles, but long, thin peduncles and at best only fair burr burial. Its formononetin content is low, and it has moderate hard-seededness and physiological seed dormancy.

92. Collie C. J.G., Collie 1962; found growing with Collie B, but less common. Very similar to Ludlow (see above for points of distinction). A smooth-stemmed, prostrate-growing strain with relatively short petioles but long, thin peduncles and very weak burr burial. Other agronomic features are more favourable: high hard-seededness for its maturity, moderate physiological seed dormancy, and reasonably low formononetin content.

93. Midland B. J.G., Midland 1962; as a fairly small patch in a vacant block off Railway Parade. Midland B is a small-seeded strain with prostrate, fine, compact growth in the seedling stage, but it becomes coarser and more vigorous in spring. Its leaf crescent markings and calyx colour bear some resemblance to those of Dinninup, but Midland B is readily distinguished by: its much narrower and more triangular strongly indented leaflets, which are more yellowish green and have abundant red flecking under conducive conditions (compared with none in Dinninup); by its less hairy petioles and stems; and particularly, sparsely hairy to almost glabrous peduncles, in contrast to those of Dinninup which are densely hairy.

Midland B first attracted attention as a possibly waterlogging-tolerant strain of the subspecies *subterraneum*, because it was originally collected from a very wet micro-location. However, tests by Francis and Devitt (1969) did not sustain this supposition.

Row evaluation nevertheless suggested that it could have potential for general agronomic use in the early-midseason maturity range, on the grounds of its consistently very low formononetin content, outstandingly high hard-seededness for its maturity, and high physiological seed dormancy. The strain's main observed weakness was its only fair burr burial. It was one of eight strains selected by Gladstones in 1967 for seed bulking and further testing. Subsequent field plot trials by A. C. Devitt (unpublished data), under a moderate defoliation regime, showed Midland B to have superior seed production compared with Yarloop, Seaton Park and Dinninup. Collins (1978) confirmed this for undefoliated or lightly defoliated swards, but found that under very heavy defoliation throughout flowering its seed production fell to a level well below that of Seaton Park. The experiments of Walton (1975) and of Collins, Francis and Quinlivan (1976) confirmed that Midland B's burr burial is relatively weak, though not untypically so for its maturity. The latter authors showed it to have a very high capacity to form normal, viable seeds above ground when burial is prevented.

In 1972, the Species and Cultivar Evaluation Sub-committee of the Western Australian Herbage Plant Liaison Committee recommended Midland B for commercial release, but this recommendation was not accepted by the parent committee. Midland B has nevertheless been used extensively in cross-breeding and has proved to be a particularly valuable source of genes for low formononetin content and high hard-seededness. It is a grandparent of cvv. Junee, Green Range and Karridale. Field evaluation of Midland B has continued in Western Australia in long term grazing/rotation and mixture trials. In New South Wales it has been included in numerous plot trials throughout the State, and has been a consistently good but not outstanding performer (E. C. Wolfe, O. R. Southwood, private communications). More recently Midland B has shown considerable promise in the Bairnsdale area of Victoria (L. J. Hamilton, personal communication).

94. Walebing. J.G., Walebing 1967, growing fairly extensively around the post office; also collected near the homestead of a nearby farm. Walebing shows considerable resemblance in its appearance and habits to Midland B, but it has still finer and denser growth. Flowering and seed development appear to be rapid. The leaves and petioles are smooth, but the stems and peduncles are moderately hairy. Walebing's isoflavone pattern and partial smoothness, like those of Midland B, suggest a possible relationship to the "Shenton Park A" group. Its formononetin content is moderately low, hard-seededness quite high for its maturity, and physiological seed dormancy moderate. In central and northern New South Wales it has shown considerable agronomic promise in small-scale plot tests (E. C. Wolfe, O. R. Southwood, personal communication).

95. Lake Leschenault. J.G., Lake Leschenault 1969; on the west bank of the lake. Although having some features in common with the "Late Dwalganup" types, this strain has distinctive features which seem to place it outside the group and to rule out an origin by crossing among other strains present, such as Mt. Barker and Dwalganup. The leaves are small and fine, fairly light green, but strongly flecked. The leaflets are broad but triangular, and are held

on stiff petioles in a dispersed canopy which allows good light penetration. The peduncles are long, thin, and slightly sarmentous; burr burial is weak. Formononetin is moderately high, and hard-seededness moderate.

96. Helena Vale. J.G., Helena Vale 1961. Fairly common throughout the Helena Vale-Bellevue-Blackboy Hill area; collected also in Greenmount and Midland. Helena Vale is distinctive in appearance, the leaves being a brownish light green with a prominent pointed C3 crescent low on the leaflet and a fairly strong, brown anthocyanin bar along the midrib below it; the calyx tube deep purplish red about one-half its length; and the growth habit sprawling, with long runners and peduncles. It has a very high formononetin content, very poor burr burial, slow seed development, and low levels of both hard-seededness and physiological seed dormancy.

97. Guildford E. J.G., Guildford 1960; apparently well-established as a natural pasture on flats of the Helena River at East Guildford. A typical "Late Dwalganup" type with the Dwalganup isoflavone pattern, but distinct from other members of the group examined. The leaflets are broad, with non-indented margins. Growth is robust, burr burial good, and hard-seededness moderate. Guildford E appears to have a slight degree of clover scorch tolerance.

98. Mayanup. J.G., Mayanup 1970. On the roadside of Jaye's Road just west of the bridge over the Blackwood River. A "Late Dwalganup" type, most closely resembling Byford in appearance. Mayanup is retained as a distinct, representative member of the group, but no information is available on its distribution to indicate whether it is a primary naturalized strain or alternatively a Dwalganup/Mt. Barker hybrid.

99. Dingup. J. G., Dingup 1970; common around the old hall. Another "Late Dwalganup" type, but distinct. Its moderately extensive presence as an apparently uniform type suggests that Dingup is a primary or perhaps a secondary naturalized strain, rather than a recent Dwalganup/Mt. Barker hybrid. The leaflets are triangular and strongly flecked, and the petioles, stems and peduncles are all strongly hairy. The peduncles are long and thin and burr burial is poor. Formononetin content and hard-seededness are both moderate.

100. Koongamia. J.G., Koongamia 1961; from a fairly extensive patch; also collected at Greenmount and Midland. A very high-formononetin, coarse-growing strain with notably thick petioles. The leaflets are broad but triangular, and have strong crescent markings and strong brownish flushing. Burr burial is fairly strong, but hard-seededness low.

101. Albany. J.G. and C.F., Albany 1967; in the township in the grounds of "Norman House". A fine, compact-growing strain, prostrate when plant spacing allows, with narrow, triangular, heavily flecked leaflets. The leaflets, and to a lesser extent other plant parts, are densely hairy, giving the plant a furry appearance. Albany has short internodes and short, but (relatively) thick, petioles, with good burr burial for its maturity; but a low level of hard-seededness. Its formononetin content is very low and it appears to have some degree of clover scorch tolerance.

102. Clare. This strain was reported by Walker and Neal Smith (1959) to have been first noticed by J. E. Butler on his farm at Clare, South Australia, about 1921. It is one of only two strains of the subspecies *brachycalycinum* to have been found in Australia. The first commercial seed was certified and released in South Australia in 1950. Since then small areas have been sown from time to time in Western Australia. Clare has never become an important variety here, but is occasionally found as a volunteer, especially on west coastal, sandy soils derived from beach sand or limestone, south of Perth. For further descriptions see Quinlivan and Francis (1977); Collins, Francis and Quinlivan (1984).

103. Bassendean H. J.G., Bassendean 1961; on top of river terrace at west end of the railway bridge over the Swan River. Appears identical with Mt. Barker except that it flowers some two weeks earlier. Bassendean H was collected at the same time and site as a group (Bassendean A to G, now all discarded) which appeared to be members of a hybrid swarm from a cross between Dwalganup and Mt. Barker, or strains closely resembling them. The possibility that Bassendean H came from the same swarm cannot be entirely discounted, but its apparently complete identity with Mt. Barker other than in flowering time points to a more likely origin as a simple mutant of Mt. Barker.

104. Boyup B, syn. Boree. Supplied under the latter name by C. Sumner, who found it at Dinninup some time before 1963. Later collected by J.G., near Mayanup. Although perhaps related to the "Late Dwalganup" group, as witnessed by its typical Dwalganup-type isoflavone pattern, Boyup B is very distinctive in its narrow and triangular, strongly idented, dark green leaflets; strong C4 leaflet

crescent; strongly pigmented calyx; and robust but very prostrate growth habit. Burr burial is good for its maturity, but hard-seededness is only moderate. It has reasonably good resistance to clover scorch. Boyup B is an agronomically interesting strain, but direct use is precluded by its high formononetin content.

105. Jarrahdale B. J.G., Jarrahdale 1970; as a small patch; not collected or sighted elsewhere. A lightish green, fine, prostrate, compact-growing strain which in rows appears to lack vigour. The leaves are large in proportion to other plant parts, and are round and non-indented. Jarrahdale B is highly hard-seeded for its maturity, but has a high formononetin content and poor burr burial.

106. Parkerville A. J.G., Parkerville 1961; on vacant land by the roadside. Appears to be identical with Mt. Barker except that under Perth conditions it flowers some two weeks earlier and is slightly darker green. The latter character distinguishes it fairly consistently from Bassendean H. Parkerville A is probably another simple mutant of Mt. Barker.

107. Bacchus Marsh. A cultivar first collected at Myrniong, Victoria, in 1929 and released commercially in that State in 1937 (Drake 1940). Imported into Western Australia as commercial seed during the 1940s. Although now little grown commercially in Western Australia, Bacchus Marsh has persisted in some high rainfall areas as a more or less naturalized strain. For further description see Quinlivan and Francis (1977); Collins, Francis and Quinlivan (1984).

108. Toodyay C. C.F., Toodyay 1969; in the old cemetery. Toodyay C very closely resembles Gidgegannup in appearance, but is distinct in its insoflavone pattern, maturity, and other physiological characteristics. Together with Toodyay D and E, as later described, it forms a group which could possibly have arisen from a natural cross between Mt. Barker and Gidgegannup or some other strain related to the "Rocky Gully" group. Toodyay C has fairly dark green leaves, broad, non-indented leaflets, and a conspicuous C2A2 crescent marking. Growth is very prostrate when plant spacing allows, and appears to be slow in early and mid winter. Formononetin content is low, burr burial reasonably good compared with present commercial varieties of comparable maturity, and seed physiological dormancy moderate. However the level of hard-seededness is very low. Toodyay C has attracted interest as a potential cultivar because of its low formononetin content and a reasonable degree of tolerance to clover scorch. But its apparently slow winter growth and serious lack of hard-seededness would probably limit its usefulness compared with the superior scorch-resistant crossbred cultivars now coming forward.

109. Toodyay D. C.F., Toodyay 1969; in the old cemetery. Another selection from the putative hybrid group including Toodyay C and Toodyay E. It resembles Toodyay C except in having strong flecking and purple flushing of the leaflets. Toodyay D has good clover scorch resistance and a higher level of hard-seededness than Toodyay C or E, but its burr burial appears inferior and its formononetin content is somewhat higher.

110. Toodyay E. C.F., Toodyay 1969; in the old cemetery. The third member of the putative hybrid group including also Toodyay C and Toodyay D. This is a coarser-growing strain than the other two and is of a more promising agronomic type, having semi-prostrate, quite vigorous growth, reasonable burr burial and hard-seededness for its maturity, quite good clover scorch resistance, and a very low formononetin content with an overall isoflavone pattern more or less identical with that of cv. Mt. Barker.

111. Woogenellup, syn. Pearson's. This strain was first noted by B. J. Quinlivan in 1948 in a planting of cv. Mt Barker on a Group Settlement farm near Manjimup, and shortly after in a Mt. Barker pasture on the property of L. Pearson at Benger. Subsequent investigation (B. J. Quinlivan, personal communication) showed that both paddocks had been sown with seed from the property of W. Scott at Elgin, where on inspection it was found still to be present. Originally known as Pearson's, it was renamed Woogenellup by Quinlivan in 1957. The initial pure-lining, seed increase and subsequent promotion of the cultivar were undertaken by three farmers in the Woogenellup, Bridgetown and Boyup Brook districts, assisted by Quinlivan (Quinlivan 1958). [In another paper (Gladstones and Collins 1983), we incorrectly stated that the cultivar was developed commercially by farmers in the Woogenellup district.] Certified seed first became available in 1959. A probably identical strain was selected under the name Marrar in New South Wales. Another selection, Burnley, from Victoria, appears essentially identical morphologically, although Gibson (1968) found that the line he had under that name differed from Woogenellup and Marrar in its nodulation response to a range of *Rhizobium* strains.

Collection data have given no grounds on which to suggest that Woogenellup was primarily naturalized in Western Australia, although the possibility can not be ruled out completely. Quinlivan (1958) noted that by then it had been found in commercial pastures in practically all districts of Western Australia where Mt. Barker was the basic cultivar. He surmised that it must have been introduced into Western Australia as an impurity in South Australian Mt. Barker seed during the early 1920s. Woogenellup's strain characteristics preclude the possibility of it having arisen from Mt. Barker by either mutation or natural crossing. For further description, see Quinlivan and Francis (1977); Collins, Francis and Quinlivan (1984).

112. Mt. Barker. Amos Howard first noticed this strain at Mt. Barker in South Australia in 1889 (Hill 1936). Its first recorded introduction into Western Australia was in 1902, with further introductions from 1907 onwards (Underwood and Gladstones 1979). Mt. Barker was extensively planted in high-rainfall south-west areas of Western Australia during the 1920s under the Group Settlement Scheme, as well as in adjacent drier districts until the commercial advent of Dwalganup in the 1930s. Apparent survivors of these plantings include a number which are thought to be natural early-flowering variants, e.g. Blackwood, Bassendean H and Parkerville A (Gladstones 1966; this bulletin). Additionally the progenies of natural crosses, particularly with Dwalganup, survive as frequent contaminants in pastures of the parent varieties and perhaps in some naturalized populations (Quinlivan 1957; Gladstones 1966; Cocks and Phillips 1979; this bulletin). For further description of cv. Mt. Barker, see Quinlivan and Francis (1977); Collins, Francis and Quinlivan (1984).

113. Nangeela. Quinlivan and Francis (1977) reported that this Victorian cultivar was found in several pastures in the Manjimup district. It has not yet been found genuinely naturalized in Western Australia.

114. Wenijup, syn. Late Brunswick. According to Adams (1924), The Wenijup strain had been known at Wenijup, near Bridgetown, since before 1904. In more recent years it has been reported at Brunswick and elsewhere, but deliberate cultivation may have played a role both in its survival and in its distribution (see Quinlivan 1957). Indeed, a deliberate original introduction seems not unlikely. The strain is of a type which occurs commonly and prominently by roadsides in Mediterranean countries and the Atlantic islands, and would thus have been readily collected; also, with such late maturity, it seems unlikely that it could have survived for long as a truly naturalized plant in the area where it was first recorded in Western Australia. Donald and Neal Smith (1937) reported that at Bridgetown it was disappearing in competition with earlier-flowering strains. Wenijup is the only strain of the subspecies *brachycalycinum* to have been found in Western Australia other than the commercially-introduced cv. Clare. It is very late-flowering, with coarse, long petioles and large leaves which are strongly flecked but have no crescent markings or anthocyanin flushing. It has the low formononetin, high genistein, low biochanin A isoflavone pattern typical of its subspecies, and low to moderate hard-seededness and physiological seed dormancy.

115. Tallarook. A commerical variety, first discovered in 1928 at Tallarook in Victoria and placed on the market there in 1935 (Donald and Neal Smith 1937). According to Quinlivan (1957) it was first introduced into Western Australia about 1940. Cultivation in Western Australia has been confined by its late maturity to very high rainfall districts, where occasional patches now exist in an essentially naturalized state. For further description see Quinlivan and Francis (1977); Collins, Francis and Quinlivan (1984).

Discussion

Nature and distribution of the naturally occurring strains.

Of the 115 strains listed in the "Western Australian" collection to 1979, the numbers falling into different categories are as follows:

(1) Forty-five are almost certainly primary naturalized strains (see appendix 1), on the basis of their unique characteristics and their occurrence, as uniform types, over significant areas or at multiple locations.

(2) Twenty-six more are probably primary naturalized strains, as judged by their unique characteristics and lack of nearby putative parents, but have not been observed growing widely enough to confirm that they come from extensive, uniform populations.

(3) A further 18 may fall into category 2, but with greater doubt.

(4) Eleven appear to be simple mutants of other stains, but have been retained as being potentially useful.

(5) Six appear to have arisen locally by natural crossing, but have likewise been retained for their potentially useful qualities.

(6) Three were found as contaminants of commercial cultivars and could have been introduced from interstate with commercial seed.

(7) Six are interstate commercial cultivars, secondarily naturalized in Western Australia to varying degrees.

The evidence thus suggests that some three-quarters, or about 80 of the strains retained in the collection, are primarily naturalized and were introduced in their present forms; or if they are secondary naturalized strains, all trace both of parents and of obviouly related sibling strains has since disappeared. Given the low rate of natural cross-pollination in subterranean clover (Marshall and Broue 1973), and the scattered and often isolated nature of the naturalization sites in Western Australia, the likelihood of a secondary origin for many of these strains seems small.

The remaining one-quarter or so of strains in the collection were either formed by natural crossing in mixed stands or by mutation, and

have been retained for particular features of interest or value; or else they were introduced as commercial varieties from interstate or as contaminants in them.

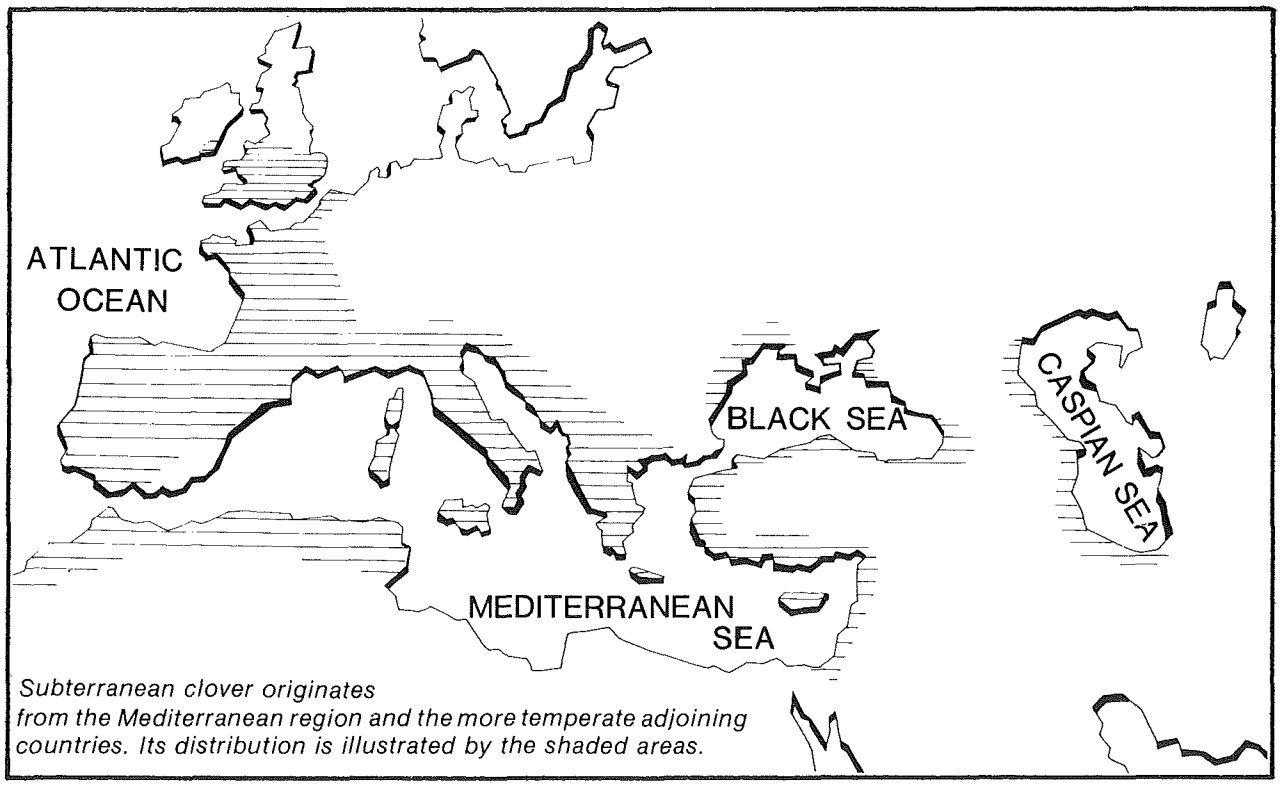
The numbers of strains in the different categories, as defined, do not reflect the proportions they constitute of the total naturalized population. Commercial varieties, which have spread secondarily, form the great bulk of the naturalized population by virtue of their much greater population pressure and opportunities for spread, particularly by stock. By contrast, natural mutants and recent (post-introduction) hybrids still form only a very small part of the total subterranean clover population in Western Australia, whether naturalized or cultivated. Nevertheless they stand out to the collector against their parent strain "backgrounds". Indiscriminate collection of all novel types inevitably yields large numbers of such genotypes. In our experience very few of them, particularly those from commercial pastures, have been of sufficient interest or potential value to warrant their retention and maintenance in a permanent collection.

A particularly striking aspect of our results has been the almost complete absence, among the selections from commercial material, of any of the naturalized but non-cultivated strains. We suggest that this is partly because many of the original areas of establishment are now sequestered from commercial agriculture in towns. Also, pre-existing naturalized strains, where present on grazing and cropping properties, would largely have been destroyed in the processes of clearing, cropping and sowing down to commercial cultivars. Without fertilizer in the early years of settlement, and with usually low rates in the initial years after clearing, the old naturalized populations in Western Australia would generally have been sparse and weak.

Agronomic implications

Gladstones (1966) noted that naturalized subterranean clover strains might be expected to be better adaped to local soils and climates than random introductions, having already passed through the sieve of natural selection.

Further, the extent of an individual strain's spread as a naturalized plant might give some clue to its degree of adaptation, although this is subject to the reservation that many chance factors would have governed opportunities for spread. In the context of agronomic evaluation a further reservation must be added: that the factors contributing to success as a naturalized plant may have only partial relevance to conditions in an improved pasture. With these reservations in mind it is nevertheless instructive to compare the characteristics of the more successful naturalized strains with those of strains which were less successful, or which were collected in other environments.



Subterranean clover originates from the Mediterranean region and the more temperate adjoining countries. Its distribution is illustrated by the shaded areas.

All the strains truly naturalized in Western Australia (discounting the commercially introduced cultivars) are of early to early-midseason maturity, and on average much earlier than strains collected in eastern Australia or overseas. This has already (Gladstones 1966) been adduced as evidence that the strains now naturalized in Western Australia must be the highly selected survivors of much larger original numbers: a conclusion which agrees with that reached earlier by Donald and Neal Smith (1937) and by Aitken and Drake (1941), for Australian naturalized strains generally.

Among the strains surviving in Western Australia, a small number stand out as having been widely successful. A second group could be classified as moderately successful. Strains in the first group are Williams, Geraldton, Daliak and Graylands, with the possible addition of Dwalganup for which the evidence is unclear because of its widespread cultivation. The second group includes Northam A, B, C and D, Gingin Brook, Daglish, Blackboy Hill, Greenmount A, Bellevue, Lake Claremont, Rocky Gully, Cannington B, Gingin, Dinninup and South Perth. Some marginal strains, either on the grounds of their less extensive known distributions or because they occur only in wet areas, where climate is unlikely to be a limitation, are Toodyay A, Mt. Helena A, Hollywood C, Mogumber A, Dalkeith, Collie A, Toodyay B, New Norcia A, Kojonup, Clackline, Mahogany Creek, Jarrahdale A, Mogumber B, Helena Vale and Koongamia.

Growth habit does not seem to have played a large part in determining success. Some of the most successful strains are fine and/or compact in their growth habits, such as Geraldton and Daliak. It does appear however, that abnormally erect and/or "straggly" strains, with very long petioles, internodes and peduncles, are mostly among the less successful.

A strong relationship is apparent between success and hard-seededness. To some extent it is more apparent than real because of the confounding positive correlation between hard-seededness and early maturity. Also, it is possible that some of the strains of most limited distribution originated by natural crossing, with a high probability that the old-established, but very soft-seeded, cultivar Mt. Barker was one parent. Even allowing for these factors, the evidence still seems to indicate that the most successfully naturalized strains in Western Australia, other than in high or very high rainfall areas, have higher than average levels of hard-seededness. The need for hard-seededness in commercial cultivars, which must persist through crop years "as well as" periodic drought in marginal areas, can be predicted to be greater still (see discussion by Quinlivan 1971; Gladstones 1975; Francis *et al.* 1976).

The evidence on physiological seed dormancy is less clear, Most of the successful strains have at least moderate levels of dormancy. Some, such as Dinninup, are very dormant as well as being hard-seeded. However, the present data are insufficient to allow the definition of any overall relationship between physiological seed dormancy and agronomic success.

One characteristic common to all successful strains, other than a few confined to high rainfall areas, is strong burr burial. Those with weak burial characteristics, for their maturities, are mostly of very limited distribution in Western Australia. Again, there is the possible confounding factor that some of the strains of most limited distribution could have originated from natural crossing with weak-burying cultivars such as Mt. Barker. But this would seem to be insufficient to account for more than a part of the relationship observed.

The evidence thus suggests that adaption of subterranean clover to the Western Australian environment, as a naturalized plant, is associated with:—

- early to early-midseason maturity,
- a fairly high level of hard-seededness, and
- strong burr burial,

as compared with the average of strains found in the original Mediterranean environment. Other adaptive features are undoubtedly involved, and probably include growth habit and physiological seed dormancy, but their roles appear to be less clear-cut.

Acknowledgments

We wish particularly to acknowledge the contributions of Dr C. M. Francis, in collecting a number of the strains and providing some of the data on isoflavone contents, and of Dr B. J. Quinlivan and Mr C. J. B. Sykes who provided most of the off-types of commercial cultivars examined as part of the study. Mr D. W. Roberts assisted with transport and guidance in searches around the Benedictine Monastery at New Norcia. Mr R. J. Pack and Dr Yvonne Aitken kindly supplied seed of some of the previously-known naturalized strains, and Dr R. C. Rossiter provided valuable information on the early history of the CSIRO collection in Western Australia. Field and laboratory assistance over the years by the staff of the University of Western Australia Field Station, Shenton Park, is gratefully acknowledged. Financial support was provided by the Wheat Industry Research Committee of Western Australia, the Australian Wheat Industry Research Council and the Australian Wool Research Trust Fund. The manuscript was typed by Mrs V. Blyton and Miss D. Franklin. The design and layout was done by Ms F. Roberts and figure 2 by Ms J. Mallard of the Information Branch, Western Australian Department of Agriculture.

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Appendix I

Definitions of terms for strains, naturalization sites, and naturalization processes.

Strain

We use the term strain, as applying to subterranean clover, to denote a substantially uniform and true-breeding genetic type, which is of natural origin and has been collected and maintained under a permanent name or other accepted designation. Minor variation within it, related either to a mixed origin or to accumulated mutation or introgression, is not precluded. The term implies a greater degree of distinction and recognition than necessarily exists among lines: a non-specific term for selections of all types which may or may not be clearly distinct, and which have not necessarily been given permanent designations or retained in a collection.

Sub-strain

A sub-strain is a variant selected from, or found in association with, a previously known strain; which appears to have arisen from that strain by mutation or introgression, and differs from it only in one or a few characteristics. It is denoted by a numerical suffix to the name of the putative parent strain, e.g. Northam A_2 (Gladstones 1966).

Cultivar

A cultivar is any strain, sub-strain, line etc., which has been brought into commercial cultivation.

Variety

We do not use the term variety, which in popular usage covers both strain and cultivar, but botanically is used more inclusively to indicate a grouping of related or similar strains, ecotypes or other forms at a lower than subspecies level.

Primary naturalization site

A primary naturalization site is where a strain initially became naturalized following its introduction. In the broad sense this includes the immediate surrounds to which it may have spread later by natural means, e.g. through seed disperal by grazing stock.

Secondary naturalization site

Secondary naturalization sites are those where a strain became naturally established following transport for some distance from its primary site, usually by artificial means—e.g. with stock transported by road or rail, or in hay or seeds sold off a property. Theoretically, higher-order naturalization sites could also be defined; but because there is little chance in practice of their being distinguished from secondary sites, they have normally to be subsumed under that term.

Primary naturalized strain

A primary naturalized strain is one which entered the country essentially in its present form. Evidence of primary naturalization includes a strain's existence as a unique and more or less uniform population over a significant area or multiple areas, together with the local absence of possible putative parents.

Secondary naturalized strain

A secondary naturalized strain is one which has arisen *de novo* from primary naturalized or commercial strain(s) by major mutation or natural crossing, and which has attained a natural population size and genetic uniformity great enough for it to be regarded as a distinct entity. The local presence of possible putative parents and/or sibling lines, combined normally with only a limited extent of spread, are taken as evidence suggesting secondary as opposed to primary naturalization. However, it should be noted that because groupings of similar and perhaps related strains could equally have resulted from multiple introductions from the same overseas habitats, the distinction between primary and secondary naturalized strains is often uncertain in practice.

The potential exists for development of tertiary and higher-order naturalized strains, but as with naturalization sites these are unlikely to be distinguishable from secondary naturalized strains.

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