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Serradella, subterranean clover and medic research, Esperance, Western Australia

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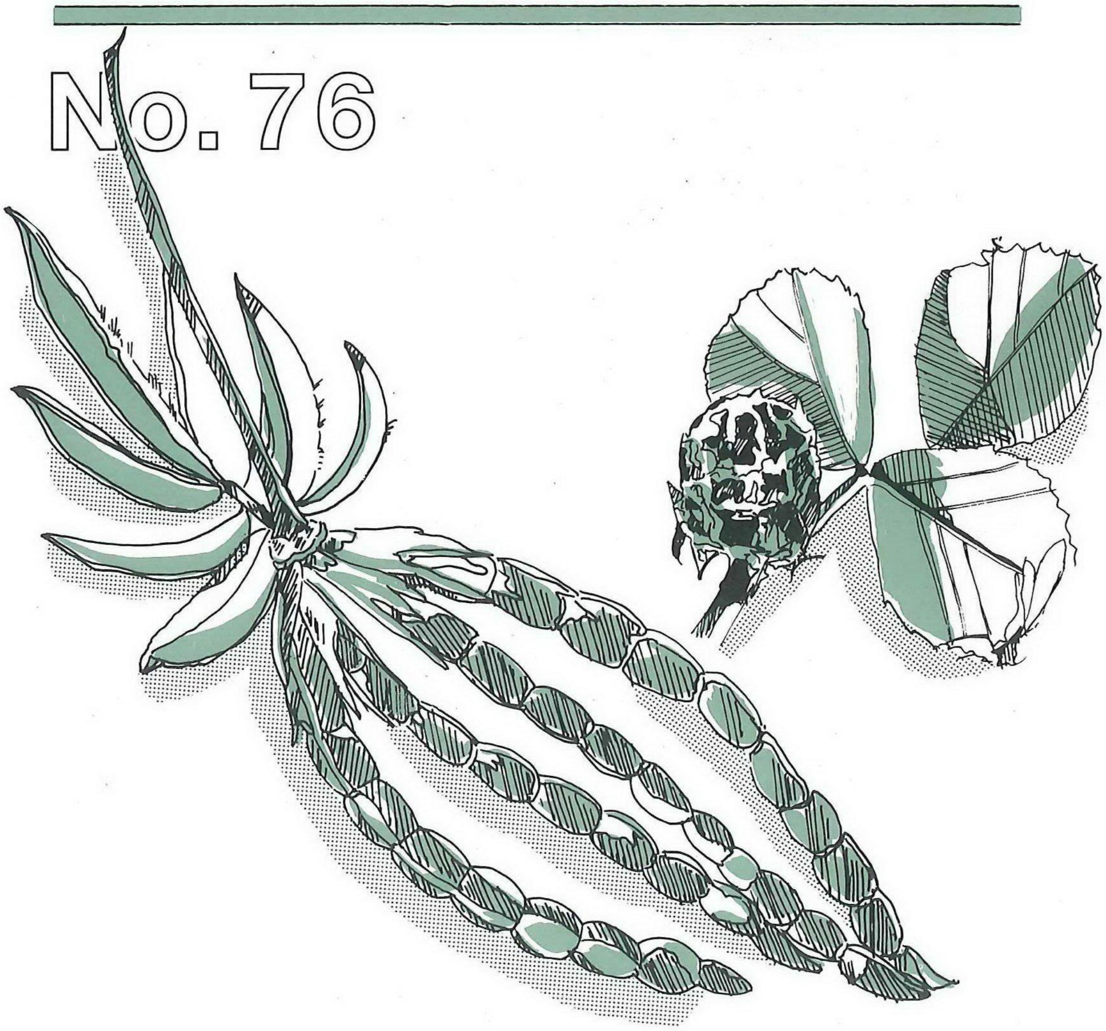
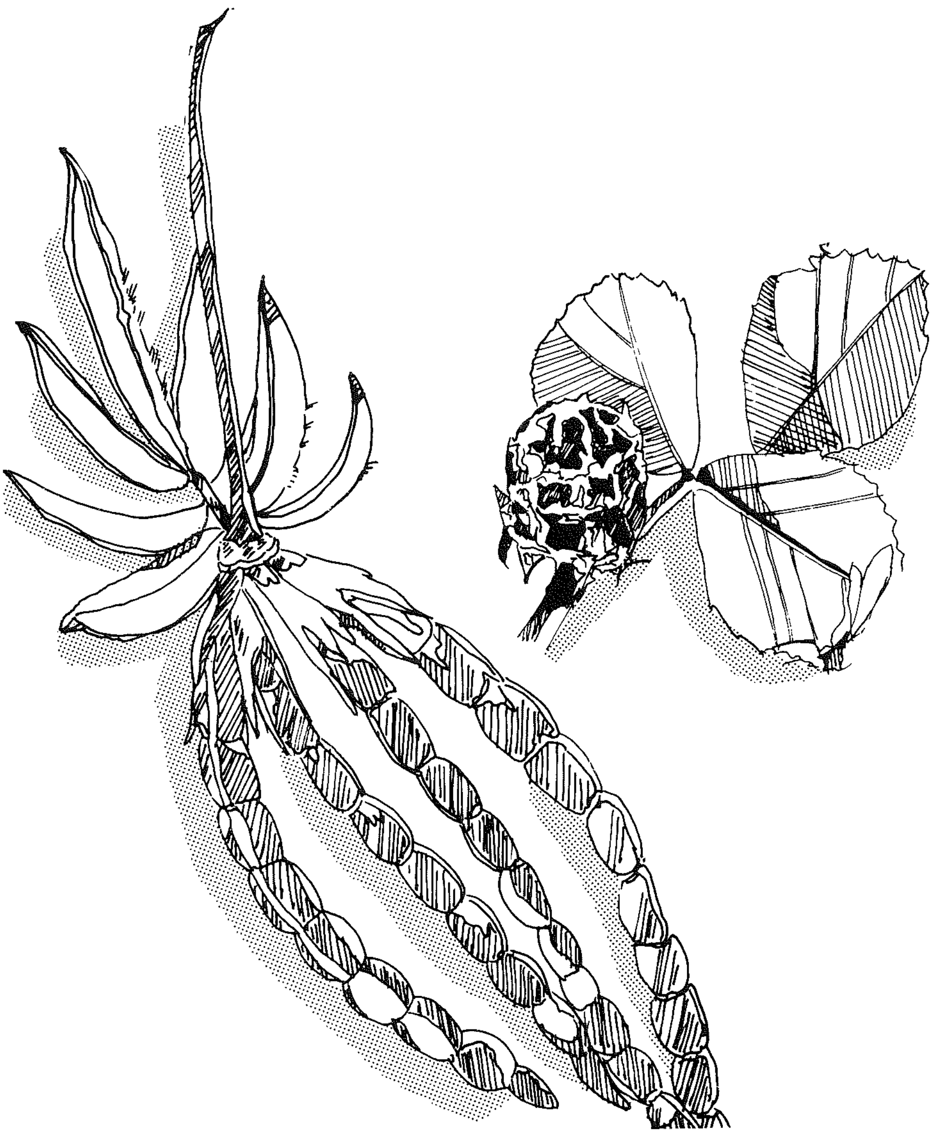


M.D.A. Bolland



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Summary

Serradella (*Ornithopus*)

In experiments located on sandy soils near Esperance, 33 accessions of five serradella species were assessed, during the four years 1980 to 1983, for maturity and seed yields in single strain, ungrazed swards. Samples of mature serradella pods were collected from two of these experiments in 1981 and 1982 for determination of the rate of softening of hard-seeds in a diurnal 15/60°C alternating temperature oven. There was a 30 d difference for the interval from sowing to the appearance of first flowers for *Ornithopus compressus*. Rates at which podded seeds softened were qualitatively similar for each accession between years, but within years varied markedly between species and strains of *O. compressus*. This wide range of maturity and hard-seededness should enable the eventual release of further serradella cultivars to increase the choice of serradellas which, at present, is limited to only two cultivars, *O. compressus* cv. Pitman and cv. Uniserra. In particular, strains of *O. compressus* which originate from Paros in southern Greece were the earliest flowering serradellas tested. They consistently produced amongst the highest seed yields, are relatively hard-seeded and are worthy of further investigation for deep sands and very acid soils in low rainfall areas (< 400 mm/a).

Constant temperature treatments of dehulled serradella seed before storage in the oven (control; 15°C for 2 d and 7 d; 30°C for 2 d, 7 d and 30 d) had no statistically significant effect on the softening of the serradella seed. Podded serradella seed was also collected from the plots during summer for a germination test. Compared with field tests, the proportion of soft-seeds counted from the laboratory oven tests were always higher. Qualitatively the trends were similar for both methods.

Monthly applications of nitrogenous fertilizer about doubled the herbage yields of serradella in winter. However, in spring, nitrogen had no effect on serradella herbage yields. By comparison subterranean clover herbage yields were unaffected by nitrogen application at any time, as were the seed yields of both serradella and subterranean clover. Cobalt applications had no effect on herbage or seed yields of serradella or subterranean clover. I conclude that low winter temperatures limit the symbiotic nitrogen fixation in serradella root nodules, which in turn limits winter herbage production. The implications for management of serradella-based pastures on deep sandy soils are discussed later.

Medic (Medicago)

In experiments in 1980 and 1981 on alkaline soils near Esperance, maturity, seed yield and the rates at which hard-seeds soften (in a diurnal 15/60°C alternating temperature oven) were measured for annual medic species grown as single strain, ungrazed swards. *Medicago polymorpha* cv. Serena produced amongst the highest seed yields. It was the earliest flowering medic tested. It was very hard-seeded and worthy of further testing in low rainfall (< 400 mm/a), intense cropping areas. *M. scutellata* also produced good seed yields at most sites. It was very hard-seeded and worthy of further testing on farms admixed with other medics as it is an insect resistant medic.

Phosphorus from superphosphate markedly increased medic seed yields by increasing the number of inflorescences and burrs. Phosphorus applications had no effect on burr weight, number of seeds/burr, seed weight and the rate of softening of hard-seeds.

Introduction

Part 1. Serradella research

For regenerating annual legumes, the capacity to regenerate effectively each year under the management conditions encountered on farms is essential. This depends on the seed-producing capacity of the legume and efficient seed germination control mechanisms. For annual legumes in south-western Australia, seed coat impermeability to water (hard-seededness), has been shown to be the most important germination control mechanism in the low rainfall (< 400 mm/a) areas (Quinlivan 1971 a and b). The seed coat becomes permeable to water as a result of fluctuating summer temperatures, which cause expansion and contraction of the seed coat and its eventual rupture, enabling water to enter the seed.

The sandplain soils near Esperance are texture contrast or duplex soils, being sand over lateritic gravel over a yellow mottled clayey subsoil (Teakle and Southern 1936; S.T. Smith, unpublished data). The principle soil profile is Dy 5.82 (Northcote 1979). The soils are marginally acidic and the depth of sand varies from a few centimetres to many metres. About 75% possess relatively shallow sand (< 0.5 m). Subterranean clover (*Trifolium subterraneum*) is well adapted to the shallow sandplain soils and has persisted as a successful self-regenerating annual legume on farms (Quinlivan and Francis 1976; Rossiter 1978; Collins *et al.* 1984).

Subterranean clover fails to persist on the deeper sandy soils near Esperance. These are grey sands (0-10 cm) over yellow sand, over gravel and clay at depths > 0.5 m. On farms, yellow serradella (*Ornithopus compressus*) has successfully persisted as a regenerating annual on some of these soils, but not on other apparently similar soils. Pitman is the only serradella cultivar which is readily available at Esperance. It is a late maturing yellow serradella, the origins of which are given by Gladstones and Barrett-Lennard (1964). Uniserra is the only other local cultivar of yellow serradella. It is an artificially produced mutant of Pitman, but flowers earlier (Gladstones and Devitt 1971). In Western Australia certified Uniserra seed is only produced near Eneabba, north of Perth, and then only infrequently and in small quantities.

In the absence of a persistent legume, the deep sandplain soils are non-productive and may present erosion problems. Emphasis was placed on extending areas sown to persistent serradella-based pastures on these soils. The difference between success and failure of serradella on the deeper sandplain soils appeared to be related to management of the pastures. Farmers with successful serradella-based paddocks believe the legume grows slowly in winter and, to ensure the persistence of the serradella, stress the importance of heavy winter grazing, together with cereal cropping every three to four years. They believe both strategies are essential to control the competition from volunteer herbs and grasses, which on these soils are principally capeweed (*Arctotheca calendula*); erodium (*Erodium moschatum* and *E. botrys*); flatweed (*Hypochoeris glabra*); annual ryegrass (*Lolium rigidum*); ripgut and soft brome (*Bromus diandrus* and *B. mollis*) and silver grass (*Vulpia myuros*). Farmers evolved these strategies based on their observations and experience with serradella-based pastures.

The release of cultivars that mature earlier than cv. Pitman may help extend the areas of deep sandy soils sown to persistent serradella-based pastures. This was the case with the release of subterranean clover cultivars which mature earlier than the first used cultivar, Mt Barker, and which markedly increased areas sown to persistent subterranean clover-based pastures (Donald 1960; Rossiter 1978). About 400 strains of the five serradella species have been collected in countries bordering the Mediterranean Sea and in central and northern Europe. Based on preliminary row evaluations in Perth by J.S. Gladstones, a selection of 33 strains of the five species were chosen for evaluation near Esperance. Details of the five serradella species are given by Gladstones and McKeown (1977).

Local knowledge of serradella is limited. Little is known of the maturity range; seed-producing capacity; germination control mechanisms; rooting depth; nutritional requirement; or insect and disease resistance in the field. The first aim of the research was to investigate some of the aforementioned factors, more particularly the first three.

The second aim was to determine whether low winter temperatures and/or cobalt deficiency limit symbiotic nitrogen fixation in serradella. Applications of cobaltic fertilizer increased the vegetative yields of sweet lupins (*Lupinus angustifolius*) (Gladstones *et al.* 1977; Chatel *et al.* 1978) by increasing nitrogen fixation (Robson *et al.* 1979). Thus, applications of cobaltic fertilizer may also improve herbage yields of serradella in winter. Commercially both serradella and sweet lupins are inoculated with *Rhizobium lupini* strain WU 425.

Materials and methods

There are two main soil types in the farming areas around Esperance, situated parallel to the south coast of south-western Australia (see maps 1 and 2). These are the sandplain soils located adjacent to the coast and alkaline soils to the north (map 2). Research with serradella was done on the sandplain soils and annual medic research on the alkaline soils.

All the serradella experiments were on newly cleared, well drained grey sand (0-10 cm) over yellow sand over lateritic gravel or gravelly clay subsoil (Dy 5.82, Northcote 1979)(map 1). The depth of sand was between 15-60 cm. Detailed descriptions of these soils are given by Teakle and Southern (1936).

The methods used in the serradella research to investigate the two aims of the work, are itemised separately. In section 1, a preliminary assessment was undertaken of 33 strains of five serradella species compared with subterranean clover. In experiments 1 to 4 maturity, seed yield, and the rate of softening of hard-seeds was measured as determined in a diurnal 15/60°C alternating temperature oven, the standard procedure used to study hard-seededness (Quinlivan 1961, 1965, 1966, 1971a and b; Taylor 1981). In experiment 5 the influence of different constant temperature treatments on serradella seed before storage in the oven was also investigated. In this study, the rate of softening of hard-seeds determined in the laboratory oven was compared with the proportion of soft-seeds measured from samples collected periodically in the field during summer. Section 2 assesses the effect of fertilizers of nitrogen (N) and cobalt (Co) on the herbage and seed yields of serradella and subterranean clover as measured in experiments 6 and 7.

1. — Preliminary assessment of serradella species and strains compared with subterranean clover

Maturity, seed yields and the pattern of softening of podded hard-seeds of serradella strains and cultivars compared with subterranean clover was measured in four experiments which differed as to location, year started and in the strains of each species studied. In the fifth experiment, only serradella was grown.

1. Condingup, — 1980
2. Condingup (adjacent to 1), — 1981
3. Mt Ney, — 1981
4. Myrup, — 1982
5. Myrup (adjacent to 4), — 1982

Experiments 1 to 4 were completely randomized blocks, with one replication for experiment 1 due to lack of seed, and three replications for the other three experiments. The species and strains for each experiment are listed in table 1. The day before sowing, the dehulled seed was inoculated and lime pelleted. *Rhizobium lupini* strain WU 425 (as commercial group G inoculum) was used for the serradellas and *Rhizobium trifolii* strain WU 95 (as commercial group C inoculum) for the subterranean clovers. The seed was mixed with the fertilizer just before sowing and applied by hand to the soil surface within plots 2 m wide and 40 m long. There was a 2 m buffer between plots. The seeding rate, with approximate individual seed weight (mg) in parenthesis, was: *O. perpusillus* 1.5 kg/ha (1.4); *O. pinnatus* 1.0 kg/ha (1.0); all other serradellas 2.5 kg/ha (range 2.3-3.0) and subterranean clover 8 kg/ha (5-10). The fertilizer applied at seeding (mid May) was 450 kg/ha superphosphate No. 1 (9.5% P, 11% S, 24% Ca, 0.66% Cu, 0.52% Zn and 0.08% Mo); 450 kg/ha ordinary superphosphate (9.5% P, 11% S and 24% Ca) and 100 kg/ha potassium chloride (50% K). In late August, 50 kg/ha of ordinary superphosphate and 50 kg/ha potassium chloride were applied to all plots. High rates of fertilizers were used to ensure that nutrients were non-limiting because in phosphorus- deficient situations, annual pasture species have different phosphorus requirements (Asher and Loneragan 1967), and use fertilizer applied phosphorus with different efficiencies (Ozanne

et al. 1965; Barrow 1975). Pasture species have different rooting depths and morphologies which affects the ability of the plants to use nutrients (Ozanne *et al.* 1965). Light harrows were dragged along each plot after seeding to cover the seed. With the exception of experiment 2 in 1982, which was grazed with about 3 adult sheep/ha until the first flowers appeared on the early maturing serradella strains, the experiments were not grazed. Apart from experiment 2, the experiments were sprayed with 2 L/ha DDT soon after emergence of the seedlings to prevent red-legged earth mite (*Halotydeus destructor*) damage. These insects can kill emerging seedlings. Once flowering had commenced, the experiments were sprayed once with 2 L/ha DDT to control native budworm (*Heliothis punctiger*) which can severely reduce serradella seed yields by eating seed from immature, green pods. From early August onwards bluegreen aphids (*Acyrthosiphon kondoi*) were found in the vicinity of the experiments, and the plots were sprayed with 150 g/ha pirimicarb once a fortnight.

Measurements

• Maturity — The interval from sowing to appearance of first flowers (considered to have occurred when there was one flower per dm^2) was recorded. In table 1, these have been expressed as a maturity grading (MG), which was calculated by subtracting the interval from sowing to appearance of first flowers of the earliest flowering serradella strain from that determined for each of the other serradella or subterranean clover strains. A strain flowering 10 d after the earliest flowering strain had an MG value of 10.

• Seed yield — Serradella seed yields were measured from the whole plot (the experiments were also used to bulk up seed for further field evaluations). Serradella pods on dried stems were collected with a lawnmower. Mature serradella pods and individual pod segments eventually drop onto the soil surface. Pods and segments on the soil surface were collected using a Toro vacuum machine, which had a 50 cm inlet. The machine was moved along the whole plot to harvest as many pods as possible. The pods collected from each plot were separated from the stems, sand and debris by sieving and were bulked. The pods (husks) were removed from around the serradella seed by passing the podded seed through an Engle's dehuller, similar to that described by Weeldenburg and Smith (1969). This machine was further modified resulting in > 98% of the dehulled and scarified seeds being viable, with the exception of *O. sativus*, for which about 70% of the seed was viable. The seed was separated from the empty pods by sieving and was then weighed.

Subterranean clover burrs were collected by digging up soil to a depth of 5 cm from ten randomly selected 10 cm x 100 cm quadrats per plot. Sand was removed by sieving and the seed removed from the burrs by threshing.

• Hard-seed — The method used to measure hard-seededness was similar to that described by Quinlivan (1961). After the plants had dried off, serradella pods and subterranean clover burrs were collected from each plot of experiments 3 and 4 (1982 only) and stored in calico bags in an oven programmed to produce a gradual diurnal temperature fluctuation of 15/60°C. Thermometers were placed with the pods or burrs within the calico bags in the oven and the temperature recorded hourly for several 24 h periods. A temperature pattern similar to that obtained by Quinlivan (1961, figure 2, p. 1013) is shown in figure 1.

After 7 d storage in the oven, subsamples of seed were removed for a germination test. Further subsamples were collected for determination of moisture content. Podded serradella seed was used for these tests. The seeds of subterranean clover were removed from the burrs by hand before doing the tests. For the germination test, samples were placed on moist filter paper in a petri dish, using three subsamples for each replication and stored in a 15°C germination cabinet for 14 d, when the number of soft (i.e. swollen and germinated) seeds were counted. The pods (husks) were easily removed from the serradella seed after the 14 d storage to count the swollen seeds. The germination test was repeated at least once a month thereafter.

For the measurement of moisture content, the seed was weighed and then dried at 105°C for 48 h before being weighed again. The moisture content was determined on a dry weight basis.

Preliminary experiments were conducted to compare the moisture contents determined for podded serradella seed which was untreated, chopped up (using a scalpel), mashed (using a pestle and mortar) and drying the samples at 105°C or 150°C for 48 h and 168 h. The differences between the various procedures were not statistically significant ($P > 0.05$).

In experiment 5, the laboratory data on the rate of seed softening was compared with the measurements of soft-seeds using a germination test for samples of seed collected periodically in the field over summer.

The design of experiment 5 at Myrup, 12 km north-east of Esperance was a randomized block of three serradella species and strains (*O. compressus* cv. Pitman and CPI 47250, and *O. perpusillus* GM 034) with six replications. Management was as described for experiments 1 to 4, except a seeding rate of 25 kg/ha was used for *O. compressus* (average seed weight about 2.5 mg) and 15 kg/ha for *O. perpusillus* (average seed weight 1.5 mg). The experiment was sown in late May 1982.

When the plots had dried off and the pods were mature (mid December 1982), samples of pods were collected from each plot. Seed was carefully removed from the pods using a scalpel. Damaged seed was discarded. Samples of seed were then stored in ovens at the following temperatures and for different periods of time: 15°C for 2 d; 15°C for 7 d; 30°C for 2 d; 30°C for 7 d and 30°C for 30 d. A sample of 200 seeds was then selected from each treatment and placed in small plastic ice-cube trays. A control sample of 200 dehulled serradella seed which had received no temperature treatment was also included. The trays were stored in a diurnal 15/60°C fluctuating temperature oven for 7 d. At the end of this period, water was added to the trays and they were stored for 48 h at 15°C in a germination cabinet. The water was removed from the trays with Pasteur pipettes, and the swollen (i.e. soft) seed removed and counted. The trays were returned to the alternating temperature oven and the procedure repeated about once a month for 10-12 months.

Before the start of this experiment, subsamples of podded seed were selected for determination of moisture content as described for experiments 2 and 4.

Samples of podded serradella seed were collected from the field plots during 1982/83, for determination of seed moisture and a germination test. For the latter test, pods were placed on moist filter paper in petri dishes in a 15°C germination cabinet for 14 d. The pods were then easy to remove from around the seed. Germinated and swollen seeds were counted.

2. — Effect of fertilizers of nitrogen and cobalt on herbage and seed yields

These effects were measured in experiment 6 in 1982 and 1983. The trial was at Myrup, adjacent to experiments 4 and 5. An ancillary experiment 7 at Neridup, 30 km north-east of Esperance was started in 1983.

The design of the main experiment 6 was a randomized block of 24 treatments which were six rates of cobalt sulphate (21% Co) x two fertilizer N treatments (with and without nitrogenous fertilizer treatments applied regularly to the surface) x two pasture species (serradella cv. Pitman and subterranean clover cv. Esperance) with three replications.

The seed was inoculated and lime pelletted and sown mixed with the fertilizer as described in section 1. Serradella was sown at 50 kg/ha (average seed weight 2.5 mg), and subterranean clover at 100 kg/ha (seed weight 5.0 mg). Plots were 2 m x 5 m, with 2 m buffers around each plot. Basal fertilizer applied at sowing (June 2, 1982) was: 850 kg/ha superphosphate; 100 kg/ha potassium chloride; 10 kg/ha copper sulphate (27% Cu); 2 kg/ha zinc oxide (80% Zn) and 0.5 kg/ha molybdenum trioxide (67% Mo) and 3 kg/ha sodium borate (11% B). Cobalt as $CoSO_4.7H_2O$, (rates shown in table 5), was applied, together with nitrogenous fertilizer, with the seed and the basal fertilizer as for experiments 1 to 5. The nitrogen was applied as granulated ammonium nitrate (34% N). The amount of N applied at sowing was 51 kg/ha and 17 kg/ha was applied at the beginning of July, August, September and October in 1982 and early June and July in 1983. Potassium chloride was re-applied at 100 kg/ha in August 1982 and June 1983 mixed with superphosphate which was applied at 50 kg/ha and 400 kg/ha, respectively.

Slender serradella, *Ornithopus pinnatus.* The strains studied were collected from Morocco and Tunisia in North Africa and at Esperance produced large quantities of small seeds.

Control of red-legged earth mite and native budworm was as described. The plots were not grazed. Herbage yields were measured by cutting all top growth in random quadrats, using a new section of the plot each time. The herbage was dried at 70°C in a forced draught oven before weighing. Serradella seed was collected from random quadrats in early February, 1983. Subterranean clover burrs were collected as described earlier. Seed yields of both serradella and subterranean clover were measured as before.

In late July 1982, ten plants, selected at random, were dug up from each plot and the root nodules examined. Nodules were dissected to check for colour and the number of nodules developed on the tap and lateral roots counted. If nodules are red they are successfully nodulated.

In the ancillary experiment 7 the design was a randomized block of 10 treatments which were five pasture species with or without regular applications of N fertilizer applied to the surface with four replications. The pasture species were: *O. compressus* cv. Pitman; *O. pinnatus* GT 045; *O. perpusillus* GM 034 and *T. subterraneum* cv. Daliak and cv. Seaton Park. Sowing rates on May 12, 1983 were 50 kg/ha for Pitman (average seed weight 2.5 mg); 30 kg/ha for GM 034 (seed weight 1.5 mg); 20 kg/ha for GT 045 (seed weight 1.0 mg); 100 kg/ha for Daliak (seed weight 5.0 mg) and 140 kg/ha for Seaton Park (seed weight 7.0 mg).

The plots were sown, managed and sampled as described for experiment 6 except that cobalt sulphate (21% Co) was applied to all plots at 2 kg/ha.

Results

1. ·Preliminary assessment of serradella species and strains compared with subterranean clover

There was a difference of about 30 d in the appearance of first flowers between strains of *O. compressus*. Those earlier than cv. Uniserra (table 1) were GT 046 and all the DP strains. These strains also consistently produced amongst the highest serradella seed yields (table 1). The rate of softening of podded serradella varied markedly between serradella species and between strains of *O. compressus* (tables 2 and 3). After 7 d storage in the alternating temperature oven, the moisture content of all podded serradella seed and subterranean clover seed was < 4%. Thus, the seeds were likely to be impermeable. The early maturing *O. compressus* strains were generally relatively hard-seeded. The rate of softening of podded serradella seed and subterranean clover seed were qualitatively similar for both experiments 3 and 4, but quantitatively different (compare tables 2 and 3). The seed from experiments 3 and 4 were grown in different years at different locations.

Emergence of all species and strains was satisfactory, being about 81 (± 12) plant/m^2 for each of the experiments 1 to 4 in the first year. However, there were two exceptions. For the two *O. sativus* strains, only about 32 (± 18) plants/m^2 emerged. Reasons for the large losses (about 60%) for *O. sativus* are not known, but probably a large proportion of the seed was destroyed in dehulling, a relatively severe process involving passing seed between a rotating and stationary disc both faced with coarse emery paper.

Seed harvesting was never completely successful, as subsequently all plots self-generated to the original strains in the following year. Plant densities measured in mid June 1982 for experiment 2, which was the second year of the experiment, were about 70 plants/m^2 for both *O. pinnatus* strains, about 45 plants/m^2 for the *O. perpusillus* strain and about 25 plants/m^2 for all other strains.

The average seed weights for serradella harvested were consistently about 0.9 mg for both *O. pinnatus* strains; about 1.4 mg for the *O. perpusillus* strain and about 2.5 mg (range 2.0-3.0 mg) for strains of the other serradella species.

The proportion by weight of seed in the harvested serradella pods ranged from 15 to 30%, depending on strain and species. Results shown in table 4 for experiment 4 in 1982 are consistent with the data for experiments 1, 2 and 3.

The strains of the serradella species had markedly varied growth habits when they were ungrazed. Both strains of *O. sativus* and *O. isthmocarpus* had erect growth habits, as did the *O. compressus* strains GT 046; CPI 47250; CPI 47251; M 34; M 115; M 133; M 167 and cv. Uniserra. By contrast, *O. compressus* cv. Pitman; GS 046.1; GS 046.2; CPI 50484 and CPI 50774 were prostrate and a darker green when ungrazed. However, in experiment 2 when the serradellas were grazed by sheep before flowering in the second year (1982), all strains and species were prostrate and the *O. compressus* strains were difficult to identify using morphological features.

Irrespective of the constant temperature treatment of serradella seed before storage in the alternating temperature oven, the rate of softening of hard-seeds was similar (figure 2). When the data were transformed (using an arcsine $\sqrt{x}$ transformation) there was no statistical difference ($P > 0.5$) between any of the treatments for each species at each sampling time. Before the constant temperature treatments, the moisture content of the seeds was < 4% (dry weight basis). Results of the germination tests on samples of podded seed collected from the plots during summer are listed in table 5. The results

qualitatively follow the general trend measured in the oven, but the number of soft seeds counted for the samples stored in the oven were higher, particularly for *O. compressus* cv. Pitman.

2. — Effect of fertilizers of nitrogen and cobalt on herbage and seed yields

In the main experiment 6 there was no herbage or seed yield responses to cobalt applications for serradella or subterranean clover, both in the absence and presence of nitrogen (table 6).

Regular applications of N fertilizer did not affect the herbage or seed yields of subterranean clover (table 6). However, N applications had a marked effect on the herbage yields of serradella. Yields of dried serradella herbage were increased by a factor of about 2.4, 2.8 and 1.5, respectively, for the first three samplings in 1982 and by a factor of about 1.8 for the August 1983 sampling. Nitrogen applications did not affect serradella herbage yields in late spring (November 1982), or the 1982 serradella seed yields.

For the late July 1982 sample, irrespective of Co and N fertilizer treatments, many dissected serradella and subterranean clovers nodules were bright red indicating successful nodulation. The number of nodules and distribution of nodules between tap and lateral roots were similar.

In the ancillary experiment 7 regular applications of N fertilizer improved dried serradella herbage yields measured in August (1983) by between 3 and 8 times, depending on species (table 7). However, by September, the herbage yields for each species were similar, both for the no-N and plus-N treatments. For subterranean clover, dry herbage yields measured in both August and September were similar for both N treatments. Seed yields of serradella and subterranean clover were unaffected by the N treatments.

Discussion

On the basis of serradella seed yields and the rate of softening of podded seed in the laboratory oven, the early flowering strains of *O. compressus* warrant further investigation on deep sandy soils and very acidic soils in marginal areas with < 400 mm/a rainfall. Pitman persists on deeper sandy soils near Esperance, but probably flowers too late for those soils located in low rainfall zones with < 400 mm/a. Serradella and lupins, particularly *L. cosentinii*, are the only annual legumes to persist on very acid soils in marginal rainfall areas of New South Wales (Freebairn 1980) and Western Australia (M.A. Ewing, unpublished data). For marginal rainfall areas, seed-producing capacity and high levels of hard-seededness are probably the two most important factors determining the successful persistence of regenerating annual legumes on farms (Rossiter 1966a and 1977; Quinlivan 1971 a and b).

On the basis that a wider choice of maturity types will enable serradella to be better exploited on farms, my research showed that *O. compressus* CPI 47250; GM 016; M 115; M 167 and *O. perpusillus* GM 034 warrant further study. The last named strain has been found to spread rapidly from old experimental sites and to eventually become the dominant serradella on and around the sites.

O. compressus cv. Pitman was probably the best of the later flowering strains tested, though *O. compressus* strains CPI 50484 and CPI 50774 probably warrant further study for their adaptation to deep sandy soils or acid soils in rainfall areas of > 400 mm/a.

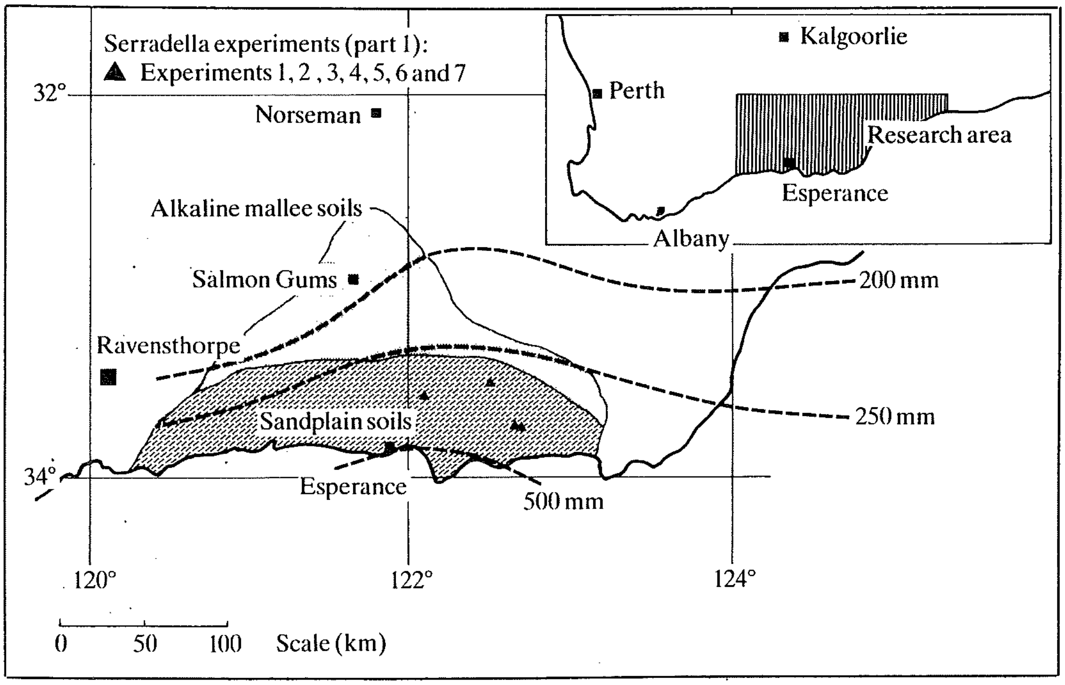
The appropriate level of hard-seededness for serradella at Esperance is unknown. However, *O. compressus* cv. Pitman has persisted successfully at Esperance when grazed and cropped in a 1 year crop: 3 to 4 year pasture ley rotation. Pitman is relatively soft-seeded (tables 2 and 3).

None of the constant temperature treatments on serradella seed before storage in the alternating temperature oven altered the rate at which the seeds softened. As for other annual legumes (Quinlivan 1971a), the major cause for the serradella seeds softening was fluctuating temperatures. However, for subterranean clover, Taylor (1981) found that the higher and longer the constant temperature treatment was before storage in an alternating temperature oven, the faster the subsequent rate of softening of hard-seeds. He observed these effects for both higher and longer exposures to constant temperatures, before storage in the alternating temperature oven, than was used in my serradella experiment.

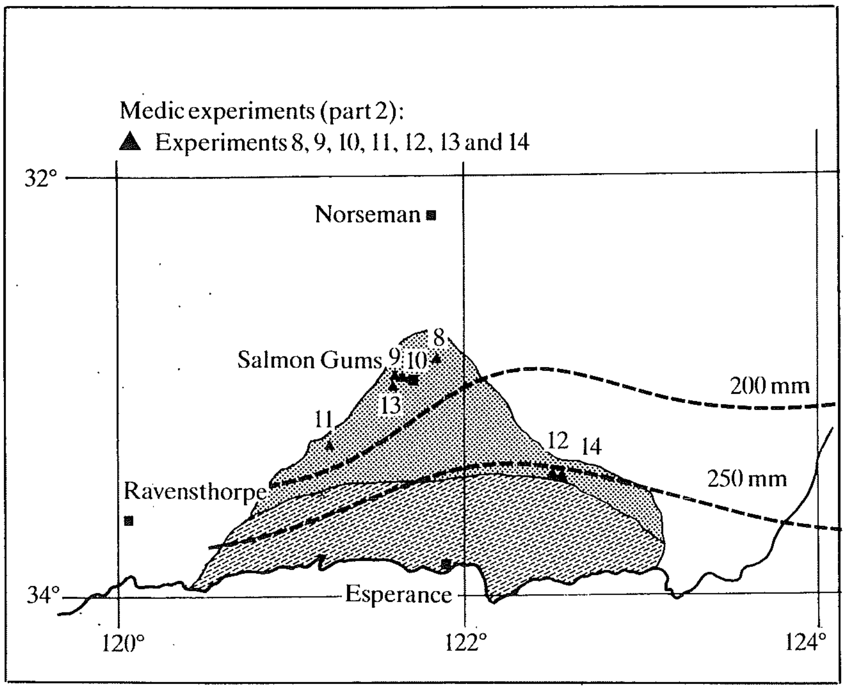
From the results of experiments 6 and 7, I conclude that low winter temperatures limit the rate of symbiotic N fixation in the root nodules of serradella. In turn, this lack of N limits winter herbage production. As temperatures increase in spring, the rate of N fixation no longer limits herbage production and the serradella seed yields were similar for both N treatments. Cobalt had no effect on herbage and seed yields of both serradella and subterranean clover.

The sandplain soils adjacent to the south coast near Esperance appear to have a low capacity to accumulate organic matter and thus organic N (K.P. Young and A.D. Robson, personal communication). These soils are subject to summer rainfall, which may cause rapid mineralization of soil organic matter in the relatively warm summer temperatures. Therefore, in cold winter months, in the absence of fertilizer N and with little accumulated organic N, growth of serradella may be limited. Unless the pastures are grazed to prevent the volunteer companion grasses and herbs over-topping the serradella, the serradella may disappear. The practice of heavy winter grazing of cv. Pitman serradella-based pastures is probably the key factor in maintaining serradella on these soils. The release of earlier maturing, harder-seeded cultivars will expand the area of serradella-based pastures on deep sandy and acid soils in low rainfall areas. The maturity of Pitman and Uniserra currently restricts successful sowings to areas with an average annual rainfall > 400 mm/a (Gladstones and McKeown 1977). Moreover, the earlier maturing Uniserra is difficult to purchase commercially.

Maps and tables



Map 1



Map 2

Map 1 Location of serradella experiments, average length of the winter growing season and average rainfall May to October. (Commonwealth Bureau of Meteorology).

Map 2 Location of the medic experiments and mean rainfall (May to October). Dotted area represents the approximate area of the alkaline soils cleared for agriculture and which are suitable for growing annual medics. The hatched area represents the approximate area of neutral to marginally acidic sandplain soils and about 75% are suitable for subterranean clover. The remainder are deep sands which are suitable for serradella.

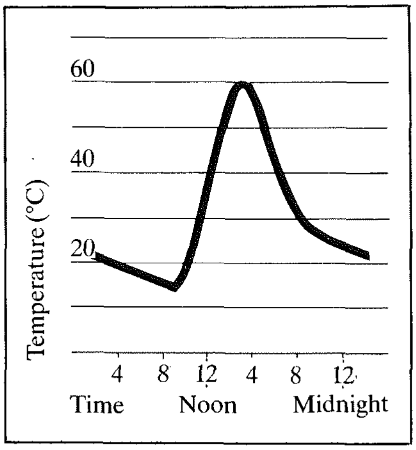


Figure 1 **Temperature pattern in the 15/60°C diurnal alternating temperature oven as measured by thermometers placed inside serradella pods, subterranean clover burrs and medic burrs stored in calico bags.**

Figure 2 **Relationship between per cent soft-seed and the storage period in a diurnal 15/60°C alternating temperature oven for samples of dehulled serradella seed collected from experiment 3 and which had been subject to different constant temperature treatments before storage in the alternating temperature oven.**

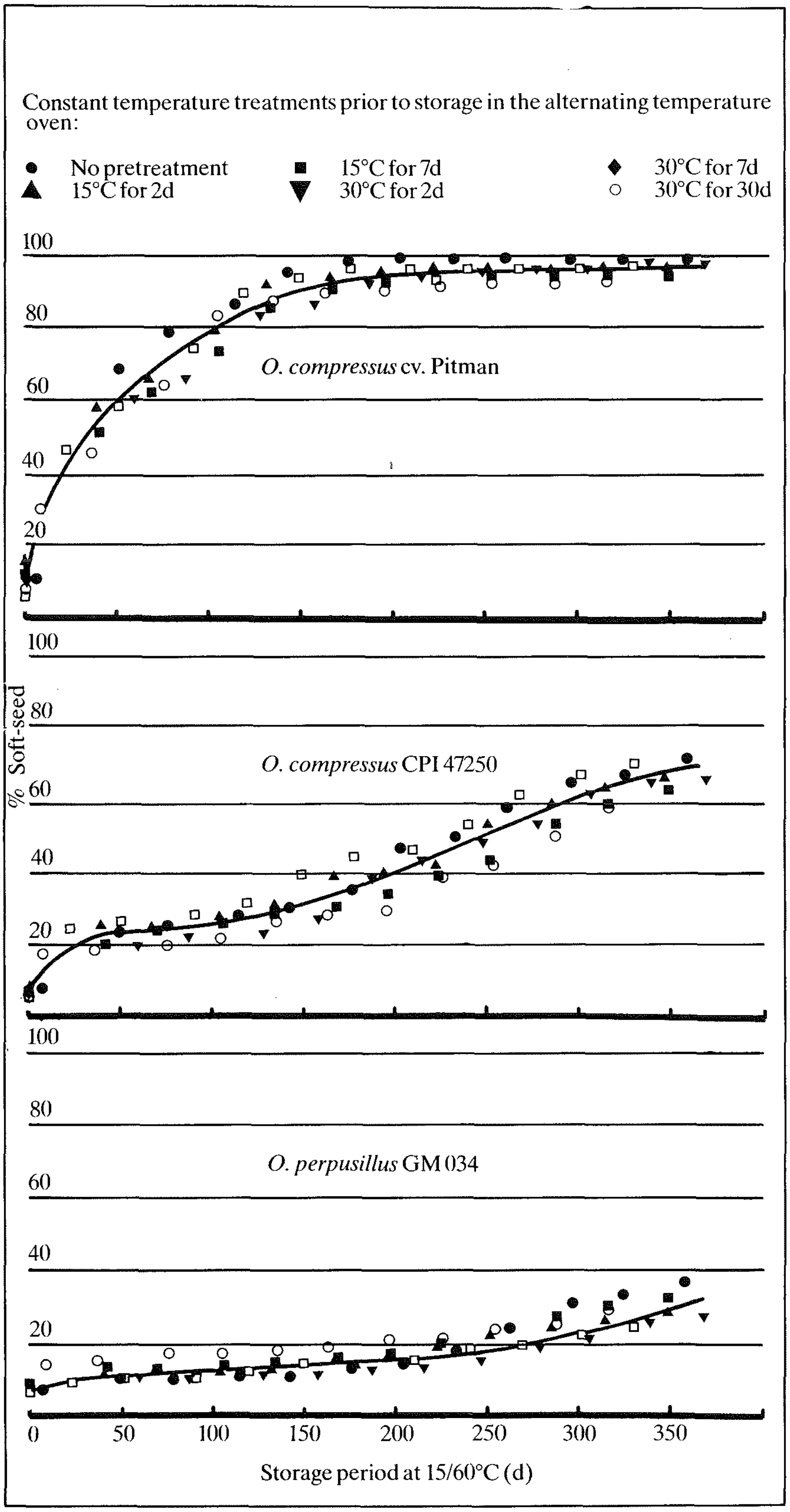


Table 1: Maturity grading (MG) ++ in days and seed yield (SY) (g/m^2) for strains of the serradella species and subterranean clover cultivars for experiments 1, 2, 3 and 4. The standard error is shown in parenthesis (± s.e.)+

Species and strain*	Expt 1 1980		Expt 2 1981		Expt 2 1982		Expt 3 1981		Expt 4 1982		Expt 4 1983	
	MG	SY	MG	SY	MG	SY	MG	SY	MG	SY	MG	SY
Ornithopus												
O. compressus												
cv. Pitman			26	19(4)+	29	34(2)+	23	15(4)+	25	18(2)+	23	18(3)+
cv. Uniserra							9	10(3)				
GM 016	10	4	16	15(4)	17	19(1)	11	12(1)	10	26(2)	9	28(3)
GM 043.2	20	7	30	20(5)	28	18(3)	16	12(1)	14	7(2)	10	7(3)
GM 057.1	11	2	18	4(1)	17	12(2)	10	7(2)	10	8(1)	9	8(1)
GM 065.1	11	1	18	5(1)	23	18(1)	12	8(2)	12	10(3)	9	10(3)
GM 065.2	9	17	16	9(1)	17	28(2)	9	12(3)	10	15(1)	10	16(2)
GM 065.3	11	6	16	11(3)	20	13(1)	11	6(1)	12	10(1)	10	7(2)
GM 107	10	1	16	15(4)	23	12(1)	10	28(5)	17	11(2)	15	10(3)
GT 046	2	10	9	25(6)	12	21(3)	9	11(4)	3	20(3)	4	23(2)
GT 047.1	14	7	23	7(2)	23	15(4)	16	1(1)				
CPI 47250	20	11	18	12(1)	28	25(3)	16	18(2)	14	11(3)	9	11(4)
CPI 47251	27	1	38	4(1)	35	18(2)	33	7(1)	29	8(2)	22	10(2)
CPI 50484	27	3	38	23(5)	35	12(1)	32	21(6)	29	8(2)	22	8(3)
CPI 50774	19	17	30	22(8)	27	13(1)	30	21(3)	29	6(1)	25	6(1)
GS 046.1	15	5	19	19(1)	35	12(1)	18	10(3)	20	8(2)	17	5(1)
GS 046.2	27	5	38	13(2)	23	9(1)	18	37(5)				
DP 3			0	17(4)	0	38(6)			0	29(3)	0	27(3)
DP 4			4	13(2)	3	42(5)	3	38(4)	3	17(2)	2	21(2)
DP 5			0	20(5)	0	48(8)						
DP 6			0	17(3)	0	44(3)	0	26(5)	0	31(2)	0	22(6)
M 34	0	3					5	6(2)				
M 115	6	7	13	14(2)	17	21(1)	11	7(2)	5	21(2)	5	21(5)
M 133	6	3	16	7(7)	14	24(1)	9	10(3)	7	8(1)	7	8(2)
M 167	9	6	16	8(5)	17	26(2)	9	8(2)	5	25(2)	5	26(3)
O. sativus												
CPI 16006	26	3	39	5(3)	38	24(5)	30	20(5)	31	2(1)	27	3(1)
CPI 47656	28	5	42	4(2)	40	8(2)	33	6(2)	34	6(1)	0	5(3)
O. pinnatus												
GM 134.1	19	5	26	16(4)	28	21(1)	16	16(4)	23	17(2)	19	9(2)
GT 045	27	25	38	12(1)	35	24(5)	30	11(5)	25	13(2)	22	24(5)
O. perpusillus												
GM 034	10	15	18	13(2)	29	24(2)	16	10(3)	21	14(3)	17	16(4)
O. isthmocarpus												
GM 17	22	3	30	12(2)	29	16(3)	31	21(5)	24	9(2)	19	5(1)
GM 30.1	16	2	26	10(1)	28	6(1)	20	15(6)	20	7(2)	15	4(2)
*O. species***												
GM 113.2	18	14	38	14(3)	37	13(1)	18	16(3)	27	11(2)	21	10(1)
Trifolium												
T. subterraneum												
cv. Esperance			12	15(3)	15	42(7)	9	38(6)	7	41(8)	5	25(7)
cv. Daliak			5	38(8)	7	52(15)	4	62(5)	2	59(7)	1	43(6)
cv. Nungarin			-7	52(12)	-5	75(12)	-5	57(7)	-6	68(2)	-9	47(10)
cv. Trikkala			14	15(3)	16	21(6)	13	20(4)	15	13(3)	7	7(2)

\+ Standard error. There was only one replicate for experiment 1.

* CPI = Commonwealth Plant Introduction
M = Mutants of cv. Pitman (Gladstones and Devitt 1971).
G = Seed collected by J.S. Gladstones in M = Morocco, T = Tunisia, S = Spain
DP = Seed collected by D.J. Gillespie in Paros, southern Greece.

** Unknown species, but probably *O. compressus* (J.S. Gladstones, personal communication).

++ *Maturity grading (MG) is calculated each year by subtracting the interval from sowing to appearance of first flowers of the earliest flowering serradella strain from that determined for each of the other serradella or subterranean clover strains.*

Table 2: Percentage of soft-seeds determined for podded serradella seed collected from experiment 3 in 1981 and stored in a diurnal 15/60°C alternating temperature oven, (± s.e.)+

Species* and strain	Per cent soft-seed								
	Storage period (d)								
	7	33	61	90	160	205	244	279	315
Ornithopus	%	%	%	%	%	%	%	%	%
O. compressus									
cv. Pitman	29(5)+	49(2)+	58(5)+	70(3)+	66(3)+	76(4)+	79(1)+	93(1)+	91(2)+
cv. Uniserra	33(1)	42(3)	40(3)	62(2)	67(7)	66(4)	62(3)	76(6)	81(2)
GM 016	3(1)	4(2)	5(1)	4(1)	5(1)	12(2)	16(1)	19(2)	21(3)
GM 043.2	8(1)	7(1)	5(1)	6(1)	12(2)	14(5)	14(1)	31(4)	29(2)
GM 057.1	4(1)	3(1)	4(1)	3(1)	18(1)	26(2)	22(2)	47(4)	49(3)
GM 065.1	5(1)	6(1)	5(1)	5(2)	9(2)	19(1)	22(3)	33(2)	26(2)
GM 065.2	4(1)	5(1)	4(1)	6(1)	5(1)	11(2)	8(2)	21(1)	47(3)
GM 065.3	7(1)	7(1)	7(1)	7(1)	12(2)	20(1)	22(3)	30(1)	41(4)
GM 107	6(1)	8(2)	6(1)	8(2)	10(2)	11(1)	11(1)	30(4)	30(2)
GT 046	7(2)	11(1)	4(2)	9(3)	18(4)	18(2)	26(3)	26(2)	43(3)
GT 047.1	5(2)	14(1)	16(4)	20(3)	34(4)	40(3)	51(3)	76(6)	78(4)
CPI 47250	7(4)	13(3)	13(1)	9(2)	15(2)	17(1)	15(3)	18(3)	21(4)
CPI 47251	9(3)	9(2)	13(3)	14(2)	23(7)	24(3)	28(5)	31(2)	50(5)
CPI 50484	7(2)	25(4)	24(2)	21(2)	20(2)	32(1)	28(4)	33(2)	34(2)
CPI 50774	9(2)	8(1)	9(2)	9(2)	21(2)	20(2)	21(2)	29(2)	43(4)
GS 046.1	1(1)	4(1)	6(2)	14(2)	29(7)	50(6)	68(8)	69(3)	72(2)
GS 046.2	4(2)	6(2)	6(2)	13(1)	24(2)	25(4)	44(5)	44(6)	54(2)
DP 4	1(1)	10(3)	6(2)	5(1)	19(1)	23(2)	43(2)	59(5)	77(9)
DP 6	6(3)	11(4)	10(2)	12(2)	19(2)	21(2)	23(1)	28(2)	39(5)
M 34	11(2)	12(2)	13(3)	26(2)	32(4)	40(2)	39(3)	45(3)	47(4)
M 115	36(5)	51(7)	44(4)	54(4)	74(7)	91(7)	85(4)	86(1)	88(2)
M 133	10(3)	33(1)	36(4)	33(2)	72(3)	65(7)	87(2)	90(5)	94(4)
M 167	28(1)	54(4)	70(5)	77(3)	75(4)	88(1)	90(2)	89(2)	88(2)
O. sativus									
CPI 16006	100	100	100	100	100	100	100	100	100
CPI 47656	100	100	100	100	100	100	100	100	100
O. pinnatus									
GM 134.1	5(1)	8(2)	7(1)	13(1)	14(4)	12(2)	30(2)	28(2)	43(5)
GT 045	14(1)	19(2)	14(2)	18(2)	13(3)	20(3)	17(2)	33(6)	34(7)
O. perpusillus									
GM 034	10(1)	10(2)	11(1)	12(1)	9(2)	10(1)	11(2)	11(1)	24(3)
O. isthmocarpus									
GM 017	6(1)	11(3)	8(1)	13(1)	11(2)	24(1)	22(2)	46(2)	49(2)
GM 030.1	13(2)	16(3)	12(3)	15(1)	18(3)	25(3)	40(3)	42(1)	65(4)
*O. species***									
GM 113.2	1(1)	1(1)	0	1(1)	1(1)	3(1)	0	1(1)	3(1)
Trifolium									
T. subterraneum									
cv. Esperance	12(2)	24(2)	37(5)	53(4)	76(4)	83(3)	89(2)	92(3)	97(2)
cv. Daliak	21(2)	29(2)	34(2)	43(3)	67(4)	77(4)	81(4)	86(3)	88(4)
cv. Nungarin	12(1)	20(3)	24(3)	35(3)	50(2)	64(4)	73(3)	81(2)	87(3)
cv. Trikkala	24(10)	47(3)	75(5)	88(3)	98(1)	97(2)	100(1)	100(2)	100(2)

* For meaning of letters, see footnote to table 1.
** See footnote to table 1.
\+ Standard error.

Table 3: Percentage of soft-seeds determined for podded serradella seed collected from experiment 4 in 1982 and stored in a diurnal 15/60 deg. C alternating temperature oven, (± s.e.)+

Species * and strain	Per cent soft-seed											
	Storage Period (d)											
	7	35	64	97	126	161	190	221	252	281	312	344
Ornithopus	%	%	%	%	%	% %	%	%	%	%	%	%
O. compressus												
cv. Pitman	8(1)+	7(1)+	9(2)+	14(2)+	31(4)+	38(4)+	44(2)+	56(2)+	59(2)+	68(6)+	72(5)+	85(4)+
GM 016	2(1)	8(1)	11(1)	10(1)	10(2)	8(2)	10(2)	15(2)	21(3)	21(3)	25(4)	26(1)
GM 043.2	2(1)	3(1)	5(1)	6(1)	5(2)	9(1)	15(2)	19(2)	20(2)	20(2)	21(2)	29(1)
GM 057.1	3(1)	6(1)	6(2)	7(1)	6(2)	7(1)	10(1)	12(1)	17(3)	18(2)	22(2)	32(4)
GM 065.1	2(1)	2(1)	2(1)	2(2)	5(1)	9(1)	9(2)	10(2)	11(1)	13(2)	15(3)	19(1)
GM 065.2	2(1)	4(2)	3(1)	4(2)	5(1)	11(2)	10(1)	13(1)	17(1)	20(4)	27(3)	29(3)
GM 065.3	1(1)	4(1)	4(1)	9(1)	10(1)	11(1)	11(1)	15(3)	17(1)	20(4)	21(1)	28(4)
GM 107	1(1)	3(1)	4(1)	5(3)	9(1)	11(1)	11(1)	12(2)	16(3)	20(3)	26(3)	37(4)
GT 046	3(2)	4(2)	6(2)	7(2)	8(3)	11(1)	13(3)	12(1)	13(2)	17(3)	25(3)	31(2)
CPI 47250	4(2)	8(2)	11(1)	12(2)	13(2)	10(1)	11(1)	11(2)	15(2)	19(1)	23(3)	24(2)
CPI 47251	7(1)	10(2)	14(2)	11(1)	13(2)	11(1)	14(1)	14(2)	25(1)	26(2)	27(2)	42(3)
CPI 50484	7(2)	6(3)	12(2)	12(3)	13(2)	13(3)	14(2)	12(3)	21(2)	21(2)	27(2)	33(3)
CPI 50774	9(1)	13(2)	13(1)	12(1)	17(2)	14(2)	15(1)	16(3)	24(2)	24(3)	30(2)	41(7)
GS 046.1	6(4)	9(2)	13(2)	12(1)	17(4)	12(2)	16(2)	21(3)	26(4)	38(3)	59(4)	86(2)
DP 4	2(1)	1(1)	1(1)	4(2)	8(2)	10(3)	8(2)	10(1)	9(1)	9(1)	20(2)	42(7)
DP6	2(1)	3(1)	2(1)	3(1)	4(2)	3(1)	5(5)	7(3)	9(2)	14(1)	21(2)	28(5)
M 115	7(3)	15(3)	18(3)	19(4)	31(2)	25(5)	32(3)	31(2)	39(1)	49(2)	67(2)	76(5)
M 133	7(2)	15(2)	19(1)	17(2)	22(3)	24(2)	24(3)	26(3)	28(2)	28(2)	36(5)	60(2)
M 167	4(3)	15(1)	16(6)	19(3)	22(6)	21(2)	23(2)	25(2)	30(2)	39(5)	45(5)	61(5)
O. sativus												
CPI 16006	96(1)	94(1)	98(1)	100	100	100	100	100	100	100	100	100
CPI 47656	90(3)	98(1)	100	100	100	100	100	100	100	100	100	100
O. pinnatus												
GM 134.1	4(1)	5(1)	9(3)	11(1)	9(1)	9(3)	26(7)	16(4)	18(2)	21(3)	25(3)	52(7)
GT 045	2(1)	4(2)	6(2)	8(1)	8(2)	10(3)	16(3)	17(3)	24(2)	24(3)	32(2)	62(8)
O. perpusillus												
GM 034	1(1)	2(2)	3(2)	5(1)	12(3)	14(2)	14(2)	19(5)	18(2)	21(2)	25(3)	27(2)
O. isthmocarpus												
GM 017	4(1)	5(3)	10(2)	11(1)	10(3)	18(1)	18(6)	15(3)	19(2)	30(4)	47(6)	55(6)
GM 030.1	2(1)	6(2)	5(1)	12(2)	9(5)	16(3)	14(3)	14(2)	19(3)	20(3)	41(2)	49(5)
*O. species***												
GM 113.2	1(1)	1(1)	2(1)	7(5)	13(4)	13(3)	15(1)	20(1)	22(2)	22(2)	29(5)	45(4)
Trifolium												
T. subterraneum												
cv. Esperance	3(1)	10(3)	21(3)	26(4)	34(2)	50(5)	71(3)	91(4)	90(3)	88(2)	99(1)	99(1)
cv. Daliak	4(1)	16(1)	19(3)	29(4)	40(4)	51(6)	67(6)	85(2)	90(1)	93(2)	95(2)	95(3)
cv. Nungarin	2(1)	14(2)	20(4)	20(2)	30(5)	46(1)	63(5)	64(6)	60(5)	73(5)	81(5)	87(3)
cv. Trikkala	54(3)	70(3)	80(3)	97(3)	97(2)	97(2)	100(1)	100	100	100	100	100

* For meaning of letters, see footnote to table 1.
** See footnote to table 1.
+ Standard error.

Table 4: Proportion of seed in serradella pods measured in experiment 4 in 1982.

Species* and strain	Seed proportion	Species and strain	Seed proportion
O. compressus		*O. compressus*	
cv. Pitman	0.30 (0.04)+	M115	0.23 (0.07)+
GM 016	0.23 (0.07)	M 133	0.23 (0.05)
GM 043.2	0.27 (0.04)	M 167	0.25 (0.02)
GM 057.1	0.15 (0.03)	*O. sativus*	
GM 065.1	0.23 (0.04)	CPI 16006	0.18 (0.02)
GM 065.2	0.26 (0.06)	CPI 47656	0.27 (0.01)
GM 065.3	0.22 (0.02)	*O. pinnatus*	
GM 107	0.18 (0.01)	GM 134.1	0.31 (0.01)
GT 046	0.30 (0.02)	GT 045	0.32 (0.02)
GT 047.1	0.27 (0.01)	*O. perpusillus*	
CPI 47250	0.29 (0.01)	GM 034	0.44 (0.04)
CPI 47251	0.25 (0.01)	*O. isthmocarpus*	
CPI 50484	0.25 (0.01)	GM 017	0.20 (0.01)
CPI 50774	0.20 (0.02)	GM 030.1	0.18 (0.01)
GS 046.1	0.20 (0.01)	*O. species***	
DP 3	0.32 (0.04)	GM 113.2	0.30 (0.01)
DP 4	0.33 (0.04)		
DP 6	0.30 (0.02)		

* See footnote table 1 for meaning of letters
** See footnote table 1
\+ Standard error

Table 5. Percentage of soft-seeds counted for the germination test on podded serradella seed collected from experiment 5 during the 1982/83 summer.

Species, strain or cultivar	Sampling dates Dec. 20 1982	Feb. 4 1983	Mar. 3 1983	Apr. 1 1983	May 5 1983
	Per cent soft seed				
	%	%	%	%	%
O. compressus					
cv. Pitman	3 (2)+	6 (2)+	12 (1)+	15 (2)+	25 (3)+
CPI 47250	1 (1)	3 (2)	5 (3)	6 (3)	11 (2)
O. perpusillus					
GM 034	4 (1)	3 (2)	4 (2)	5 (2)	5 (1)

\+ Standard error

Table 6. Yield of dried herbage and seed measured for experiment 6 (main experiment) during 1982 and 1983.

	Fertilizer nitrogen treatment	Applied Co (kg/ha)	Yield of dried herbage (kg/ha) 1982 Aug.26	Sept.14	Oct.6	Nov.2	1983 Aug.3	1982 seed yield (samples collected Feb.7 1983) (kg/ha)
Ornithopus		0.00	127 (31)+	287 (82)+	2047 (141)+	4410 (39)+	740 (48)+	443 (36)+
		0.05	143 (20)	233 (70)	2120 (177)	4970 (670)	694 (54)	553 (49)
		0.11	120 (36)	253 (24)	2377 (515)	4190 (366)	693 (78)	430 (53)
O. compressus cv. Pitman	Nil N	0.21	127 (15)	267 (31)	2103 (383)	4830 (304)	683 (65)	477 (128)
		0.42	137 (49)	247 (82)	1977 (87)	4390 (474)	655 (39)	487 (43)
		0.84	133 (15)	287 (31)	2093 (320)	4665 (264)	700 (44)	430 (95)
		Mean	131 (27)	262 (53)	2119 (289)	4576 (439)	694 (54)	470 (77)
		0.00	316 (63)	640 (72)	3150 (429)	5190 (26)	1115 (104)	473 (83)
		0.05	347 (32)	767 (51)	3360 (433)	4515 (519)	1276 (36)	480 (49)
		0.11	300 (17)	693 (61)	3340 (343)	4450 (226)	1248 (88)	477 (85)
O. compressus cv. Pitman	+N	0.21	307 (90)	820 (53)	2780 (520)	4735 (219)	1245 (116)	443 (29)
		0.42	313 (31)	760 (71)	3489 (522)	4972 (877)	1289 (190)	533 (20)
		0.84	327 (61)	733 (43)	3503 (389)	5065 (473)	1225 (160)	443 (41)
		Mean	318 (49)	735 (77)	3271 (575)	4821 (490)	1233 (121)	475 (58)
Trifolium		0.00	406 (65)	760 (71)	1103 (136)	1400 (121)	1445 (335)	593 (32)
		0.05	380 (56)	787 (129)	1207 (199)	1402 (37)	1391 (355)	717 (70)
		0.11	383 (60)	760 (53)	1103 (284)	1249 (49)	1526 (491)	627 (10)
T. subterraneum cv. Esperance	Nil N	0.21	370 (10)	713 (99)	1093 (90)	1476 (60)	1820 (70)	690 (105)
		0.42	403 (94)	767 (61)	1163 (238)	1385 (194)	1327 (202)	697 (100)
		0.84	393 (24)	733 (65)	1250 (146)	1367 (82)	1499 (287)	647 (41)
		Mean	389 (51)	753 (75)	1153 (173)	1383 (117)	1502 (313)	662 (73)
		0.00	443 (90)	793 (129)	1207 (179)	1416 (185)	1390 (202)	746 (48)
		0.05	387 (24)	780 (20)	1273 (185)	1367 (253)	1356 (292)	623 (36)
		0.11	403 (37)	800 (80)	1110 (128)	1449 (39)	1408 (196)	610 (31)
T. subterraneum cv. Esperance	+N	0.21	453 (65)	789 (61)	1290 (267)	1380 (105)	1330 (51)	787 (51)
		0.42	437 (54)	800 (126)	1267 (202)	1407 (175)	1524 (309)	747 (95)
		0.84	390 (17)	807 (43)	1097 (111)	1367 (31)	1338 (43)	740 (95)
		Mean	419 (60)	794 (73)	1207 (175)	1397 (133)	1392 (189)	708 (83)

+ Standard deviation

Table 7. Herbage and seed yields measured in experiment 7 (ancillary experiment) during 1983.

	Dried herbage yield (kg/ha)				Seed yield (kg/ha)*	
	Aug. 2		Sept. 26			
	Nil N	+N	Nil N	+N	Nil N	+N
Ornithopus						
O. compressus cv. Pitman	52	148	2044	2015	471	456
	(16)+	(14)+	(118)+	(110)+	(31)+	(115)+
O. pinnatus GT 045	9	71	1706	1686	395	379
	(4)	(26)	(124)	(146)	(41)	(56)
O. perpusillus GM 034	52	168	1937	1913	379	375
	(10)	(36)	(98)	(102)	(51)	(45)
Trifolium						
T. subterraneum cv. Daliak	159	175	1739	1600	690	589
	(16)	(58)	(80)	(88)	(117)	(165)
T. subterraneum cv. Seaton Park	205	243	1753	1763	494	546
	(24)	(50)	(112)	(124)	(42)	(77)

* Plots samples February 2, 1984
\+ Standard deviation

Table 8. Description of soil profiles for the medic trials (experiments 8-13). Values in parenthesis are from Northcote's key (Northcote 1979).

Experiment 8	
Dowak clay loam (Gc 1.12)	
0-12 cm	dull brown calcareous clay loam to sandy clay loam
12-80 cm	grey and dull brown, calcareous sandy clay loam
>80 cm	dull brown, red and grey mottled, acid stiff clay.
Experiments 9 and 13	
Kumarl clay loam (Gc 1,22)	
0-15 cm	rich brown to dull brown calcareous clay loam
15-105 cm	rich brown and brown to red brown stiff calcareous clay
>105 cm	red brown and grey mottled stiff acid clay.
Experiment 10	
Deep Circle Valley sand (Dy 5.43)	
0-30 cm	pale grey coarse sand
30-400 cm	yellowish grey and yellowish brown calcareous clay loam to sandy clay. Calcareous nodules present
>400 cm	brown and grey stiff sandy clay.
Experiments 11, 12 and 14	
Scaddan sandy loam (Dy 5.43)	
0-5 cm	pale grey brown sand
0-150 cm	dull yellow grey, pale brown and brown mottled calcareous sandy clay loam to sandy loam.

Table 9: Maturity grading (MG) in days and seed yield (SY) (g/m²) measured for the five medic seed yield experiments in 1980 and 1981.

Species* and strain	Expt 8				Expt 9				Expt 10				Expt 11				Expt 12			
	1980		1981		1980		1981		1980		1981		1980		1981		1980		1981	
	MG	SY	MG	SY	MG	SY	MG	SY	MG	SY	MG	SY	MG	SY	MG	SY	MG	SY	MG	SY
Medicago																				
M. truncatula																				
cv. Cyprus	5	0.2	2	14.5	10	13.8	7	3.0	6	2.5	5	0.0	5	15.0	4	7.1	7	15.8	3	33.0
cv. Jemalong					20	7.2	15	0.3	10	1.3	11	0.0	15	1.0	12	4.7	12	7.5	8	19.0
Zaura 3	5	0.6	2	3.2	20	11.1	15	3.1	10	2.1	11	0.0	15	22.8	12	12.1	12	12.0	8	12.5
SAD 633 (Sanza)																	21	1.5	18	8.0
SAD 2411																	12	4.5	8	20.0
SAD 6297 (Sephi)																	12	6.0	8	31.5
SAD 7176																	12	16.5	8	42.0
M. tornata																				
cv. Tornafield	10	0.7	7	0.0	21	36.8	15	2.1	10	1.4	8	0.0	9	6.5	7	4.9	14	13.3	12	20.0
Swani	4	0.3	2	0.5	5	13.0	15	2.4	5	1.6	5	0.2	3	18.0	3	0.0	4	1.0	2	7.5
Saleg																	19	15.8	17	36.0
SAD 2562																	19	12.3	17	20.0
M. littoralis																				
cv. Harbinger	8	0.3	5	4.5	10	17.7	12	1.5	8	6.1	7	1.0	9	14.8	8	21.3	8	14.3	6	11.0
Sabratha	4	2.8	2	11.1	5	8.0	5	8.4	5	1.3	5	0.5	3	34.0	3	11.1	3	10.5	2	9.5
W. Azizia A5	5	0.1	3	3.0	5	23.7	5	4.0	5	2.1	5	0.1	5	8.8	5	10.9	7	13.3	5	15.0
M. polymorpha																				
cv. Serena	0	7.3	0	5.0	0	56.7	0	11.2	0	5.3	0	2.0	0	58.3	0	17.5	0	39.5	0	42.5
cv. Circle Valley	10	0.2	8	0.0	20	31.6	18	0.8	10	2.1	11	0.0	15	21.0	12	6.9	12	13.0	10	21.0
M. scutellata																				
cv. Robinson					21	9.9	20	3.2	12	1.6	11	0.0	19	21.3	15	16.4	19	14.5	15	33.5
cv. Sava	8	0.9	6	0.0	8	57.2	6	6.6	10	3.0	9	0.0	15	35.8	12	24.7	12	24.5	10	46.0
cv. Sair	8	0.1	6	0.0	10	12.9	8	4.6	8	4.2	7	0.0	15	31.0	12	19.5	7	18.3	5	30.0
M. Rugosa																				
cv. Sapo	10	0.2	8	0.0	21	13.8	18	0.1	12	2.7	10	0.0	15	4.8	12	3.5	12	8.0	10	23.0
cv. Paraponto					21	24.2	18	1.8	12	2.5	10	0.0	15	8.3	12	5.1	12	11.5	12	25.0
cv. Paragossa																	12	4.3	10	15.0
M. aculeata																				
SAD 2629																	13	1.0	12	0.8
SAD 4175																	29	4.8	20	7.0
SAD 4311																	19	4.0	17	9.5
Trifolium																				
T. subterraneum																				
cv. Nungarin																	7	8.00	5	2.0
cv. Daliak																	12	2.0	10	1.0
LSD ($P<0.05$)		1.3		3.8		11.1		1.6		1.0		0.7		8.9		3.8		3.2		5.5

* 1. SAD accessions, Saleq, *M. scutellata* and *M. rugosa* strains donated by M.J. Mathison, South Australian Department of Agriculture.

2. Zuara 3, Sabratha, W. Azizia A5 originate from north-western Libya (Khalil *et al.* 1977).

Table 10. Percentage of soft-seeds for experiment 13.

Species and strain	Days stored in alternating temperature oven 7	36	70	99	132	164	192
	Per cent soft-seed						
	%	%	%	%	%	%	%
M. truncatula							
cv. Cyprus	2(1)+	5(2)+	12(4)+	19(2)+	20(2)+	21(2)+	23(3)+
Zuara 3	1(1)	2(1)	4(1)	18(1)	21(1)	24(1)	28(2)
M. littoralis							
cv. Harbinger	1(1)	4(2)	10(2)	22(3)	30(1)	31(1)	33(1)
Sabratha	3(1)	7(1)	13(1)	21(1)	23(1)	25(1)	26(1)
M. polymorpha							
cv. Serena	1(1)	2(1)	6(1)	12(1)	14(1)	15(1)	16(1)
cv. Circle Valley	1(1)	4(1)	8(1)	15(2)	20(2)	21(3)	25(3)
M. scutellata							
cv. Sair	2(1)	4(1)	7(1)	11(2)	15(2)	16(3)	19(2)
M. rugosa							
cv. Sapo	1(1)	3(1)	8(2)	26(4)	30(5)	33(4)	39(6)

\+ Standard error

Table 11. Effect of phosphorus from superphosphate on the seed yields (mean ± s.e.*, n = 3) of the annual medics (experiment 14).

Species, strain or cultivar	Applied P (kg/ha)	Seed yield (g/m^2)	
M. polymorpha cv. Serena	0	3.3	(0.6)*
	20	34.0	(2.4)
	40	37.6	(2.0)
	60	38.4	(2.0)
	80	44.9	(0.9)
	100	47.7	(0.6)
	2000	59.8	(1.1)
M. polymorpha cv. Circle Valley	0	7.1	(1.8)
	20	37.6	(1.4)
	40	44.0	(5.0)
	60	47.7	(6.2)
	80	53.0	(10.0)
	100	54.0	(10.8)
	2000	71.4	(6.5)
M. truncatula cv. Cyprus	0	4.6	(1.3)
	20	21.6	(4.8)
	40	29.0	(1.3)
	60	34.4	(0.4)
	80	51.6	(2.2)
	100	51.7	(2.1)
	2000	54.0	(2.4)
M. truncatula cv. Jemalong	0	7.9	(2.7)+
	20	25.6	(1.5)
	40	31.3	(3.0)
	60	37.7	(1.8)
	80	44.4	(1.9)
	100	53.2	(1.2)
	2000	68.8	(5.8)
M. tornata Swani	0	7.9	(0.9)
	20	21.6	(6.5)
	40	28.3	(0.3)
	60	36.5	(6.1)
	80	43.0	(4.4)
	100	57.4	(2.3)
	2000	73.4	(7.9)
M. tornata cv. Tornafield	0	4.6	(1.5)
	20	44.8	(2.5)
	40	50.1	(2.9)
	60	57.0	(3.5)
	80	60.5	(0.4)
	100	74.6	(11.2)
	2000	89.0	(14.8)

* s.e. = standard error

Table 12. Initial slope of the relationship between seed yield (kg/ha) and amount of applied P (kg/ha).

Species and strain or cultivar		Initial slope
M. polymorpha	cv. Serena	10.0
	cv. Circle Valley	10.5
M. truncatula	cv. Cyprus	6.6
	cv. Jemalong	6.4
M. tornata	Swani	5.5
	cv. Tornafield	13.1

Table 13. Effect of phosphorus from superphosphate on the burr weight, number of seeds/burr, and seed weight. Data given are means of 3 subsamples per replicate ± s.e.+

Species and strain or cultivar	Applied P (kg/ha)	Burr weight (mg)		No. seeds per burr		Seed weight (mg)	
M. polymorpha cv. Serena	0	32.7	(4.0)+	2.9	(0.3)+	3.8	(0.1)+
	20	38.3	(1.0)	3.6	(0.3)	3.9	(0.1)
	40	38.6	(3.5)	3.3	(0.6)	3.9	(0.1)
	60	37.5	(2.0)	3.2	(0.1)	3.6	(0.3)
	80	36.2	(2.3)	3.2	(0.2)	4.0	(0.2)
	100	40.3	(2.3)	3.3	(0.2)	3.9	(0.1)
	2000	37.0	(1.2)	3.5	(0.6)	3.6	(0.3)
M. polymorpha cv. Circle Valley	0	45.3	(6.1)	3.5	(0.3)	3.4	(0.1)
	20	50.7	(4.9)	4.1	(0.7)	3.2	(0.5)
	40	48.5	(4.2)	3.2	(0.4)	3.6	(0.2)
	60	48.5	(1.8)	3.6	(0.3)	3.5	(0.2)
	80	45.5	(1.4)	3.8	(0.3)	3.8	(0.5)
	100	46.7	(2.3)	4.2	(0.5)	4.0	(0.4)
	2000	44.5	(4.6)	4.2	(0.6)	3.6	(0.2)
M. truncatula cv. Cyprus	0	94.4	(3.9)	5.5	(0.2)	3.8	(0.2)
	20	89.7	(8.8)	6.2	(0.5)	3.9	(0.3)
	40	91.4	(4.3)	6.0	(0.3)	4.1	(0.1)
	60	93.9	(2.4)	5.7	(1.1)	4.2	(0.2)
	80	87.9	(6.3)	5.8	(0.2)	4.0	(0.3)
	100	100.2	(8.5)	5.5	(0.4)	4.4	(0.3)
	2000	100.1	(5.6)	6.0	(0.4)	4.0	(0.1)
M. truncatula cv. Jemalong	0	132.2	(6.0)	7.1	(0.7)	4.1	(0.3)
	20	132.2	(11.8)	7.2	(0.7)	4.5	(0.2)
	40	136.3	(15.5)	8.0	(0.9)	3.9	(0.3)
	60	124.1	(11.3)	7.8	(0.9)	4.2	(0.1)
	80	125.5	(7.3)	7.5	(1.6)	4.4	(0.3)
	100	139.5	(4.6)	7.8	(0.6)	4.0	(0.2)
	2000	131.0	(6.3)	7.9	(0.5)	4.0	(0.1)
M. tornata Swani	0	12.9	(0.5)	1.5	(0.2)	4.6	(0.2)
	20	13.0	(0.7)	1.6	(0.1)	4.8	(0.2)
	40	13.8	(1.1)	1.6	(0.1)	5.1	(0.3)
	60	12.4	(0.6)	1.6	(0.1)	5.1	(0.4)
	80	14.1	(0.9)	1.7	(0.2)	5.0	(0.3)
	100	13.0	(1.8)	1.6	(0.1)	5.2	(0.4)
	2000	14.2	(1.2)	1.4	(0.2)	5.0	(0.2)
M. tornata cv. Tornafield	0	31.5	(2.5)	2.7	(0.3)	4.5	(0.3)
	20	30.9	(2.7)	3.3	(0.3)	4.1	(0.5)
	40	34.0	(1.4)	2.7	(0.3)	5.1	(0.3)
	60	33.6	(3.5)	3.0	(0.2)	5.2	(0.6)
	80	30.6	(3.9)	3.1	(0.2)	4.5	(0.6)
	100	35.5	(4.3)	3.2	(0.2)	4.8	(0.2)
	2000	34.2	(2.6)	2.9	(0.3)	4.6	(0.3)

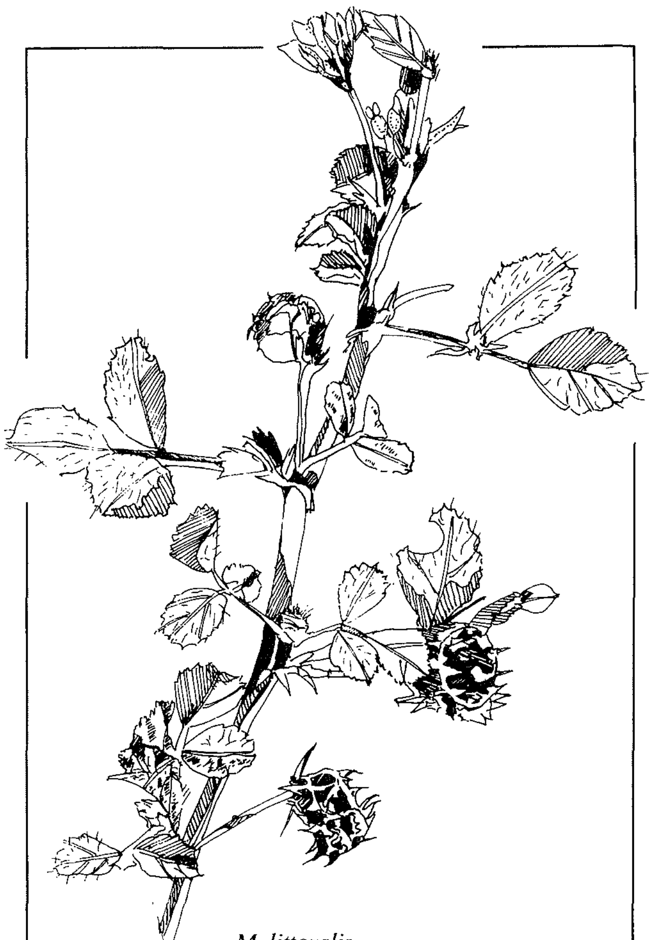
+ s.e. = standard error

Table 14: Percentage of soft-seeds of annual medic measured after different storage periods in the diurnal 15/60°C alternating temperature oven for two phosphorus treatments (± s.e.) (experiment 13).

		Per cent soft-seeds								
Species, strain or cultivar	kg P/ha applied	Storage period (d) at 15/60°C								
		7	26	62	94	162	206	247	275	308
		%	%	%	%	%	%	%	%	%
M. polymorpha										
cv. Serena	20	1.7	2.0	5.2	5.5	6.4	10.4	13.6	17.8	20.9
		(0.1)+	(0.2)+	(0.4)+	(0.7)+	(0.6)+	(0.8)+	(0.1)+	(1.1)+	(2.7)+
	2000	1.4	1.6	6.4	8.5	10.4	11.0	12.2	23.0	24.9
		(0.1)	(0.4)	(0.7)	(0.8)	(2.5)	(0.1)	(1.0)	(2.6)	(2.2)
cv. Circle Valley	20	4.4	4.5	5.7	6.2	8.1	16.8	20.9	24.9	27.1
		(0.9)	(0.8)	(0.2)	(0.7)	(1.5)	(1.5)	(7.7)	(5.4)	(5.3)
	2000	4.9	6.8	8.3	11.3	11.5	19.9	21.1	20.8	25.2
		(0.7)	(1.3)	(2.6)	(2.0)	(2.0)	(1.6)	(4.2)	(0.1)	(0.5)
M. truncatula										
cv. Cyprus	20	1.6	1.5	2.1	2.6	2.9	14.7	26.2	30.8	33.1
		(0.3)	(0.1)	(0.4)	(0.1)	(0.1)	(1.4)	(4.6)	(2.8)	(0.2)
	2000	1.2	1.6	3.1	3.8	8.8	14.2	26.0	29.2	31.0
		(0.2)	(0.3)	(0.4)	(0.9)	(0.5)	(1.9)	(0.7)	(0.8)	(2.2)
cv. Jemalong	20	1.4	2.0	2.6	3.2	7.0	18.4	32.3	37.4	38.2
		(0.4)	(0.1)	(0.6)	(0.3)	(1.8)	(1.4)	(1.5)	(0.8)	(0.6)
	2000	1.4	3.0	4.5	4.6	6.9	14.4	29.4	33.3	36.5
		(0.4)	(1.0)	(1.2)	(1.7)	(3.1)	(5.0)	(0.9)	(3.1)	(1.6)
M. tornata										
Swani	20	1.7	3.0	6.0	6.9	7.9	14.6	24.4	29.2	28.4
		(0.5)	(0.3)	(0.7)	(0.2)	(0.8)	(1.5)	(3.4)	(1.0)	(1.8)
	2000	3.2	4.0	7.4	8.9	9.3	14.8	21.7	25.1	29.6
		(1.4)	(0.6)	(1.1)	(1.4)	(1.0)	(1.1)	(4.1)	(2.6)	(3.2)
cv. Tornafield	20	1.7	2.0	3.5	6.5	9.6	16.3	33.5	41.6	45.6
		(0.3)	(0.6)	(1.4)	(2.3)	(1.1)	(1.9)	(1.6)	(1.9)	(3.0)
	2000	2.6	2.9	5.6	7.9	13.8	19.6	38.3	48.0	53.9
		(0.8)	(0.8)	(1.4)	(1.5)	(4.4)	(2.9)	(4.2)	(4.4)	(2.4)

+ Standard error.

Introduction
Part 2. Medic research



M. littoralis

About half the farms around Esperance are located on alkaline soils (map 2). The soils have been described by Prescott (1931), Burvill (1936), Teakle (1938), Teakle and Burvill (1939) and Burvill (1987). The principle soil profile is Dy 5.43, with some Gc 1.12 and Gc 1.22 (Northcote 1979). Annual medics (*Medicago* sp.) are well adapted to these soils and are successful, persistent legumes. *M. truncatula* cv. Cyprus is the most widely sown medic on the alkaline soils, with some *M. truncatula* cv. Jemalong sown in some high rainfall areas with > 400 mm/a rainfall. *M. littoralis* cv. Harbinger has been sown on some of the sandy surfaced alkaline soils in low rainfall areas with < 400 mm/a, and *M. tornata* cv. Tornafield on some of those soils in the high rainfall areas. All these medics persist successfully on these soils.

Wheat, barley and wool production are the major enterprises on the alkaline soils. The common rotation is a 1 year crop:1 year medic ley pasture. The pasture ley is usually 100% medic, as the reduction of soil nitrogen levels by the cereal crop does not favour non-leguminous volunteer annual grasses or herbs. The medic ley builds up soil nitrogen levels for the next crop, and acts as a cleaning plant reducing the incidence of cereal root diseases, principally the 'take-all' fungus (*Gaeumannomyces graminis* var. *tritici*) (I.C. Rowland, unpublished data). This fungus infects the roots of volunteer grasses in the pasture ley and is carried over to infest the next cereal crop. The principle volunteer grasses infected are annual ryegrass (*Lolium rigidum*) and barley grass (*Hordeum* sp.).

Some old (up to about 50 years) and newly established farms on the alkaline soils are located in low rainfall areas of < 400 mm/a. There are also new clearings on these soils into even lower rainfall areas. When this present research began in 1980, Cyprus was the earliest flowering medic cultivar, but an even earlier cultivar for the alkaline soils in the low rainfall areas was considered desirable. *M. polymorpha* is found in a range of environments in its natural habitats around the Mediterranean Sea and the Near East (J.A. McComb and C.M. Francis, personal communication) and volunteers widely into the pastoral and cereal areas of Western Australia (Rossiter 1966b; Quinlivan *et al.* 1974). It may

be the most widely adapted annual medic species from which to select cultivars (J.A. McComb, personal communication). This species, however, is only effectively inoculated by specific *Rhizobium meliloti* strains which were not present in commercial medic inoculum at the time of my research. This inoculum contained the *Rhizobium meliloti* strains U 45 and SU 47. The absence of suitable *Rhizobia* strains accounts for the inconsistent results obtained in field tests of *M. polymorpha* in south-western Australia. J.A. McComb has produced the very early maturing Serena strain in her *M. polymorpha* breeding programme. This medic, together with the appropriate *Rhizobium meliloti* strain, may be well adapted to heavy alkaline soils [principle soil profile GC 1.12 and Gc 1.22 (Northcote 1979)] and the sandy surfaced alkaline soils (Dy 5.43, Northcote 1979) in low rainfall areas < 400 mm/a. The later maturing *M. polymorpha* cv. Circle Valley was also tested in the experiments as a potential cultivar for the heavy and light surface textured alkaline soils in high rainfall areas > 400 mm/a.

During the early 1980s, the spotted alfalfa aphid (*Therioaphis trifolii*) and bluegreen aphids (*Acyrthosiphon kondoi*) appeared in farming areas around Esperance. Both are potentially serious pests of annual medics (Franzmann *et al.* 1979; Lodge and Greenup 1980). Screening tests in South Australia showed that *Medicago scutellata* and *M. rugosa* were resistant to both aphid pests (M.J. Mathison, personal communication).

M. polymorpha, *M. scutellata* and *M. rugosa* are not widely sown on farms. There is some doubt about the persistence of *M. scutellata* under grazing because of the accessibility of its large, smooth seed-pods to stock. Preliminary assessments of strains of these three species were undertaken on the alkaline soils near Esperance.

New land is still being cleared for agriculture on the alkaline soils. Initial income is often derived by growing seed of annual medic cultivars. These are sown at low seeding rates (between 1 and 5 kg/ha) on newly cleared soil. Due to lack of fencing and water supplies, the resultant pastures are usually not grazed in the first year. These newly cleared soils are

M. truncatula

acutely phosphorus deficient, and relatively large amounts of superphosphate (between 300 and 400 kg/ha) are applied in the first year. As in the work on serradella, there were similar aims with the research on medics. The first aim was to assess the various medic strains and cultivars either in comparison with each other or with subterranean clover (one experiment only). The second aim was to determine what effect phosphorus had on seed yield, burr weight, seed weight, seeds per burr and rate of seed-softening.

Materials and methods

A description of the soils is given in table 8, and their location in maps 2 and 3. The location of the medic research sites is shown in map 3.

The methods used to investigate the two aims of the medic research are itemised separately. Section 1, describes the preliminary assessment undertaken on strains of *Medicago polymorpha*, *M. scutellata* and *M. rugosa* compared with strains and cultivars of *M. truncatula*, *M. littoralis* and *M. tornata*. Strains of *M. aculeata*, and cultivars of subterranean clover (*Trifolium subterraneum*) were included in one of the six experiments. Maturity, seed yield, and the rate of softening of hard-seeds (experiment 13 only) was measured. Section 2 describes the effect of phosphorus (P) on seed yield, burr weight, numbers of seed/burr, average seed weight and the rate of softening of hard-seeds for *M. polymorpha*, *M. truncatula* and *M. tornata*.

M. tornata

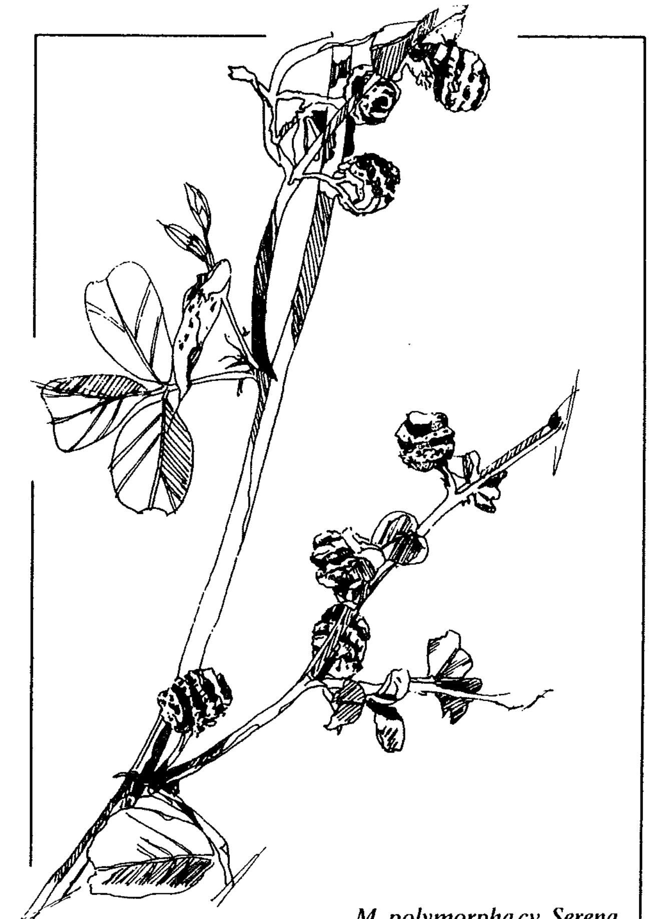
1. — Preliminary assessment of annual medic species and strains

There were six experiments in this series numbered 8 to 13. These differed as to site, species, strain and year started.

8. Kumarl, 1980
9. Salmon Gums Research Station, Salmon Gums, 1980
10. Salmon Gums Research Station, 1980
11. North Cascades, 1980
12. Mt Ney, 1980
13. Near Salmon Gums, 1982

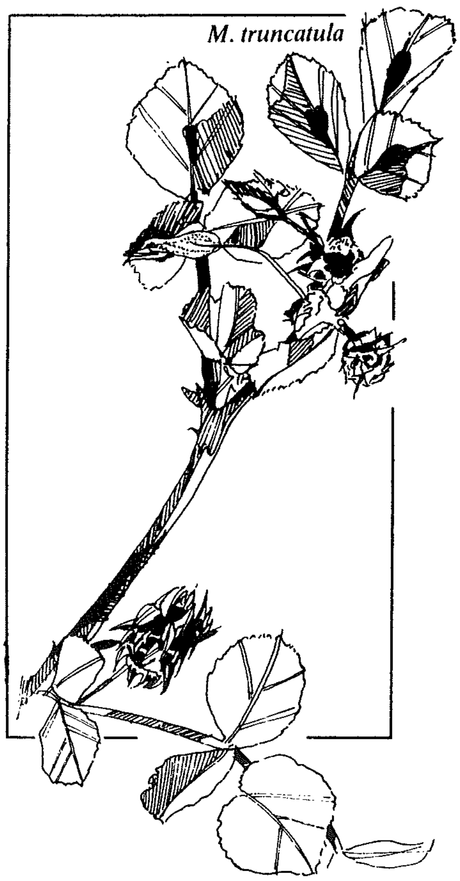
The design was a randomized block of 12 medic species and strains in experiment 8; 15 medic species and strains in experiments 9, 10 and 11; 25 medic species and strains together with two subterranean clover cultivars in experiment 12, and eight medic species and strains in experiment 13. There were four replications for each experiment. A list of the species and strains is given in tables 9 and 10.

Seed was hand-sown at 50 kg/ha mixed, just before sowing, with the fertilizer. The plots measured 2 m x 3 m. There were 2 m buffers around each plot. The seed was inoculated and lime pelleted the day before sowing using inoculum containing the *Rhizobium meliloti* strain NA 2290 for *M. polymorpha*. The

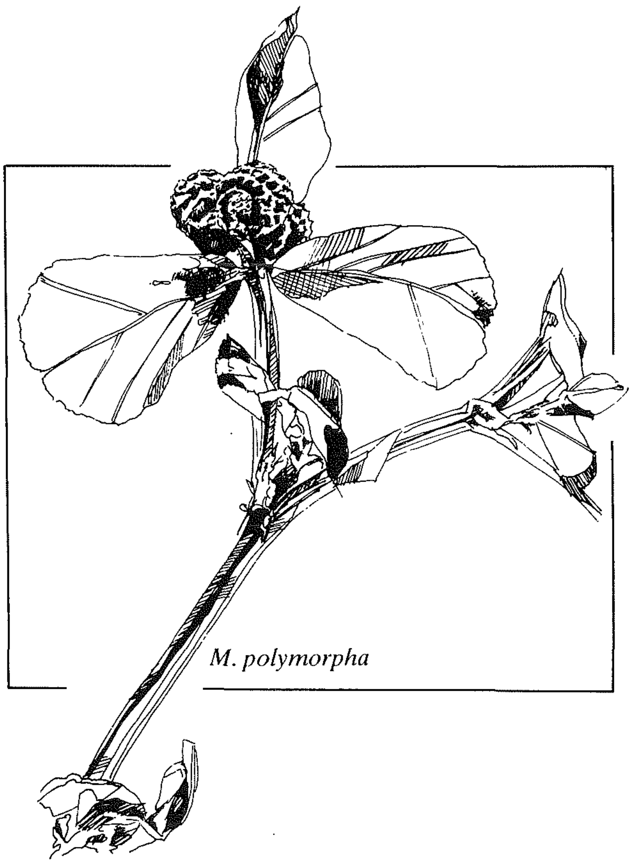


M. polymorpha cv. *Serena*

Paragosa commercial inoculum containing the *Rhizobium meliloti* strain W 118 was used for *M. rugosa*. The commercial 'group A' inoculum, containing the *Rhizobium meliloti* strains U 45 and SU 47 was used for all other medics, and commercial 'group C' inoculum, containing *Rhizobium trifolii* strain WU 95, was used for subterranean clover in experiment 12. The fertilizer used in the first year (1980) was superphosphate No. 1 (9.5% P, 11% S, 24% Ca, 0.66% Cu, 0.52% Zn and 0.08% Mo) at 600 kg/ha for experiments 8, 11, 12 and 13, on newly cleared soil, and 200 kg/ha for experiments 9 and 10 on old land. The same levels of ordinary superphosphate (9.5% P, 11% S and 24% Ca) was used in year 2 (1981), the fertilizer being applied to the surface within the plots during winter (mid-June). Potassium chloride (50% K) at 50 kg/ha was applied to the surface of the soil within the plots in both 1980 and 1981 after mixing it with the superphosphate and seed just before application, in the first year and with only superphosphate in the second year. After the seed and fertilizer were applied in 1980, the plots were lightly raked to cover the seed. The plots were not grazed.



M. truncatula



M. polymorpha

Measurements

Maturity and seed yields were measured for experiments 8, 9, 10, 11 and 12, and the rate of softening of hard-seeds for experiment 13.

• Maturity — The appearance of first flowers were recorded when there was an average number of five inflorescences per 3 dm^2. Maturity grading (MG) was calculated as described for the serradella experiments.

• Seed yields — After the plants had dried off and the burrs matured, medic burrs were collected from five random 0.5 m^2 quadrats per plot, using a new section of the plots each year. Subterranean clover burrs were dug up from the soil as described earlier. In the second year, freshly formed burrs were hand picked from the total burrs collected within each quadrat. Freshly formed medic burrs were a light grey and firm. The year old burrs were brown and more fragile. For subterranean clover (experiment 12), the freshly formed burrs were firm and readily distinguishable from the year old burrs. The seeds were rubbed out of the burrs on corrugated rubber matting and weighed.

• Hard-seed (experiment 13) — The method was similar to that described by Taylor and Palmer (1979). Mature burrs were collected from the plots and the seed removed by hand. A random subsample of 200 seeds were placed in ice-cube trays and stored in a diurnal alternating 15/60°C temperature oven as described by Quinlivan (1961) for 7 d. Further subsamples of seed were stored in the oven for 7 d, after which the moisture content of the seeds was determined as described for the serradella experiments. After 7 d, the trays were removed from the fluctuating oven and water added. The trays were stored for 48 h at 15°C in a germination cabinet. The water was then removed from the trays with a Pasteur pipette, and the number of soft (i.e. swollen or imbibed) seed removed and counted. The remaining seeds in the trays were returned to the alternating temperature oven. The number of imbibed seeds were counted in this fashion about once a month for 10-12 months.

2. — Effect of phosphorus on annual medic seed yields, the components of seed yield and the rate of softening of hard-seeds

Experiment 14 was the only one of this series and was located near Mt Ney, (map 3).

The design was a randomized block of 42 treatments, six annual medic species and strains or cultivars x seven levels of superphosphate, with three replications. The species and strains or cultivars were: *M. polymorpha* cv. Serena and cv. Circle Valley, *M. truncatula* cv. Cyprus and cv. Jemalong, and *M. tornata* Swani and cv. Tornafield. Commercial, granulated (0.5-2.0 mm) superphosphate was used which contained 9.6% total P; 7.4% water-soluble P; 1.2% neutral ammonium citrate-soluble P and 1.0% acid-soluble P, as determined by standard A.O.A.C. (1975) procedures. It also contained 11% S; 23% Ca; 0.035% Zn and 0.004% Cu. The amounts of P applied were: nil, 20, 40, 60, 80, 100, 2000 kg/ha. Farmers use between 30 and 40 kg P/ha for commercial seed production of annual medics on newly cleared alkaline soils near Esperance.

Seed was sown at 5 kg/ha which is the normal sowing rate used by farmers for commercial seed production. The seed was inoculated and lime pelleted the day before sowing, with the NA 2290 strain of *Rhizobium meliloti* for *M. polymorpha*, and commercial 'group A' inoculum (containing the *Rhizobium meliloti* strains U 45 and SU 47) for the other medics. The seed, mixed with fertilizer, was applied by hand (early-May 1981) to the soil surface of the plots. Plot dimensions were 2 m x 5 m, with 2 m buffers around all plots. The fertilizer applied was 100 kg/ha gypsum (18% S); 100 kg/ha potassium chloride (50% K); 10 kg/ha copper sulphate (27% Cu); 2 kg%ha ZnO (80% Zn); 0.2 kg/ha molybdenum trioxide (67% Mo) and 0.2 kg/ha cobalt sulphate (21% Co). The plots were not grazed.

Red-legged earthmite and native budworm were controlled by spraying with 2 L/ha DDT after seeding and at the commencement of flowering, respectively. Bluegreen aphids were controlled by spraying 150 g/ha primicarb once a fortnight during flowering.

Maturity grading was determined as previously described. Medic burrs were collected from five random 10 cm x 100 cm quadrats per plot, threshed and the seed weighed. Further subsamples of burrs were collected at the same time for the determination of burr weight, number of seeds/burr, average seed weight, and hard-seed studies. Three subsamples were randomly selected from each replicate for these studies. Seed was removed from the burrs by hand. For the hard-seed studies only two P treatments were used (20 and 2000 kg/ha). Burrs from each plot were stored in calico bags in an oven which was programmed for the temperatures to increase slowly from 15°C to 60°C and then decrease slowly to 15°C every 24 h, as described by Quinlivan (1961) and shown in figure 1. Figure 1 was plotted from hourly readings taken from thermometers placed amongst the burrs in the oven. The burrs were stored in the oven for 7 d and subsamples selected for determination of seed moisture content and for a germination test. For the determination of seed moisture content, the seed was removed from the burrs by hand, weighed and stored at 105°C for 48 h before being again weighed. For the germination test, the burrs were placed on moist filter paper in petri dishes in a germination cabinet at 15°C for 10 d. The numbers of germinated and imbibed seed were counted by removing the seeds from the burrs by hand. The germination tests were repeated about once a month for 10-12 months.

Results

1. — Preliminary assessment of annual medic species and strains

M. polymorpha cv. Serena produced amongst the highest seed yields at all sites in both years (table 9). It was the earliest flowering medic and this may have been a major factor in determining seed-producing capacity before the soils become too dry for plant growth. The *M. scutellata* strains also produced high seed yields by weight at most sites. This is a large seeded species (weight/seed between 15 and 30 mg, compared with 3-6 mg for most other annual medics) and the number of seeds produced/unit area may not have been as outstanding. It was always the last species to dry off at all sites, probably because the large seeds produced large seedlings and plants with deep roots. Both *M. aculeata* and subterranean clover gave disappointing seed yields in experiment 12 (table 9), located in the high rainfall areas (> 400 mm/a) with alkaline soils (map 2).

In experiment 13, the moisture content of all medic seeds measured after 7 d storage in the alternating temperature oven was < 4% (dry weight basis). This shows that all the seeds were likely to be impermeable (Quinlivan 1971a).

M. polymorpha cv. Serena and *M. scutellata* cv. Sair were the hardest-seeded medics tested in experiment 13 (table 10). The softest-seeded medic was *M. rugosa* cv. Sapo, followed by *M. littoralis* cv. Harbinger. The hard-seeds of all other medics softened at similar rates.

2. — Effect of phosphorus on annual medic seed yields, the components of seed yield and the rate of softening of hard-seeds

Seed yields in experiment 14 increased with increasing P applications (table 11). The efficiency with which each species used P from superphosphate was calculated from the initial slope of the relationship between yield and the amount of P applied (table 12). There were differences between species and strains. The results are likely to be specific to the season and management practices.

For each of the medic species, strains or cultivars tested, the amount of P applied had no effect on the burr weight, number of seeds/burr, or seed weight (table 13). Responses in seed yield resulted from an increase in the number of inflorescences and burrs produced per unit area.

After 7 d storage in the alternating temperature oven, the moisture content of seed was < 4% (dry weight basis) and so the seeds were likely to be impermeable. As determined in the laboratory oven (table 14) the rate at which the medic hard-seeds softened was not affected by P treatment although only two treatments were compared, 20 and 2000 kg/ha.

Discussion

As *M. polymorpha* cv. Serena produced amongst the highest seed yields and was the hardest-seeded medic tested it warrants further studies as a potential cultivar for alkaline soils located in low rainfall areas near Esperance, where intense cereal cropping rotations are common. The *M. scutellata* strains also produced high seed yields and are also very hard-seeded. Because of its insect tolerance, *M. scutellata* may play a useful role as a mixture in the medic pastures near Esperance, but its late maturity may restrict successful persistence to areas with a rainfall > 400 mm/a. In experiments near Salmon Gums, *M. scutellata* strains have successfully persisted for up to five years when sown as a mixture with other medics and grazed (by sheep) and cropped in a 1 year pasture:1 year crop rotation. Cultivation for cropping every second year buries some of the medic burrs. This may be vital for the persistence of the large smooth pods of *M. scutellata* because the burial of these burrs may prevent stock (usually sheep) from grazing them.

Cultivars of annual medics and subterranean clover, mainly cvs. Nungarin, Northam and Daliak, are grown on newly cleared alkaline soils near Esperance for commercial seed production. Annual medics and *Rhizobium meliloti* are better adapted to alkaline soils (Robson 1969) as confirmed by my results from experiment 12. Commercial seed on annual medics should be grown on these soils.

Phosphorus from superphosphate increased seed yields of annual medics by increasing the number of burrs produced/unit area. Superphosphate had no effect on the softening of hard-seeds in experiment 14, or on the weight of burrs, numbers of seed/burr, or seed weight.

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