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Screening germplasm and varieties for forage quality: Constraints and potentials in annual medics

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SUMMARY – Annual medics, grown as regenerating pasture in the agro-pastoral Mediterranean systems or ley-farming systems, are an important feed resource not only as green forage during the growing season but also in summer as stubbles and pods. This paper describes the differences between and within species of annual medics in terms of chemical composition, digestibility, intake, palatability, morphology, anatomy and antinutritional factors content for both forage and pods. It also reviews most of the techniques used in the past for the evaluations of medics for forage quality, pointing out that most of these studies have been conducted comparing materials with different earliness on the basis of a single stage of sampling. Some methodological remedies are thus proposed. Several key parameters have been also individuated to be used for the identification of promising genotypes.

Key words: *Medicago* spp., nutritive value, digestibility, intake, palatability.

RESUME – *"Criblage de germoplasme et de variétés pour la qualité fourragère : Contraintes et potentialités chez les luzernes annuelles". Les luzernes annuelles poussant comme des espèces à ressemis spontané dans les systèmes agro-pastoraux méditerranéens ou dans les systèmes "ley-farming" sont une source appréciable d'aliments, non seulement comme fourrage en vert durant leur période de croissance, mais aussi en été, en tant que fourrage sec et gousses. Ce travail décrit les différences parmi les espèces et variétés de luzernes les plus étudiées en terme de: composition, digestibilité, consommation, palatabilité, morphologie, anatomie, ainsi que leurs composants antinutritionnels, aussi bien dans le fourrage que dans les gousses. Il montre en outre, que la plupart des évaluations de la qualité fourragère ont été faites en comparant des matériels sur la base d'un échantillonnage unique pris à différents stades phénologiques. Des approches méthodologiques sont proposées et il est suggéré l'observation de certains paramètres-clés indispensables pour l'identification de génotypes prometteurs.*

Mots-clés : Medicago *spp., valeur nutritive, digestibilité, consommation, palatabilité.*

Introduction

The annual medics are pasture self-reseeding legumes widely represented in the native flora of the Mediterranean basin. Some medics were occasionally or voluntarily introduced to regions of Australia, Chile, South Africa and United States with Mediterranean-type climate. Many studies on the botanical taxonomy and ecology of annual medics have been carried out in the Mediterranean basin, but most of the selection programmes have been conducted in Australia where annual medics are extensively grown in a cereal/pasture legume rotation (ley-farming system). Between the 27 selected and registered cultivars of annual *Medicago*, only 14 originated from Australian ecotypes while the remainder were based on direct introduction (Loi, 1999). Recently four new varieties have been released (*Medicago littoralis* Rhode cv. Herald, *M. littoralis M. tornata* Miller cv. Toreador, *M. truncatula* Gaertner cv. Jester and *M. polymorpha* L. cv. Scimitar) and they will be commercially available in the next years. In the winter rainfall regions of South Africa medics were introduced during the mid 60s and now are one of the major pasture legumes. They are also grown in short-term rotations with wheat and barley (Kotzé *et al*., 1995). In Chile, naturalised burr medic (*M. polymorpha*) is the most frequent annual pasture legumes in a large area from latitude 29ºS, receiving 100-150 mm of annual rainfall, to latitude 38ºS, with above 1000 mm of annual rainfall (Del Pozo *et al.,* 1989). Medics are grown in California for alleyways in vineyards and orchards basically as cover crops but also as pasture (Christensen and Graves, 1996). In the Mediterranean basin, annual medics are mainly used as pasture species in extensive farming systems, especially to improve low quality natural pastures. Moreover in the European countries the recent interest given to organic production systems and low-input oriented agriculture has also increased the demand for pasture legumes such as medics. Unfortunately the commercial Australian varieties are often not well adapted to our environment and management systems. Therefore selection programs have been conducted in the western Mediterranean basin in the last decade with the successful release of new adapted varieties for

pasture improvement, as in the case of *M. polymorpha* cv. Mauguio from France (Prosperi *et al.*, 1999), cv. Anglona from Italy (Porqueddu *et al*., 1999) and also from North Africa (Morocco).

Medics, as well as other annual pasture legumes, have a high feeding quality, determined by higher protein, mineral and vitamin contents, low proportion of cell wall and particularly higher level of intake than grasses (Crespo, 1987). Forage quality, in general, was not included in most of the Australian breeding targets. However an emphasis has been put in selecting varieties with low level of estrogens, resistance to pests and diseases, climatic and edaphic adaptation, yield and seed production, maturity and grazing tolerance (Hutchinson and Clements, 1987). Usually, chemical analysis and nutritive value assessment were considered only at the final stage of the evaluation on large plot experiments under grazing or cutting. It is possible that accessions with high nutritive value have been discarded during the early phases of the selection programme, while there are evidences that forage quality can be generally increased without or with minor losses in forage yield.

Annual medics, grown as regenerating pasture in the agro-pastoral Mediterranean systems or cereal farming systems, are an important feed resource not only as green forage throughout the growing season but also as stubbles and pods in summer and early autumn. So far, also these feeding components and their quality could be considered in a selection program to identify superior lines. It demands a careful analysis and identification of agronomic traits that are correlated with forage and pod quality, including their implications in the persistence and animal performances.

This paper examines the differences among the most important commercial species and varieties of medics such as *M. truncatula, M. polymorpha, M. scutellata* Miller*, M. littoralis, M. rugosa* Desr. and *M. tornata,* considering the main parameters related to the feeding value. It begins by exploring the variability existing in terms of green and dry forage. It then explores also the differences regarding pods and seeds. Finally it underlines some relevant points to improve the selection efficiency and it briefly discusses some constraints and the potentials of medics.

Differences between species, cultivars and lines

Green and dry forage

Genetics (e.g. morphological traits, phenology) and environmental (e.g. edaphic and climate conditions) factors may influence the forage quality. The nutritive value of pasture legumes can vary between species, cultivars and plant organs with the stage of development. Late maturing cultivars maintain higher dry matter digestibility and contain more essential nutrients than early maturing cultivars during late spring (Mulholland, 1988).

Chemical composition

Seasonal influences on the chemical composition and digestibility of *M. truncatula* Gaertn. cv. Jemalong pasture over two years were studied by Brand *et al*. (1991a). Significant variation between months was found on organic matter basis and crude protein (CP) (from 11.7 to 37.5%), crude fibre (from 12.7 to 42.1%) contents, *in vitro* digestibility (from 36.4 to 77.6%) and *in vivo* digestibility (from 47.9 to 74.4%). Dry matter (DM), neutral-detergent fibre (NDF), acid-detergent fibre (ADF) and acid-detergent lignin (ADL) content showed significant variation during early spring in a sown pasture of *M. polymorpha* cv. Anglona, although CP content was relatively stable (average value 27%) and dairy ewes maintained a high average milk yield of 1.5 kg/ewe/day (Sitzia *et al*., 2000).

In a study of Zhu *et al*. (1996) on medics, significant positive relationships have been found between NDF, ADF contents and forage yield and negative relationship between CP concentration and forage production. Forage quality of several annual *Medicago* estimated by CP, NDF and ADF contents, and leaf:stem ratio appeared to be higher or comparable to those of alfalfa and clovers with wide differences between genotypes (Derkaoui *et al*., 1993; Zhu *et al*., 1996; Shrestha *et al*., 1998). The differences in concentrations among cultivars within the same species were sometimes of the same magnitude of the differences among species. Late-maturing species were generally higher in CP than early-maturing species (Table 1).

Table 1. Maturity and CP, ADF and NDF contents (g/kg) on organic matter of some medic varieties tested in Morocco (modified from Derkaoui *et al.,* 1993)

Species	Cultivar	Days	CP†	ADF††	NDF
M. littoralis	Harbinger	95	213-232	215-255	328
M. polymorpha	Circle Valley	107	208-243	195-262	316
M. polymorpha	Serena	73	197-218	222-230	328
M. rugosa	Paragosa	107	210-224	178-182	303
M. rugosa	Paraponto	106	217-246	208	324
M. rugosa	Sapo	108	212-235	185-188	324
M. scutellata	Robinson	98	199-218	218-220	303
M. scutellata	Sava	101	196-219	220-260	316
M. tornata	Tornafield	104	215-235	190-210	302
M. truncatula	Borung	102	215-259	205-218	324
M. truncatula	Cyprus	85	194-230	245-252	367
M. truncatula	Jemalong	104	216-254	215-228	339
M. truncatula	Paraggio	109	210-243	185-215	320
M. sativa	OK 61	nd	233-274	182-230	273

†Range of 3 sites.
††Range of 2 sites.

In the study of Goumiri *et al.* (1989), 12 populations representing 6 annual medics were compared for nutritive value traits. The results have shown no significant differences between populations except for CP in *M. scutellata* and *M. aculeata* Willd., while within species significant differences were observed between the quality parameters with the exception of the energy value. In Sardinia, CP content of 35 *M. polymorpha* accessions ranged from 25.8 to 30.6% at late bud stage with no flowers (Brundu, 1992) while the chemical analysis of 19 populations of four annual medics (*M. polymorpha, M. ciliaris* L. All., *M. orbicularis* Bartal. and *M. arabica* Willd.) showed wide differences for NDF (15.5-27.1%), ADF (10.1-19.6%) and ADL (3.0-10.2%) concentrations (Vargiu and Spano, unpublished data).

Numerous studies have indicated that genotype environment interaction is relatively important in determining the results of breeding for increased forage quality in perennial species (Casler, 1997) while contrasting results have been found in annual medics (Derkaoui *et al.,* 1993; Zhu *et al.,* 1996; Shrestha *et al.,* 1998). However in most of these experiments the species and accession comparison was affected by differences in the stage of maturity. Dry forage represents a summer strategic feed resource as standing hay. Burr medic stubble showed a better chemical composition compared to standing hay of fertilised and unfertilised natural pasture mainly based on grasses (Fois *et al*., 2000). Samples of *M. polymorpha* dry forage analysed in late July showed 14.0% CP, 71.4% NDF, 52.1% ADF and 11.9% ADL on organic matter basis. *M. truncatula* hay contained 17% CP and had an organic matter digestibility of 65%, it was concluded by Denney *et al.* (1979) that barrel medic hay was similar in nutritive value to a high quality alfalfa hay.

Digestibility and intake

Measurements of *in vitro* digestibility could be used to simultaneously select for digestibility and intake. High correlations were found by Taylor *et al*. (1989) between digestibility and intake ($r = 0.96$, $P < 0.001$) and also between *in vivo* and *in vitro* digestibility ($r = 0.92$, $P < 0.01$) in subterranean clover.

Radcliffe and Cochrane (1970) for example, indicated that *M. scutellata* presented higher digestibility than *M. truncatula* throughout the growing cycle. Dry matter digestibility (DMD) of *M. truncatula* declined from 72% at the vegetative stage to 60% at flowering and 30% at senescence. Jones and McLeod (1971) obtained 78% digestibility of *M. scutellata* at the vegetative stage and 50% at the end of the maturation. In a comparison of six *M. truncatula* varieties and *M. tornata* cv. Tornafield under continuous grazing by ewes Brownlee and Denney (1985) found that the overall mean cv. Cyprus *in vitro* digestibility (66%) was lower than cv. Jemalong (71%). Cv. Hannaford, Cyprus and Akbar differed significantly from that of Jemalong in terms of digestibility decay rates.

Mulholland and Scott (1992) found that intake in four medics ranged from 738 to 1131 g/day in *M. scutellata* cv. Sava and *M. murex* Willd. cv. Zodiac respectively. Lamb growth rates in spring over two years were from 140 to 211 g/day. However the authors commented that wool growth generally was positively associated with liveweight change, and that the differences were not related to recorded measurements of chemical composition of pastures or digestibility. Furthmore estimated intake of organic matter accounted for only 50 to 70% of the variation in liveweight response.

The intake of digestible organic matter (DOM) ranged between 445 and 1008 g/day and CP intake varied between 48 and 333 g/day in Merino ewes grazing a *M. truncatula* pasture (stocking rate of 5.2 ewes/ha/year), both parameters showed a clear seasonal pattern (Brand *et al*., 1991b). DOM intake of the Merino ewes was insufficient to meet DOM requirements during lactation period. CP intake, on the other hand, exceeded requirements, except during the dry season (early pregnancy). Despite these deficits overall production performance (wool and meat) was satisfactory, probably due to the ability of ewes to offset short-term nutritional gap by fat protein depot utilisation. Other authors recently found higher intake of DOM (about 1300 g/day) in dairy ewes grazing cv. Anglona burr medic (G. Molle, Istituto Zootecnico e Caesario per la Sardagna, Olmedo, pers. comm.) under a high seasonal stocking rate (27 ewes/ha).

Palatability

Despite the generally high quality forage of annual medics, relevant differences among species in terms of palatability have been identified. Specific indexes (SI, score from 1 to 5) have been attributed to define the "palatability" of a single pasture species in different environments. Their contribution to the sward Pastoral Value throughout the linear analysis of the vegetation has been assessed by Daget and Poissonet (1969). Le Houérou and Ionesco (1987) considered 14 annual medics for the steppe areas of Tunisia and assigned a high SI (between 4 and 5) to most of the species, except for *M. minima* Bartall (SI = 3). An inventory of SI has been recently made available on the internet by Roggero *et al*. (2001).

Nevertheless high relative palatability may lead to excessive selective grazing pressure for the species and its subsequent demise. The selection and use of low relative palatability varieties suggested by some authors (Kellaway *et al*., 1993) is an useful strategy for the varieties' survival in a mixed sward or it may be used as a tool for controlling undesirable weeds under heavy grazing with high stocking rates.

Morphology and anatomy

The nutritive value of the whole plant is related to the quality of the individual plant parts (leaves, petioles and stem) and their proportions in the sward. Derkaoui *et al*. (1990) found in four medics that seed size and the maturation cycle were the factors that affected biomass partitioning and root and stem development, thus influencing forage quality. Ru and Fortune (2000) have outlined that variation in both DMD and nitrogen concentration among plant parts offers a potential for selection of leafy cultivars for high nutritional characteristics in subterranean clover varieties. However, it should be noted that high leaf proportion in a pure legume pasture might cause bloat due to the high nitrogen content and could reduce the resistance of pasture to grazing, insect and wind damage. Leafy cultivars will be valuable for grazing animals if they are grown as mixed pastures.

Leaf:stem ratio is generally well known as a good indicator of forage quality. For example, Talamucci and Pazzi (1982) reported significative higher value of leaf:stem ratio in *M. polymorpha* cv. Circle Valley than *M. truncatula* cv. Cyprus and *M. tornata* cv. Tornafield with 0.97, 0.80 and 0.76 respectively. A similar dynamic was observed for CP ranging from 22.5% in *M. tornata* to 27.8% in *M. polymorpha*. Variation with the age in leaf:stem ratio showed a decline in this ratio during pod and seed formation probably related to their high demand for photosynthate also in presence of an age species interaction (Derkaoui *et al*., 1990).

Little attention has been paid to the stem thickness, that is also associated to variable plant habit, that in annual medics ranges between prostrate and semi-erect. Prostrate and erect plants differ in the physical distribution of structural components (e.g. lignin) so that prostrate stems are less rigid and have greater digestibility. Genotypic differences in stem digestibility are usually associated with variations in numbers of vascular bundles or in lignification of the parenchyma between the vascular bundles. The stem anatomy of six annual legumes (*M. murex* cv. Zodiac, *T. subterraneum* L. cv. Junee, *T.*

michelianum Savi cv. Paradana and *T. resupinatum* L. cv. Kyambro, Maral and SA12240) was examined. It was found that *M. murex* had a very high vascular bundle density per mm^2 of stem tissue, which also resulted in a poor performance under grazing (Kellaway *et al.*, 1993).

The decline in nutritive value with age in legumes is primarily due to changes in stem rather than leaf DMD and cell wall content, and to an increase in the proportion of stem to leaf tissue on the plant (Albrecht *et al.*, 1987). Moreover, as medics mature and dry off in late spring/summer, the leaves fall and decompose. Therefore, genotypes with stems of higher nutritive value, are of major interest as this is the part of the plant most available to livestock in late spring and summer.

Antinutritional factors

Coumestans, which induce only temporary infertility in ewes, are especially present in annual medics. In contrast to estrogenic activity of formononetin in subterranean clover, which ceases as the plant matures and dries, cumestrol in medics increases with maturity and reaches a high level in dry pastures. Intraspecific genetic variations in the content of estrogenic substances enable cultivars to be selected for reduced estrogenic activity or its absence. It has also been observed that plants under stress, induced by deficiencies in nutrients or biotic diseases, increase estrogenic activity (Barbetti and Fang, 1991). If grazing sheep have a varied feeding regime, the infertility problems may be avoided. Bloat is not frequent in medics and in any case can be easily avoided with an appropriate animal management. Moreover, Jurzysta and Nowacki (1979) have found significant differences in the saponin content of 24 *Medicago* species as well as great differentiation in the biological activity of saponins.

Pods and seeds

Pods of annual *Medicago* are an important component of the diet of sheep during the summer dry period both in ley farming and agro-pastoral systems. Medics with an appropriate spring management can produce over 1 t/ha of seed (Lelievre and Porqueddu, 1994) or 3 t/ha of pods with high CP content (Sitzia and Fois, 1999). The results of Brownlee and Denney (1985) demonstrated that pod is a true feeding reserve during the summer drought because it appears in the diet only when more palatable pasture components become scarce as shown in Fig. 1.

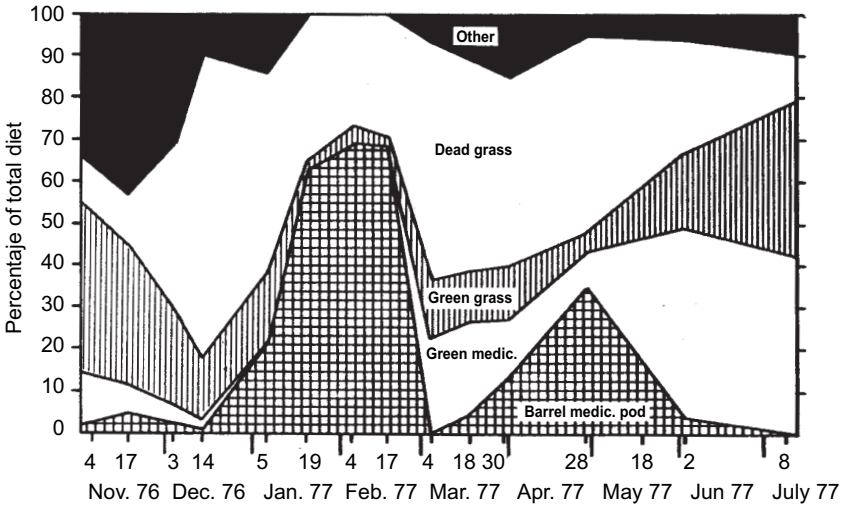

Fig. 1. Botanical composition of oesophageal fistula extrusa collected from sheep grazing *M. truncatula* pastures (source: Brownlee and Denney, 1985).

While approximately 70% of the diet in summer comprised medic pods, the proportion declined rapidly to zero when green material became available after rain. Several studies were carried out on medic pastures to set up a rational summer sward management in terms of stocking rate and grazing period to ensure adequate dry residues and seed reserves for regeneration (Cocks, 1992; Chaichi *et al*., 1996).

Medic pods are more available than that from subterranean clover. Significative differences in wool production by sheep grazing subterranean clover or medics pastures over summer/autumn were partly attributed by Doyle *et al*. (1989) to the higher pods intake of *M. truncatula* than burrs of *T. subterraneum*. However because of easy consumption of medics pods by sheep, intensive management requirement are needed during summer to avoid impoverishment of the seed bank.

Chemical composition

The nutritive value of pods of different medic cultivars is reported in Table 2. Despite the low nutritive value shown by pods of *M. truncatula* cv. Jemalong because of their high content of indigestible fibre, Denney *et al*. (1979) suggested that nitrogen in medic pods could be used more efficiently, and enhanced rumen microbial activity for a better utilisation of the stubble and dry forage.

Table 2. Nutritive value of pods of different medic cultivars (% of OM)

Species	Cultivar	CP	NDF	ADF	OMD†	Reference adapted from
M. littoralis	Harbinger	20.2	67.2	51.4	44.5	Kotzé *et al*. (1995)
M. polymorpha	Anglona	22.7	61.6	42.7	n.d.	Fois *et al.* (2000)
M. polymorpha	Santiago	24.2	61.2	36.2	39.9	Kotzé *et al.* (1995)
M. truncatula	Cyprus	18.5	69.0	47.4	38.7	Kotzé *et al.* (1995)
M. truncatula	Jemalong	23.8	85.5	77.5	24.3	Denney *et al*. (1979)
M. truncatula	Parabinga	14.8	76.9	55.7	32.3	Kotzé *et al*. (1995)
M. truncatula	Paraggio	14.8	74.1	48.7	36.7	Kotzé *et al*. (1995)
M. truncatula	Sephi	17.3	70.5	47.1	39.8	Kotzé *et al*. (1995)

†Apparent digestibility.

Digestibility and intake

As reported in Table 2, also significant differences in terms of apparent digestibility were found between cultivars in pods of *M. truncatula* (Kotzé *et al.*, 1995). A comparison of seven feedstuffs by Brand *et al.* (1991a) showed DM intake of *M. truncatula* cv. Jemalong pods of about 2000 g/sheep/day with 44% and 30% *in vivo* and *in vitro* digestibility respectively. While Fois *et al*. (2000) reported a DM intake on *M. polymorpha* cv. Anglona under dairy sheep summer grazing ranging from 981 to 1358 g/sheep/day. The DM intake of *M. truncatula* cv. Paraggio ranged from 1837 to only 343 g/sheep/day for the pods from a good and poor growing season respectively (Valizadeh *et al*., 1993). In spite of the differences in voluntary intake, rumen degradation did not differ significantly between the two samples but within each sample there was a significant difference between the DM disappearance of whole pods and the single parts. This suggested that contamination by fungal residues, or even differences in the content of some other palatable compounds could contribute to reducing the intake of poor pods.

Morphology and anatomy

Medics differ widely about pod dimension as well as pod weight and morphological characteristics (spiny or spineless, no. of coils per pod, open or close coils). Medics in general have greater seed size than clovers but with wide differences between species (from 2 to 20%) and within species (e.g. from 1.7 to 4.2% in *M. truncatula*) in seed recovery (Carter *et al*., 1989; Thomson *et al*., 1990).

Although seed survival is the result of more than one characteristic, pod size and number of seeds per pod have shown the highest correlation (r = -0.92 and r = 0.89 respectively) with seed survival in six cultivars from different *Medicago* species (Kotzé *et al*., 1995). In the same study it was found that *M. polymorpha* (34%) and *M. littoralis* (30%) had better seed:pod rate in comparison to three *M. truncatula* cultivars (18-28%). This was due to a higher seed content of *M. littoralis* and *M. polymorpha* and was also expressed in higher CP content (r = 0.94) and digestibility of the pods. Considering the whole results about the nutritive values, the ingestion and seed recovery of the different cultivars, the authors concluded that *M. polymorpha* cv. Santiago was the best suited for utilisation by sheep during the summer months.

Moreover, unknown factors other than simple physical pod dimensions influenced sheep in feed selection as recorded by Saunders and Egan (1993). These authors have found no loss of seed through grazing in a *M. orbicularis* line with larger size and discoid shape of pod whereas the other 4 varieties of *M. truncatula* and *M. littoralis* cv. Harbinger showed losses in the range of 16-30%.

Conclusions

Germplasm evaluation of annual medics based on agronomic traits should take into account the relevant variability for some characteristics related to the forage and pod quality, thus including measurements related to nutritive value (digestibility and biochemical properties) since nursery level (Roggero and Porqueddu, 1999). Much of the variation observed in CP or digestibility may be promising at first stage of selection but finally may be negligible when truncated at levels of maturity classes of herbage yield in the course of selection process. There is a general lack of information on the variability of nutritive value of whole plant and plant parts of medics of similar maturity. Therefore it is difficult to compare the results reported in the literature because of the different maturity of the varieties and also because of the different methodology of sampling (e.g. mowing height and grazing intensity).

In the cases where genotype environment interaction is important, this problem may be partly overcome by multistage selection in which putative extreme individuals are sampled a second, and possibly third time to verify their status as extreme individuals (Godshalk *et al.*, 1988). A system for quantifying maturity of annual medics was developed by Zhu *et al*. (1996) based on the numerical system used to classify the morphological stage of alfalfa. The mean stage by weight (MSW) incorporates both environmental factors and plant development into a quantitative index. Using this methodology forage CP, NDF and ADF contents are regressed against maturity.

Greater understanding of the chemical and physical structure of the anatomical fractions of medics under grazing conditions could facilitate the selection and breeding of cultivars with superior nutritive value (Kellaway *et al*., 1993). The use of alkanes in the cuticular waxes of plants appears promising, and their use in large-scale evaluation to determine intake and selection of pasture species as well as plant part is currently ongoing (Baker and Dynes, 1999). Nevertheless, the improvement of forage quality is pointed out by selection for low fibre content, high CP content or high digestibility, and it will likely cause correlated responses for other plant traits and may lead to a loss of disease resistance.

Transgenic plants expressing a gene encoding proteins that are rich in sulphur amino acids (limiting wool growth) and resistant to rumen degradation have been obtained for subterranean clover and alfalfa (McNabb *et al*., 1993). These techniques of genetic engineering may also be used in annual medics but several constraints are present: (i) inclusion of sunflower albumin to enhance muscle growth or milk production may not be biologically possible; (ii) the transgenic varieties of subterranean clover are not multiplied at commercial level mainly because of the low economic interest; (iii) the genetic variation seems still sufficient for plant breeders to continue to make significant progress using conventional and molecular techniques; and (iv) the environmental impact of transgenic plants is not completely cleared particularly in the case of pasture species used on large areas and there is also poor public acceptance of genetically manipulated material.

Recent studies have shown the beneficial role of condensed tannins contained in leaves of some forage legumes, not only for enhanced animal performance increasing rumen escape proteins, but also for ruminant welfare and health (Sulas *et al.*, 1996). The selection of new varieties should be addressed to improve feed resources with high nutritive value particularly in late spring and summer. In winter, high forage quality could be achieved using medics also in mixture with self reseeding annual grasses e.g. *Lolium rigidum* Gaudin. The evaluation of the accessions to improve feed quality in medics could be carried out with a multi-criteria approach (Roy, 1996), a tentative effort to identify the main traits is summarised in Table 3.

Legumes as source of proteins for both forage and grain have greater chances to increase their importance into the farming systems of the 21st century. Annual medic varieties with higher nutritive value could play an important role also in organic farming to balance reductions in dry matter production due to a lower input utilisation. In this context, encouraging results using annual medics were obtained for instance by Fois *et al*. (1999). *M. polymorpha* cv. Anglona pasture representing 33% of the total surface of an organic dairy sheep farming system based on legumes was compared to a conventional one based

mainly on grasses. Milk yield per head was higher in the organic (228 l/ewe/year) than the conventional system (172 l/ewe/year) despite a higher milk yield per ha in the latter system.

Table 3. Main criteria of selection to improve feeding value in annual medics for Mediterranean farming systems[†]

Forage	
Leaf:stem ratio	+++
Stem thickness	+++
Chemical composition (CP, NDF, ADF, ADL)	+
Digestibility & Intake	++
Palatability	++
Antinutritional factors	++
Pod	
Seed:pod rate	+++
Chemical composition (CP, NDF, ADF, ADL)	+
Digestibility and intake	++

[†]Important (+) to very important (+++).

Although annual medics can be highly productive and provide a source of high quality food during the growing season and summer, strict soil type preferences, intensive seed production systems and the intensive management required (e.g. control of pest and diseases, careful summer grazing) are deterrents to adoption under prevailing economic conditions.

New alternative pasture legumes recently selected in Western Australia are easily harvested and threshed. In particular *O. sativus* Brot., *T. glanduliferum* Boiss., *T. formosum* Urv. and *Trigonella balansae* Boiss can be harvested using machines freely available to farmers (such as conventional cereal harvesters) instead of the specialist and environmentally damaging suction harvester used for subterranean clover and the annual medics (Nutt and Loi, 1999). Finally, high grazing pressures and poor grazing management are the major causes of the seed bank impoverishment of medics. Species such as *B. pelecinus* L.*, T. spumosum* L. and *T. michelianum* Savi are more likely to survive ingestion by sheep during summer because of their small seeds compared to medics and subterranean clover (Loi *et al.*, 2000).

The feeding value of medics as well as the other pasture species is affected by both plant and animal factors; so far the most successful results could be achieved by selection programmes with an interdisciplinary integrated approach, where plant breeders, agronomists and animal nutritionists actively collaborate.

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