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# Phenotypic variability for morphological and yield parameters in woody forage accessions of saltbush (*Atriplex halimus* L.) and tree-medic (*Medicago arborea* L.) *

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ABSTRACT

Phenotypic variability for agronomic traits has been evaluated in 139 accessions of saltbush (*Atriplex halimus* L.) and in 54 accessions of tree-medic (*Medicago arborea* L.) collected in Mediterranean locations. The accessions of saltbush and tree-medic were evaluated over six and four cuts, respectively. A remarkable phenotypic variability in both species has been found for green biomass and dry matter yield, leaf-branch ratio and plant height. The most productive cut was in summer in saltbush (472.5 g/clone) and in spring in tree-medic (303.0 g/clone). In summer, the accessions of saltbush produced fresh biomass while those of tree-medic fell into vegetative stasis.

*Keywords: Atriplex halimus* L., *Medicago arborea* L., Mediterranean environments, Shrubs.

## INTRODUCTION

The pastures of the marginal lands of the Mediterranean environments are characterized by low and irregular forage yield (Bonciarelli and Santilocchi, 1980; Corleto *et al.*, 1980; Naveh, 1989). The causes of the pasture impoverishment, quite widespread over the last few decades in the areas in question, can be ascribed to the abandonment of the land and to a constant increase in soil degradation. As a consequence, there has been an increase in anomalous top soil whereby unproductive Mediterranean maquis has been extended. A better, stable forage distribution in these areas can be obtained by integrating natural pasture with woody fodder trees. The utility of the fodder plants arises from their adaptability to survive in harsh weather condition and in soil with anomalous pedoclimatic characteristics. The physiological mechanisms evolved in the woody species allow the plant to withstand long periods of drought with only a slight reduction in yield potential, chemical and organoleptic characteristics and palatability of the grazing parts of the plant (Mckell, 1989; Newton and Goodin, 1989; Le Houérou, 1993).

The shrubs in Mediterranean regions could be primarily used to prevent soil erosion (Chisci et al,, 1991; Le Houérou, 1993) and secondarily to increase forage availability during the summer. Moreover, when combined with other forage crops, they could provide green biomass for long periods of the year. Therefore, an experiment was undertaken to evaluate the yield potential of accessions belonging to the shrub species *Atriplex halimus* L. and *Medicago arborea* L.

The aims of the experiment were to evaluate the phenotypic variability for agronomic parameters, and select superior accessions for breeding purposes.

## MATERIALS AND METHODS

Accessions of saltbush and tree-medic collected around several Mediterranean sites were agronomically evaluated at the Forage Crop Institute located at Foggia (41°31′N, 3°16′E, and 76 m above sea level) (Table 1).

The clones were radicated in a cold greenhouse in 1989 utilizing a rooting product (α-Naphthyl acetic acid at 0.5% technical pure). Transplanting to a field nursery was carried out in March 1990. The cut schedule began

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TABLE 1

**Origin of the accession of *Atriplex halimus* L. and *Medicago arborea* L. utilized in the experiments**

| Accession code | Harvesting site: Country | Harvesting site: Region | Number of accessions |
|---|---|---|---|
| *(Atriplex halimus L.) Saltbush* | | | |
| AS | Italy | Sardinia | 50 |
| AA | Italy | Apulia | 35 |
| AC | Italy | Campania | 22 |
| AK | Italy | Calabria | 17 |
| AM | Italy | Molise | 15 |
| *(Medicago arborea L.) Tree-medic* | | | |
| ML | France | Roussillon Langue doc | 10 |
| MA | Italy | Apulia | 14 |
| MC | Italy | Campania | 8 |
| MK | Italy | Calabria | 14 |
| MM | Italy | Molise | 8 |

in 1991 (Table 2). Hitherto, a total of six and four cuts for saltbush and tree-medic were made, respectively. The bioagronomical traits evaluated were: biomass and dry matter yield (g/clone), dry matter content at cut (%), leaf-branch ratio (%), plant height and plant diameter (cm). Biomass yield was directly estimated with a grazing simulation by pruning the branches which come out from a hypothetical known volume created by a cylinder. At the time of the cut, the cylinder was fitted onto the plant and the biomass was pruned and split into leaves and woody branches. A sample of about 150 g of fresh leaf and branch was oven-dried at 60 °C for 96 h for determining dry matter content at cut. Data were analyzed using the analysis of variance following the procedure described by SATTERTHWAITE (1946) in which cuts over the two years of evaluation were considered as repetitions. In the statistical analysis the cut was considered as an independent effect, accession and year being a fixed effect. After testing the homogeneity of variance the data of two years underwent a combined analysis. The three-factor interaction (YxCxA) was the error term utilized for comparing the main effect of year, cut, clone and the effects of two-factor interactions. To select superior accessions, the data of each cut was processed according to the cluster method technique as

TABLE 2

**Dates of the cuts in the two shrub species**

| Shrub species | 1991 I | 1991 II | 1991 III | 1992 I | 1992 II | 1992 III |
|---|---|---|---|---|---|---|
| Saltbush | 5/2 | 4/6 | 9/10 | 10/4 | 30/6 | 27/10 |
| Tree-medic | 14/2 | 11/6 | — | 8/4 | 29/6 | — |

described by SCOTT and KNOTT (1974). The data of the accessions included in the higher cluster group of dry matter parameter and those of the related traits were extrapolated and statistically analysed for computing the LSD among accessions.

## RESULTS AND DISCUSSION

Saltbush. (*A. halimus*) is native to the Mediterranean basin and belongs to the Chenopodiaceae family. Its green biomass is well grazed mainly during the summer-autumn seasons. Saltbush grows in environments with 200-300 mm of rain and it is well adapted to anomalous soils particularly characterized by low pH. The species has an allogamous mating system and was introduced for pastoral consumption in the 1980s with the aim to provide fodder biomass during the critical period of the summer (CORREAL, 1993).

Tree-medic (*M. arborea*) is a common leguminous species in the Mediterranean basin, able to provide fresh biomass during spring and late autumn. The species has an allogamous mating reproductive system and grows in an environment with a thermo-Mediterranean semi-arid climate (annual average temperature of 18°C and 335 mm of rainfall).

The combined analysis of variance for both shrub species highlighted a significant effect (P = 0.01) of the cut (Table 3). The highly significant effect of the two-factor interaction (Y × C) was caused by interaction of the accession at the time of cut with weather conditions. The two species were characterized by a different trend in dry matter production during the vegetative cycle of the year. In saltbush, the dry matter yields of the summer and autumn cuts were higher (73.5 and 67.3%, respectively) than those of the spring cuts, while in tree-medic, the production of spring cut in 1992 (38.8%) was higher than that in summer (Figure 1). As previously observed by STRINGI *et al.* (1991) and LE HOUÉROU (1993), saltbush accessions produced a greater and more stable biomass yield than tree-medic. According to the cut schedule, the tree-medic shrub was characterized by vegetative stasis during the summer season; by contrast, saltbush was particularly productive at this time of year. Furthermore, the leaf-branch ratios in the first cuts were high compared to those of the second cuts, conferring high quality to the fodder. In saltbush accessions leaf-branch ratio appeared to be related to the weather conditions of the dry season (Figure 2).

**TABLE 3**

**Analyses of variance for yield and morphological characters in 139 accessions of saltbush and 54 of tree-medic**

| Source | df | Mean square: Dry matter Yeld[a] | Mean square: Dry matter At cut | Mean square: Biomass Yield[a] | Mean square: Plant Height | Mean square: Plant Diameter | Mean square: Leaf-branch ratio |
|---|---|---|---|---|---|---|---|
| *Saltbush* | | | | | | | |
| Year (Y) | 1 | 97 * | 17652 ** | 15785 ** | 19612 ** | 912 ** | 447 ** |
| Cut (C) | 2 | 1406 ** | 12433 ** | 258285 ** | 64472 ** | 247431 ** | 323 ** |
| Accession (A) | 138 | 253 ** | 59 ** | 3567 ** | 2959 ** | 6309 ** | 4 ** |
| *Interaction* | | | | | | | |
| Y × C | 2 | 7544 ** | 11952 ** | 68054 ** | 9112 ** | 62368 ** | 330 ** |
| C × A | 276 | 69 ** | 21 | 839 ** | 294 ** | 958 ** | 1 |
| Y × A | 138 | 26 | 45 ** | 322 | 130 | 478 | 1 |
| Y × A × C | 276 | 37 | 38 | 396 | 205 | 519 | 1 |
| *Tree-medic* | | | | | | | |
| Year (Y) | 1 | 169 ** | 20 | 1535 ** | 3134 ** | 145 * | 1 |
| Cut (C) | 1 | 968 ** | 383 ** | 9223 ** | 10518 ** | 24712 ** | 163 ** |
| Accession (A) | 53 | 26 * | 19 ** | 340 * | 193 ** | 415 ** | 1 |
| *Interaction* | | | | | | | |
| Y × C | 1 | 4704 ** | 4 | 58096 ** | 7919 ** | 27256 ** | 1 |
| C × A | 1 | 6 | 6 | 67 | 47 | 67 | 1 |
| Y × A | 53 | 8 | 5 | 86 | 45 | 106 | 1 |
| Y × A × C | 53 | 15 | 6 | 178 | 32 | 78 | 1 |

*, ** Significant at $P = 0.05$, and 0.01 respectively.
[a] Actual values = reported values × $10^3$.

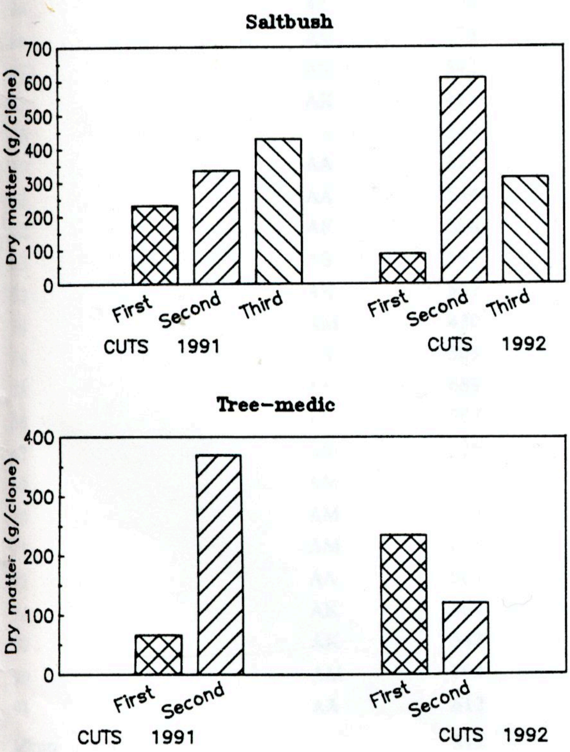


FIGURE 1 - Dry matter production in cuts.

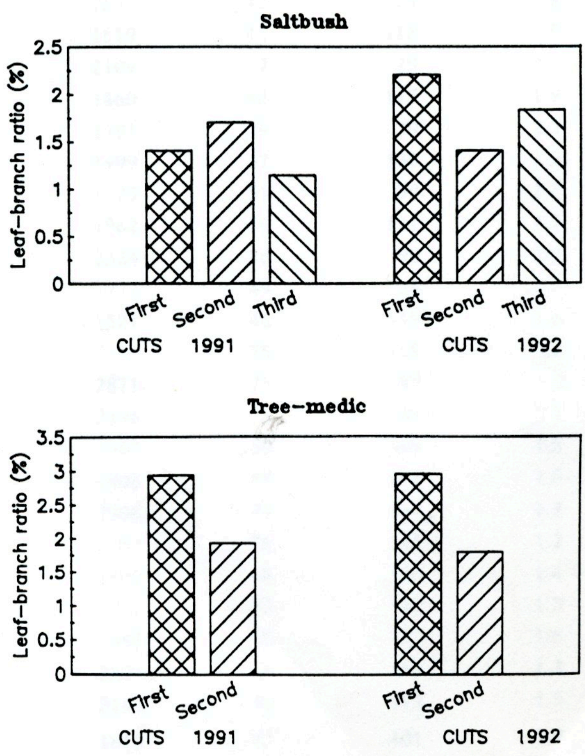


FIGURE 2 - Leaf-branch ratio in cuts.

The mean square values of the cuts in saltbush species (Table 3) were greater than those of tree-medic, indicating a more selective effect of cut on the former accessions. This behaviour could be ascribed to the greater variability of the latter clones.

The range of phenotypic variability, the general mean, the mean and number of clones associated to the superior cluster groups are shown in Tables 4 and 5 in saltbush and tree-medic, respectively. The saltbush clones had a higher yield potential than those of tree-medic. In both species, less than 37% of clones were associated to the superior cluster groups for dry matter and biomass production, plant height and leaf-branch ratio. On the contrary, most of the saltbush accessions were associated to the superior cluster group for dry matter content at cut suggesting little variability for this parameter (Table 4).

Considering the very slight influence of year on dry matter yield (two-factor interaction Y × A non-significant, Table 3) and the yield potential of the accessions in the superior cluster group, this trait seems to be useful for selecting productive and stable clones. Applying the SCOTT and KNOTT's (1974) clustering method to the dry matter data a set of superior accessions (31.7% of the total clones in saltbush and 37% in tree-medic species) was identified.

The saltbush clones from the different sites were differently represented in the superior cluster group for dry matter: 41% of the accessions from Calabria, 40% from Molise, 34% from Apulia, 24% from Sardinia and 18% from Campania were found in this cluster group. The saltbush accessions from Sardinia showed high values for biomass yield, plant height and leaf-branch ratio compared to the others clones. The clones collected in Campania had plant heights and plant diameters similar to those of the Sardinian plants. On the contrary, the clones collected in Apulia, Calabria and Molise showed, high values of plant diameter. The leaf-branch ratio of the Sardinian and Campania accessions were 58.8% larger than that of the accessions from the other sites, justifying the lower dry matter content at cut of the clones from these two sites.

In tree-medic, the accessions in the superior cluster group (Table 7) included 30% of the clones collected in Apulia, 20% of the clones from Roussillon Langue-doc and 20% from Calabria. The clones collected in Campania and Molise were less represented (15%). The high leaf-branch ratio values observed in the clones from Roussillon Langue-doc can be accounted for by their high leaf production.

In saltbush, 13 accessions were found to occur in four or five of the six superior cluster groups (Table 8); seven of them belong to the Sardinian clones. Three accessions from Campania a (8 AC, 9 AC and 10 AC) showed high values of dry matter content at cut and were characterized by a high leaf-branch ratio, indicating a reduced develop-

**TABLE 4**

**Means over six cuts, range (upper and lower values in brackets), number and mean of saltbush clones in to the superior cluster group**

| Trait | Mean | Range | Superior clones | |
|---|---|---|---|---|
| | | | Number | Mean |
| Dry matter yield (g/clone) | 335 | (1302 – 10) | 44 | 511 |
| Dry matter at cut (%) | 27 | (48 – 13) | 94 | 29 |
| Biomass yield (g/clone) | 1244 | (5100 – 31) | 46 | 1886 |
| Plant height (cm) | 51 | (125 – 28) | 38 | 73 |
| Plant diameter (cm) | 85 | (140 – 48) | 67 | 92 |
| Leaf-branch ratio (%) | 2.0 | (7.5 – 0.5) | 34 | 2.7 |

**TABLE 5**

**Range of variability, mean over four cuts, number and mean of tree-medic clones associated to the higher cluster group**

| Trait | Range | Mean | Superior clones | |
|---|---|---|---|---|
| | | | Number | Mean |
| Dry matter yield (g/clone) | 780 – 18 | 199 (± 2)[a] | 20 | 259 |
| Dry matter at cut (%) | 34 – 23 | 29 (± 1) | 23 | 30 |
| Biomass yield (g/clone) | 2.344 – 69 | 691 (± 4) | 19 | 926 |
| Plant height (cm) | 73 – 21 | 44 (± 2) | 22 | 49 |
| Plant diameter (cm) | 83 – 49 | 63 (± 3) | 16 | 72 |
| Leaf-branch ratio (%) | 6.1 – 1.1 | 2.3 (± 0.1) | 19 | 2.6 |

[a] Standard error.

**TABLE 6**

**Dry matter, biomass yield and morphological characteristics of 44 saltbush accessions comprised in the superior cluster**

| Accession | Code | Dry matter Yield (g/clone) | Dry matter At cut (%) | Biomass yield (g/clone) | Plant Height (cm) | Plant Diameter (cm) | Leaf-branch ratio (%) |
|---|---|---|---|---|---|---|---|
| 3 | AA | 421 | 28 | 1543 | 45 | 129 | 1.7 |
| 4 | AK | 506 | 30 | 1629 | 49 | 121 | 1.8 |
| 5 | AK | 552 | 30 | 1869 | 53 | 125 | 1.9 |
| 7 | AC | 538 | 24 | 2124 | 80 | 81 | 1.9 |
| 8 | AC | 586 | 23 | 2417 | 87 | 84 | 2.4 |
| 9 | AC | 385 | 24 | 1568 | 80 | 77 | 3.2 |
| 10 | AC | 504 | 23 | 2139 | 89 | 80 | 3.3 |
| 11 | AA | 579 | 29 | 1986 | 52 | 140 | 1.7 |
| 16 | AA | 426 | 29 | 1476 | 48 | 119 | 2.0 |
| 17 | AS | 411 | 24 | 1634 | 69 | 84 | 2.4 |
| 24 | AS | 448 | 26 | 1775 | 80 | 85 | 2.0 |
| 25 | AS | 441 | 24 | 1795 | 64 | 90 | 2.2 |
| 28 | AA | 438 | 28 | 1589 | 43 | 120 | 1.7 |
| 29 | AA | 478 | 28 | 1754 | 46 | 131 | 1.3 |
| 30 | AA | 444 | 29 | 1564 | 51 | 131 | 1.5 |
| 31 | AA | 466 | 30 | 1592 | 54 | 126 | 1.5 |
| 31 | AS | 506 | 24 | 2070 | 84 | 81 | 2.3 |
| 32 | AS | 404 | 22 | 1817 | 65 | 89 | 2.9 |
| 33 | AS | 543 | 27 | 1936 | 96 | 88 | 2.5 |
| 35 | AS | 648 | 24 | 2603 | 88 | 68 | 2.4 |
| 36 | AS | 431 | 23 | 1802 | 71 | 83 | 2.2 |
| 38 | AS | 404 | 25 | 1533 | 72 | 74 | 2.8 |
| 46 | AM | 473 | 29 | 1619 | 43 | 116 | 1.9 |
| 47 | AS | 543 | 26 | 2109 | 77 | 79 | 2.2 |
| 47 | AK | 426 | 30 | 1460 | 44 | 115 | 1.9 |
| 48 | AS | 389 | 27 | 1391 | 79 | 79 | 2.1 |
| 50 | AA | 527 | 29 | 1999 | 57 | 130 | 1.3 |
| 51 | AA | 544 | 32 | 1725 | 51 | 98 | 1.6 |
| 52 | AK | 598 | 30 | 1962 | 54 | 121 | 1.7 |
| 53 | AS | 593 | 26 | 2324 | 86 | 90 | 2.2 |
| 53 | AK | 509 | 29 | 1777 | 49 | 126 | 1.7 |
| 54 | AM | 430 | 28 | 1521 | 46 | 119 | 1.6 |
| 54 | AS | 509 | 24 | 2094 | 75 | 119 | 2.8 |
| 55 | AS | 689 | 24 | 2871 | 75 | 95 | 3.0 |
| 56 | AS | 507 | 23 | 2196 | 76 | 85 | 2.7 |
| 67 | AM | 426 | 27 | 1567 | 59 | 109 | 1.5 |
| 69 | AM | 538 | 28 | 1908 | 64 | 114 | 1.5 |
| 70 | AM | 659 | 27 | 2208 | 77 | 114 | 1.3 |
| 71 | AM | 655 | 30 | 2183 | 76 | 113 | 1.2 |
| 72 | AA | 504 | 28 | 1802 | 68 | 180 | 1.4 |
| 74 | AK | 464 | 27 | 1821 | 53 | 110 | 1.5 |
| 89 | AK | 542 | 28 | 1940 | 50 | 122 | 1.6 |
| 90 | AM | 794 | 28 | 2804 | 56 | 132 | 1.3 |
| 91 | AA | 612 | 28 | 2146 | 56 | 118 | 1.5 |
| Mean | | 512 | 26 | 1810 | 61 | 101 | 1.9 |
| $LSD_{0.05}$ | | 154 | 4 | 504 | 12 | 18 | 0.8 |

**TABLE 7**

**Dry matter, biomass yield and morphological characteristics of 20 tree-medic accessions comprised in the superior cluster**

| Accession | Code | Dry matter | | Biomass yield (g/clone) | Plant | | Leaf-branch ratio (%) |
|---|---|---|---|---|---|---|---|
| | | Yield (g/clone) | At cut (%) | | Height (cm) | Diameter (cm) | |
| 3 | ML | 266 | 28 | 982 | 48 | 70 | 2.6 |
| 5 | MA | 239 | 30 | 814 | 49 | 66 | 2.2 |
| 6 | MA | 360 | 30 | 1165 | 58 | 76 | 2.3 |
| 7 | MA | 256 | 28 | 898 | 46 | 75 | 2.4 |
| 8 | MM | 250 | 29 | 883 | 47 | 67 | 2.5 |
| 9 | MC | 278 | 30 | 951 | 52 | 67 | 1.9 |
| 13 | MK | 251 | 29 | 836 | 47 | 74 | 2.1 |
| 14 | ML | 217 | 31 | 702 | 49 | 63 | 2.6 |
| 18 | MK | 256 | 29 | 856 | 43 | 76 | 2.1 |
| 21 | MC | 349 | 29 | 1233 | 49 | 83 | 1.9 |
| 26 | MM | 239 | 28 | 822 | 37 | 62 | 2.3 |
| 32 | ML | 222 | 29 | 784 | 47 | 68 | 2.6 |
| 43 | ML | 221 | 27 | 807 | 46 | 64 | 2.6 |
| 51 | MC | 277 | 28 | 972 | 50 | 71 | 1.9 |
| 52 | MA | 243 | 27 | 941 | 50 | 71 | 2.3 |
| 53 | MA | 247 | 27 | 944 | 51 | 71 | 2.0 |
| 55 | MK | 214 | 28 | 781 | 43 | 65 | 2.2 |
| 57 | MA | 289 | 28 | 1035 | 49 | 77 | 2.3 |
| 59 | MK | 219 | 28 | 771 | 39 | 65 | 2.1 |
| 60 | MM | 298 | 26 | 1141 | 49 | 77 | 2.0 |
| Mean | | 259 | 28 | 915 | 48 | 70 | 2.3 |
| $LSD_{0.05}$ | | 120 | 2 | 414 | 6 | 9 | 1.0 |

**TABLE 8**

**Dry matter, biomass yield and morphological characteristics of superior accessions of saltbush and tree-medic**

| Accession | Code | Dry matter | | Biomass yield (g/clone) | Plant | | Leaf-branch ratio (%) |
|---|---|---|---|---|---|---|---|
| | | Yield (g/clone) | At cut (%) | | Height (cm) | Diameter (cm) | |
| *Saltbush* | | | | | | | |
| 8 | AC | 587 | — | 2417 | 87 | — | 2.4 |
| 9 | AC | 385 | — | 1568 | 80 | — | 4.1 |
| 10 | AC | 504 | — | 2139 | 89 | — | 4.1 |
| 17 | AS | 402 | — | 1634 | 69 | — | 2.4 |
| 32 | AS | 412 | — | 1817 | 65 | — | 2.9 |
| 35 | AS | 648 | — | 2603 | 88 | — | 2.4 |
| 38 | AS | 404 | — | 1533 | 72 | — | 2.8 |
| 54 | AS | 509 | — | 2094 | 75 | 93 | 2.8 |
| 55 | AS | 689 | — | 2871 | 75 | 95 | 3.0 |
| 56 | AS | 507 | — | 2169 | 76 | — | 2.7 |
| 69 | AM | 538 | 28 | 1909 | 65 | 113 | — |
| 70 | AM | 659 | 28 | 2208 | 77 | 122 | — |
| 72 | AA | 504 | 28 | 1802 | 68 | 108 | — |
| *Tree-medic* | | | | | | | |
| 3 | ML | 266 | — | 981 | 48 | 70 | 2.6 |
| 5 | MA | 239 | 30 | 814 | 49 | 66 | 2.2 |
| 6 | MA | 360 | 30 | 1165 | 58 | 76 | — |
| 8 | MM | 250 | 29 | 883 | 47 | 67 | 2.6 |
| 32 | ML | 222 | — | 784 | 47 | 68 | 2.6 |

ment of the woody part of the plant. In tree-medic, five superior accessions have been identified (Table 8). The accessions 5 MA and 8 MM were present in all the six superior cluster groups.

The variability existing among these accessions could be utilized for breeding new clones with high yield potential. The phenotypic variability observed in both species could be considered adequate for selecting superior clones adapted to the marginal Mediterranean areas.

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