

Ecogeography of Perennial Legume Collecting Missions in Italy

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Summary

An ecogeographic survey was conducted in three regions of Italy in 1999. The three regions selected for the survey were central Italy, Sicily and Calabria, and Sardinia. A total of seventy-nine sites were visited across the three regions in May when the botanical composition of perennial legume species was documented, including recording companion annual species. Detailed ecogeographic information was collected at each site, and soil samples were taken for later laboratory analysis. Climate data for each site were obtained from the Central Bureau of Agricultural Ecology. The sites were revisited in July to collect seed of the perennial species.

One hundred and forty-seven legume species were identified, fifty-two of which were perennial. The most common perennial species were *Trifolium pratense*, *T. repens* and *Lotus corniculatus*, and these were also found to be the species with the widest distributions. Species distribution and site variability was analysed using *k*-means clustering. This identified eleven different climate clusters and nine soil clusters. Particularly acid soils were rare. Cross-tabulation of soil and climate clusters resulted in several environment combinations, which could be explained by geography to a limited extent.

The results obtained in this study provide useful preliminary information in the search for perennial legumes for the farming systems of southern Australia, particularly in areas with acid soils.

Introduction

Dryland salinity in southern Australia is at present affecting about 2.5 m ha, and rapidly increasing (National Land and Water Resources Australia 2001). This is

the result of rising saline ground water as a consequence of low water use by shallow-rooted annual crops and pastures. In order to prevent further degradation, it has now been recognised that perennial deep-rooted species should be introduced to the farming system (Hatton & Nulsen 1999). These have been shown to utilise more rainwater, and thus avoid the accumulation of water in the ground water and associated waterlogging during the rainy season. In areas with a neutral to alkaline soil pH, lucerne is already being used with some success (Ward et al. 2001), confirming the potential of introducing perennial legumes into the farming system. However the problem also exists in areas with acid soils, and here adapted perennial legumes are scarce (Cocks 2001).

In order to identify potential species to be introduced into the Australian farming system and eventually into breeding programs, it is important to understand their distribution and adaptation in natural ecosystems. Some information is available for species of agricultural importance, such as lucerne, sainfoin, sulla, and white and red clovers, where breeding strategies are currently in place. However, while the ecology of annual self re-seeding pasture legumes in areas with a mediterranean climate is well known (Cocks 1993; 1997; Bennett 1998), literature about perennials is scarce. The flora of the Mediterranean Basin is very rich in legumes, including perennials, which may provide valid alternatives to annuals in the farming systems of southern Australia. Roggero and Porqueddu (1999) suggest that this wild germplasm should be exploited for productive and non-productive uses.

In Italy, it has already been recognised that perennial legume fodder crops are essential in regions where there is a need to improve soil fertility. Some species can also have a role beyond a strict agricultural use. In the field of ornamental plants, there are several species normally used as soil covers. They are herbaceous plants or shrubs characterised by fast, horizontal growth, used in city gardens or parks as green fringes or as ground covers. Although biomass production is limited, these plants play an important role in covering sloping flowerbeds, rocky gardens or areas under tree plantations. The advantages of these species are several: decorative effects, providing spots of colour, perfume and biomass; as barriers against noise and air pollution; and as protection against soil erosion. At present very few species are used (common examples in Italy are *Hypericum* sp. and *Cotoneaster* sp.), despite the huge diversity of the Mediterranean flora.

The objective of the present work was to investigate the perennial legume flora of central and southern Italy, and to relate species distribution to climate and soils; a knowledge of which is a pre-requisite of any utilisation or improvement program. While this type of information on annual species has increasingly been available for the past fifteen years, perennial species have been badly neglected.

Materials and Methods

Botanical survey

The botanical survey was carried out according to the procedure described by Ehrman and Cocks (1990) for annual legumes. A total of seventy-nine sites were surveyed during the late spring of 1999, twenty-four sites in central Italy, twenty-six in Calabria and Sicily, and twenty-nine in Sardinia (Fig. 9.1). The sites were chosen in places where natural vegetation was present and no cultivation had previously occurred. Generally all sites were on marginal, rocky, or non-arable lands, variably subjected to grazing. At each site the botanical composition of perennial legume species was assessed in an area of approximately 50×50 m in size, recording presence and abundance, as well as annual companion species. Taxonomic nomenclature follows the *Flora of Italy* (Pignatti 1982).

At each site a soil sample was collected for laboratory analysis, combining five subsamples taken at the apices and the centre of the area. Soil samples were analysed for texture, pH, total nitrogen, available phosphorus (Olsen), organic matter, lime, electrical conductivity, exchangeable acidity and exchangeable calcium, magnesium, potassium and sodium. Site information (geographical data, aspect, slope, depth of soil, drainage, grazing pressure) were also recorded.

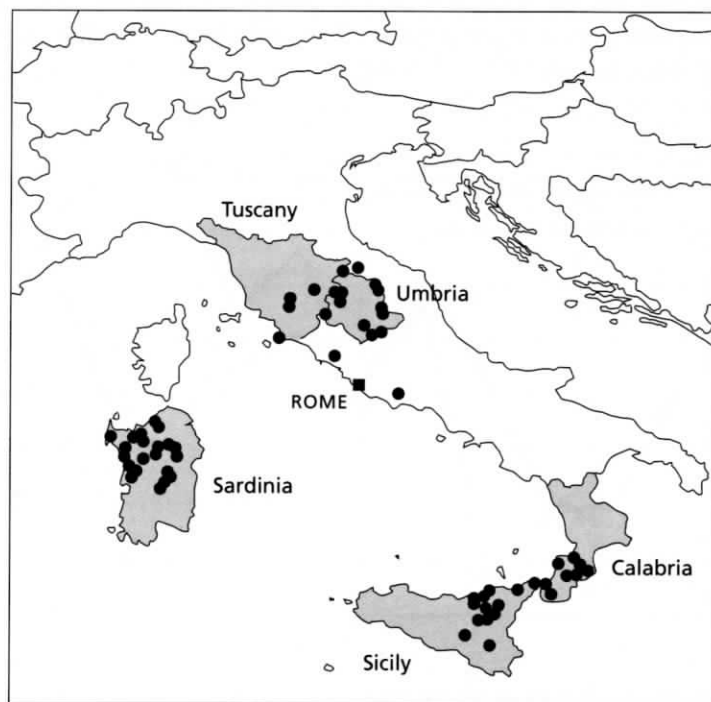


Fig. 9.1: Sites surveyed in Italy during the spring of 1999.

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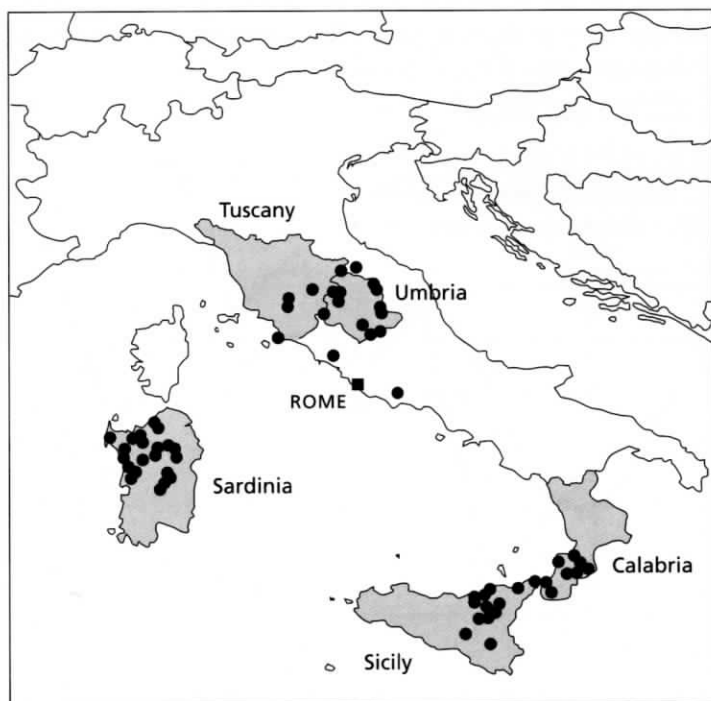


Fig. 9.1: Sites surveyed in Italy during the spring of 1999.

Climatic data of each site—mean minimum temperature of the coldest month (MinCM), mean maximum temperature of the warmest month (MaxWM), total annual rainfall and number of rainy days—were provided by the Central Bureau of Agricultural Ecology (UCEA). Climatic data were based on long-term recordings of at least twenty-five years. Significant differences in altitude between an observation site and the closest meteorological station required adjustments for temperature. This was done by devising an ad hoc neural network that was able to predict values after a training procedure based on data from stations scattered within the same area (Russi, unpub. data).

The sites were visited a second time in July to collect the seeds of the perennial legumes, sampling most of the genetic variation present. Pods and seeds were threshed and used to establish an evaluation trial (Pagnotta et al. 2002).

Statistical analysis

K-means clustering was performed (MacQueen 1967), classifying the climate and soil variables separately. Data were first standardised and subjected to a principal component procedure to reduce the large number of variables down to a smaller and more manageable number of principal components; the components were then used in a hierarchical cluster analysis (Ward's method) with the sole objective of obtaining 'seeds' to be used in the FASTCLUS procedure (SAS Institute Inc. 1990). The *k*-means clustering was then calculated using the recommended number of clusters from the Cubic Clustering Criterion (Sarle 1983; Milligan & Cooper 1985) (Fig. 9.2).

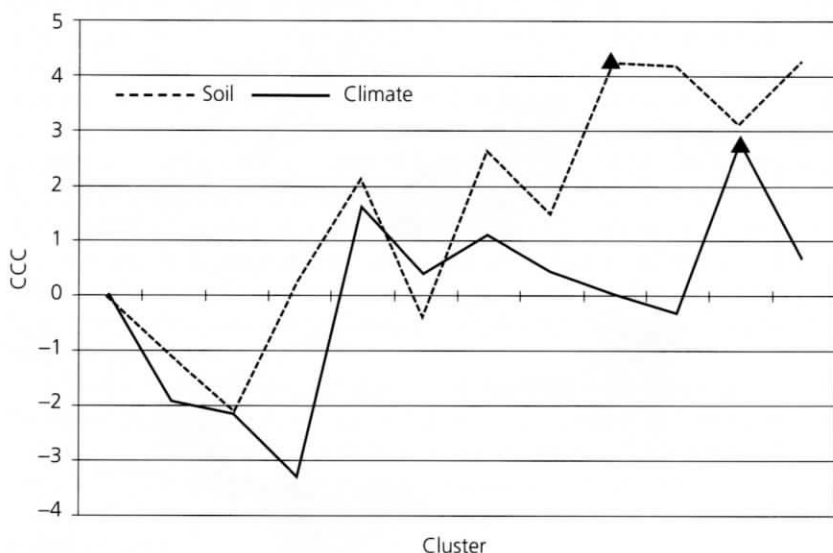


Fig. 9.2: Changes in the value of the cubic clustering criterion at increasing number of clusters, separately for climatic and soil *k*-mean clustering. Closed triangles indicate the optimum number of clusters for each group.

Results and Discussion

Botanical survey

Across the seventy-nine sites a total of 147 legume species were identified. Of these, ninety-five species were annuals and fifty-two were perennials. Statistical analyses were conducted only on the perennial species. To simplify the procedures and increase the significance of the results, analyses were only performed on the species with a frequency of more than five per cent. The most common perennial species were *Trifolium pratense*, *T. repens*, and *Lotus corniculatus* (Table 9.1). Differences in distribution between the three regions were also observed: *Onobrychis viciifolia*, *Hippocrepis comosa* and *Dorycnium pentaphyllum* for instance, were found only in Central Italy, while *Hedysarum coronarium* was found mainly in Sicily. *Medicago lupulina* and *Psoralea bituminosa* were common in central Italy, Sicily and Calabria (Table 9.1).

Classification of environments

K-means clustering of the soil and climate variables highlighted the range of environments in the three regions. Using the results of the Cubic Clustering Criterion, the optimum number of climate clusters (C) was eleven (Table 9.2), and the optimum number of soil clusters (S) was nine (Table 9.3).

In defining the climate clusters, temperature was more important than rainfall. With this in mind the eleven clusters could be linked to four main temperature groups, which can be defined as: (1) cold, characterised by MinCM well below 0°C, and MaxWM above 25°C (C1, C2); (2) cool, with the MinCM

Table 9.1: The most common perennial species identified during the survey and their distribution in the three regions. Values are number of collections per region.

Species	Central Italy	Sardinia	Calabria & Sicily	Total
<i>Anthyllis vulneraria</i> L.	6	1	5	12
<i>Dorycnium hirsutum</i> (L.) Ser.	8	1	1	10
<i>Dorycnium pentaphyllum</i> Scop.	6	0	0	6
<i>Hedysarum coronarium</i> L.	1	0	5	6
<i>Hippocrepis comosa</i> L.	8	0	0	8
<i>Lathyrus clymenum</i> L.	3	0	9	12
<i>Lathyrus latifolius</i> L.	1	4	4	9
<i>Lotus corniculatus</i> L.	24	10	8	42
<i>Lotus tenuis</i> W. et K.	4	4	0	8
<i>Medicago lupulina</i> L.	13	2	14	29
<i>Medicago sativa</i> L.	14	2	2	18
<i>Onobrychis viciifolia</i> Scop.	6	0	0	6
<i>Ononis spinosa</i> L.	5	1	0	6
<i>Psoralea bituminosa</i> L.	4	0	15	19
<i>Trifolium fragiferum</i> L.	5	4	1	10
<i>Trifolium ochroleucum</i> Hudson	6	6	2	14
<i>Trifolium pallidum</i> L.	1	0	8	9
<i>Trifolium pratense</i> L.	22	25	9	56
<i>Trifolium repens</i> L.	15	23	8	46

above 0°C but the MaxWM lower than 25°C (C3, C4), thus showing less annual variation than the previous group; (3) mild, a group of five clusters comprising over sixty per cent of the sites (C5–C9), characterised by MinCM ranging from 2 to 3°C, and MaxWM ranging from 28 to 30°C, and (4) warm, includes the warmest sites, characterised by MinCM well above 6°C, and MaxWM above 30°C (C10, C11). Climate clusters were also distinguishable from one another by total rainfall and number of rainy days. The range of total annual rainfall, although wide (from 544 to 1775 mm), did not include really dry sites, the driest being Piazza Armerina in Sicily with an average annual rainfall of 544 mm.

Physical and chemical soil properties were quite diverse at the seventy-nine sites, resulting in the identification of nine clusters (Table 9.3). These clusters can be linked to six groups, defined as: (1) poor or sandy soils, rich in gravel (S1 and S2); (2) shallow soils with available phosphorus around 10 mg/L (S3 and S4); (3) good soils, deep with a low pH (S5); (4) shallow but clay, organic soils (S6); (5) deep soils, rich in phosphorus (S8), and (6) alkaline, calcareous soils (S7 and S9), with differing phosphorus content. In several soils the lime content was nil (cluster S5) or just a trace (cluster S2). Although several clusters showed a mean soil pH of less than 7.0, only those of cluster S5 could be classified as acid. The generally high values for organic matter are explained by the dry matter accumulation of plant residues year by year, particularly where grazing is less common, as a result of impractical tillage due to stones and rocks. These high values counterbalance the shallowness of the soils or richness in gravel or sand.

Combining the two *k*-means clustering procedures, individual sites were coded for their relationship to a specific soil and climate cluster, and codes were then used to cross-tabulate them, as shown in Table 9.4. In this collection, soils from cold, wet sites were of low pH, free of lime, shallow and with a good content of clay and organic matter. Soils from cool sites were sandy and shallow,

Table 9.2: Mean values in each climate group of the four variables used in the *k*-mean clustering, and number of sites classified in each cluster.

Temperature	Rainfall	Cluster	No. of sites	T. min (°C)	T. max (°C)	Rainfall (mm)	Rainy days
Cold	High	C1	1	-4.6 ^d	26.5 ^{cd}	1526.0 ^a	122 ^b
	Medium	C2	7	-2.4 ^c	26.4 ^{cd}	833.1 ^{bc}	91 ^c
Cool	High	C3	1	1.0 ^b	23.3 ^d	1775.0 ^a	130 ^b
	Medium	C4	6	2.5 ^b	24.5 ^e	877.5 ^{bc}	85 ^c
Mild	High	C5	3	2.2 ^b	30.0 ^b	1550.7 ^a	118 ^b
		C6	16	1.6 ^b	27.6 ^{bc}	1047.5 ^b	92 ^c
	Medium	C7	17	1.9 ^b	29.7 ^b	831.4 ^{bc}	79 ^c
		C8	2	3.0 ^b	30.0 ^b	820.0 ^{bc}	155 ^a
	Low	C9	11	2.7 ^b	27.7 ^{bc}	660.9 ^c	73 ^c
Warm	High	C10	1	6.1 ^a	33.3 ^a	1050.0 ^b	55 ^d
	Medium	C11	14	8.1 ^a	29.7 ^b	775.1 ^{bc}	86 ^c

Data with the same superscript are not significantly different at $P < 0.05$.

Table 9.3: Mean values in each soil group of the fourteen variables used in the *k*-mean clustering, and number of sites classified in each cluster.

	Cluster	No. of sites	Depth (cm)	Gravel (%)	Sand (%)	Clay (%)	pH	CaCO ₃ (%)	OM (%)	P-Olsen (mg/L)	CEC meq/100 g	Exch. acidity meq/100 g	Ex. Ca meq/100 g	Ex. Mg meq/100 g	Ex. K meq/100 g	Ex. Na meq/100 g
Sandy, gravel soils	S1	9	20.3 ^{ab}	47.2 ^a	57.8 ^a	18.3 ^{ab}	6.47	3.6 ^c	7.8	12.7 ^c	18.9 ^b	4.9 ^b	10.1 ^b	2.9 ^b	0.7 ^{bc}	0.3 ^c
Sandy, low CaCO ₃	S2	25	19.8 ^{ab}	17.2 ^b	58.3 ^a	15.0 ^b	6.84	0.3 ^c	4.9	11.5 ^c	15.6 ^b	2.7 ^b	9.8 ^b	2.4 ^b	0.5 ^c	0.3 ^c
Very shallow	S3	19	12.5 ^b	19.1 ^b	35.8 ^{abc}	26.5 ^{ab}	6.54	1.9 ^c	5.3	11.4 ^c	19.8 ^b	4.8 ^b	12.0 ^b	2.1 ^b	0.6 ^c	0.3 ^c
Low P	S4	6	17.2 ^b	15.7 ^b	34.7 ^{abc}	28.3 ^{ab}	6.23	0.8 ^c	7.6	10.0 ^c	26.3 ^b	7.3 ^b	10.4 ^b	6.8 ^a	0.9 ^{bc}	0.8 ^b
Deep, no CaCO ₃ , low pH	S5	5	36.0 ^{ab}	15.6 ^b	41.2 ^{abc}	26.0 ^{ab}	5.56	0.0 ^c	11.8	16.4 ^c	31.1 ^{ab}	15.1 ^b	12.7 ^b	2.5 ^b	0.5 ^c	0.3 ^c
Very shallow, clay soil	S6	7	12.7 ^b	20.0 ^b	22.1 ^c	40.3 ^a	7.39	8.3 ^c	13.7	13.1 ^c	44.2 ^b	1.6 ^b	38.9 ^a	1.8 ^b	1.7 ^b	0.3 ^c
Alkaline, calcareous soil	S7	6	25.0 ^{ab}	17.7 ^b	39.7 ^{abc}	25.8 ^{ab}	7.85	32.7 ^b	6.6	11.0 ^c	18.8 ^b	0.0 ^b	15.5 ^b	1.8 ^b	1.1 ^{bc}	0.3 ^c
Deep soil, rich in P	S8	1	50.0 ^a	12.0 ^b	46.0 ^{ab}	24.0 ^{ab}	5.70	1.0 ^c	9.5	70.0 ^b	28.5 ^{ab}	9.4 ^{ab}	9.9 ^b	2.2 ^b	5.8 ^a	1.2 ^a
Calcar. rich in P	S9	1	15.0 ^b	10.0 ^b	24.0 ^{bc}	35.0 ^{ab}	7.80	48.0 ^a	7.4	110.0 ^a	23.0 ^b	0.0 ^b	19.1 ^b	2.2 ^b	1.4 ^{bc}	0.3 ^c

 Data with the same superscript are not significantly different at $P < 0.05$.

much poorer than the former group. Soils from mild sites were of a number of different types, while those from warm sites varied in depth and lime content, with a pH above 7.5 (except Faro Superiore Cariddi, Sicily, with a pH of 6.6).

Soil and climate clustering generated several combinations of environments that to some extent could be explained by geography. All sites falling into climate clusters C1 and C2 were from central Italy, an inland, mountain area, quite cold in winter, characterised by high rainfall. For these reasons the climate of those sites could be considered to be on the edge between a mediterranean and continental type of climate (le Houérou 1989). Almost all sites falling into climate clusters C10 and C11 were from Sicily and Calabria (only two sites were from central Italy, south of Tuscany and very close to the sea; none were from Sardinia). Apart from these two extremes in which temperature played a major role, the rest of clusters included sites geographically distant, differing more in soil features.

A total of twenty sites were identified as having good soils, and these were concentrated in central Italy. The soils of the remaining sites were generally poor and geographically many of them were in Sardinia.

Influence of environmental factors on species distribution

Species presence in relation to environmental conditions is shown in Table 9.5. The survey has revealed that some of the species were distributed across a large number of environmental combinations including *Trifolium pratense* (in as many as twenty-five combinations), *T. repens* (twenty-four), *Lotus corniculatus* (seventeen) and *Medicago lupulina* (fifteen combinations). Other species were found only in specific combinations of climate and/or soils.

Trifolium pratense and *T. repens* were the most widespread perennial legume species. *Trifolium pratense* was found in almost all sites belonging to soil

Table 9.4: Number of sites within climate/soil cells obtained by combining soil and climate groups.

		Climate clusters										
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Soil clusters	S1			1		1	4	2				1
	S2				5	1	2	7		5		5
	S3		1		1	1	4	5		3	1	3
	S4						2	1		3		
	S5		2				3					
	S6	1	4					1				1
	S7							1	1			4
	S8								1			
	S9						1					

Table 9.5: Cross-tabulation of climate (C) and soil (S) clusters, and number of occurrences of each species in any particular cell. Grey cells indicate absence of cluster combinations.

A. vulneraria

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
S1											
S2							4		2		1
S3					1						
S4											
S5		1									
S6		1									

D. hirsutum

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
S1						1					
S2							4				1
S3		1					1				
S4											
S5											
S6											

D. pentaphyllum

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
S1							1				
S2							1				
S3											
S4											
S5											
S6		2									
S7											
S8											
S9					1						

H. coronarum

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
S1											
S2								1		1	
S3				1							
S4											
S5											
S6											
S7							1			1	
S8											
S9											

H. comosa

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
S1					1						
S2											
S3		1									
S4											
S5		1									
S6	1	2									

L. clymenum

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
S1					1						
S2			1			2		1		3	
S3									1		
S4											
S5											
S6											

L. latifolius

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
S1							1				1
S2							1				
S3				1	1						
S4							1				
S5											
S6											
S7										2	
S8											
S9											

L. corniculatus

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
S1					1						
S2			3	1		5		1		3	
S3		1				4		2			
S4											
S5		1			2						
S6	1	4					1				
S7								1			
S8								1			
S9					1						

Table 9.5 (cont.)

L. tenuis

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
S1							1				
S2											
S3											
S4						2					
S5											
S6		1					1				
S7											
S8											
S9						1					

M. lupulina

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
				1	2					
			1	1		2		1		3
					1	2				1
	1									
1	3									
										2
					1					

M. sativa

S1						1				
S2				1		5				
S3						3				
S4										
S5					1					
S6		2				1				
S7										
S8										
S9					1					

O. viciifolia

[illegible]

O. spinosa

[illegible]

P. bituminosa

[illegible]

Table 9.5 (cont.)

T. fragiferum

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
1											
2									1		
3									1		1
4									1		
5											
6											
7											
8	1						1				
9								1			
10											
11						1					

T. ochroleucum

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
1						1					
2						1	3		1		
3						2					
4											
5											
6		1									
7	1	1									
8											
9											
10											
11											

T. pallidum

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
1											
2											2
3											3
4											
5											
6											
7											
8		1									
9											
10											1
11											

T. pratense

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
1						1	1				
2				2	1	2	3		2		
3		1		1		4	4		3		2
4						1	1				
5		1				3					
6	1	4					1				
7							1	1			1
8								1			
9						1					

T. repens

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
1					1	2	1				
2				2	1	2	1		2		
3				1		2	3		3		2
4						2					
5		1				2					
6	1	1					1				
7							1	1			1
8							1				
9						1					

cluster S6 (shallow, clay soils) and S3 (shallow, poor soils), and in almost all sites belonging to climate clusters ranging from cold to mild. Similar behaviour was shown by *T. repens*, which was found less commonly in cold sites. The frequency with which these species were collected suggests that they must possess a number of successful adaptation mechanisms, perhaps expressing themselves alone or in combinations. Despite this there is a lack of white clover cultivars adapted to Australian dryland environments, which results in unreliable persistence and herbage yield of the species in southern Australia (Archer & Robinson 1989). Genetic improvement of *T. repens* for dryland environments is therefore an important objective (Lane et al. 2000). A closer look at the morphology, physiology and genetics of the several accessions collected at the surveyed sites will provide further information. Earlier work by Bencivenga and Negri (1983) conducted in central Italy confirmed the wide distribution of these two clovers as they were recorded in fifty-three per cent and thirty-eight per cent of pastures in mountain sites, and forty-five per cent and fifty-nine per cent of hill pastures, respectively. Both species were indicated as having potential for marginal land rehabilitation, particularly as they are very grazing tolerant.

The distribution of *Medicago sativa* seems to be determined more by temperature than soil type. It was found principally in mild sites and in almost all types of soils, except those low in available phosphorus. However, it has also been listed in two cool sites and, most interestingly, in a site with a soil pH of 5.5. Although *M. sativa* is usually reported as being intolerant of acid soils, it is the high concentrations of aluminium and manganese that are often present in highly acid soils of which the species is particularly intolerant (Humphries & Auricht 2001). *Medicago sativa* is one of the few perennial legumes that are successfully grown in Australia, but it is restricted to the medium to high rainfall areas, and to neutral to alkaline soils (Hill 1996). *Medicago lupulina* was quite common in all sites characterised by poor soils in general (but not those low in available phosphorus), irrespective of temperatures and rainfall. This species was the most common in natural hill pastures of central Italy (Bencivenga & Negri 1983), recorded in seventy-four per cent of surveyed sites. The wide distribution was probably due to its grazing tolerance and its capability to spread through high seed production.

Lotus corniculatus also has a wide distribution, third only to that of white and red clover. It was found most frequently in sites with mild temperatures (climate cluster C7), and in sandy or shallow soils (soil cluster S2 and S3). Among the other clusters, it was recorded at Gualdo Tadino (central Italy), Santu Lussurgiu (Sardinia) and Fabrizia (Calabria), all sites characterised with soil pH levels as low as 5.2, 5.2 and 5.9 respectively. Similar to *M. lupulina*, the distribution of *L. corniculatus* was restricted by low levels of available phosphorus in the soil. It has previously been reported that *L. corniculatus* has a wide distribution across Europe, north Africa and east to the Himalayas and China (Kernick 1978) and will grow in acid to mildly alkaline soils (Duke 1981). Cocks (2001) suggested that its wide distribution meant it was likely to yield

ecotypes adapted to Australian conditions. The large genetic variation contained within the species also suggests there is potential for the selection of improved varieties (Kelman et al. 1997). A more detailed discussion of the agronomic potential of *L. corniculatus* is provided in Bennett (2002) in this volume. These results also confirm earlier reports that indicate *L. corniculatus* provides good ground cover (Bencivenga & Negri 1983). *L. tenuis* was less widespread, and where present it was in mild climates, even in soils with low phosphorus.

Hedysarum comosa was restricted to cold sites, *H. coronarium* to mild and warm sites, and *Onobrychis viciifolia* mainly to cold sites. The sites where *Anthyllis vulneraria* was recorded ranged from cold to warm, the soil type influencing its distribution more than temperature: it was more common in sandy soils with low lime content. *Dorycnium hirsutum* was found only in poor, shallow, sandy soils with a pH from 6.5 to 7.8 and a lime content not higher than eight per cent. Each of these species may have a role as alternative perennial species in areas with a mediterranean climate. *Hedysarum coronarium* is currently grown extensively around the Mediterranean for forage, green manure and soil improvement (Bennett et al. 2001), and Martiniello and Ciola (1994) suggest that the wild ecotypes represent an important genetic resource for breeding programs. *Dorycnium hirsutum* has been trialled in New Zealand (Wills et al. 1999) where they found that it was drought tolerant, but was slow to establish. *D. hirsutum* is currently under intensive evaluation in Western Australia where, as a deep-rooted perennial, it is showing potential in the recharge areas of the wheat belt.

Psoralea bituminosa preferred sites with warm climates; although it was also identified in one cool site (Bagaladi, Calabria, at high altitude). It was not recorded in the Sardinian sites despite being present on the island (Pignatti 1982). The high coumarin content, typical of this species, is a negative aspect. However variation in coumarin levels have been reported by Gintzburger (pers. comm.). The growth rate of this species seems to be quite productive (Pagnotta et al. 2002, this volume), and its possible use in pure stands should look at variation in coumarin content among different populations.

The distribution of *Trifolium pallidum* was almost confined to Sicily (with only one exception in a site in central Italy), and in soils with a wide range of lime content and a pH level from 7 to 8.3. *Trifolium fragiferum* was recorded only in sites with mild temperatures, but was found also in a site over 1000 m in altitude. This species is known to be tolerant of waterlogged soils (Townsend 1985) and is being used in these conditions in southern Australia. *Trifolium ochroleucum* was absent from warm sites and soils with high lime content. Its value as a pasture species was not highly rated (Cagiotti et al. 1996).

The survey carried out during flowering time gave the opportunity to look at all the above species, not only for their potential as pasture species, but also for their use as ornamental plants in Italy, to be used as cover species in sloping flower beds, rocky gardens or areas under tree plantations in town and cities. Species with potential may be *A. vulneraria*, *H. comosa* and *L. corniculatus*.

They are legumes and therefore would have low nitrogen requirements; plus as perennials there is no need for resowing. However, as they have not been domesticated there is likely to be propagation difficulties, but once they have established they are expected to survive harsh conditions and to require low maintenance. Characters of interest for ornamental rehabilitation would be length of flowering period, seed dormancy, and persistence.

In conclusion, the ecogeographic survey reported in this paper is an important starting point for the evaluation of Italian perennial legumes for the mediterranean areas of southern Australia. The descriptions of the climates and soil types of the sites where the different species were collected provides an important background to the potential areas in which the species may be adapted in Australia, and provides an insight to how widely adapted or how specialised each of the species is. As a result of the ecogeographic survey conducted in this chapter, and the evaluation described in the following chapter, a number of species have been selected and introduced to Western Australia for further evaluation.

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