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## Post-fire regeneration of *Calicotome villosa* (Poiret) Link. and vegetation analysis

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### Abstract

*Calicotome villosa* (Poiret) Link. is a leguminous deciduous shrub that is often associated with disturbance processes, such as fires. This species is characterised by a primary dormancy imposed by its water-impermeable seed coat. In the present study, the germination rate of untreated seeds was low (10%), whereas high germination rates were achieved with different scarification techniques. Germination tests demonstrated that seeds of *C. villosa* do not require exposure to high temperatures to germinate. Indeed the highest germination rate (97%) was obtained with mechanical scarification, by chipping the seed coat with a scalpel. Therefore, the effects of fire on dormancy breakage only arises from the scarification of the seed coat that is necessary for germination of the majority of seeds. This suggests that under natural conditions, few seeds germinate during non-fire years. This will contribute to maintenance of the population, whereas most of the seeds accumulate in the soil seed bank and can then germinate when a fire occurs and they are released from dormancy. This vegetation analysis leads to better definition of the environment and geographic context in which plant communities dominated by *C. villosa* develop. The phytosociological study focused primarily on the formations in the Gargano area, where relevés were carried out 4 years and 8 years after the widespread fires. The seeds for the study of seed germination were collected in this area. These unpublished relevés were compared with other relevés attributed to several Italian localities, such as the association *Pistacio lentisci-Calicotometum villosae* described for north-west Sardinia, and with relevés of the Sardinian association *Phagnalo saxatili-Calicotometum villosae*. This analysis led to recognition of some new associations: *Spartio juncei-Calicotometum villosae*; *Teucro fruticantis-Calicotometum villosae*; *Euphorbio dendroidis-Calicotometum villosae*; *Phagnalo saxatili-Calicotometum villosae typicum* and *asparagetosum stipularis*. The relevés from Gargano were attributed to the new association *Pino halepensis-Calicotometum villosae*. The syntaxonomic attribution to the higher hierarchical levels refers the Tyrrhenian community to the new suballiance *Pistacio lentisci-Calicotomenion villosae* of the alliance *Ericion arboreae* (*Pistacio lentisci-Rhamnetalia alaterni* and *Quercetalia ilicis*). The new Adriatic association *Pino halepensis-Calicotometum villosae* is related to the Balcanic alliance *Cisto cretici-Ericion manipuliflorae*, of the order *Cisto cretici-Ericetalia manipuliflorae*, and of the class *Cisto cretici-Micromerietea julianae*. The conclusions thus highlight the dissimilarities between the two vegetation classification systems. The suballiance *Pistacio lentisci-Calicotomenion villosae* is important in order to complete the western Mediterranean hierarchical system. Indeed, the communities belonging to the new suballiance are formed by both fast resprouting species (*Pistacia lentiscus*, *Erica arborea*, *Myrtus communis* and *Arbutus unedo*) and regenerative species by seed (*Calicotome villosa*, *C. spinosa*, *Cistus* sp. pl., *Pinus halepensis* etc.).

Key words: *Calicotome villosa*, *Pistacio lentisci-Calicotomenion villosae*, ecophysiology, Gargano, post-fire regeneration, plant sociology, pyrophytes, seed germination, syntaxonomy.

### Introduction

Fire has a key role in shaping the composition and distribution of plant communities (Trabaud, 1994; Bond & van Wilgen, 1996; Blasi *et al.*, 2004; Bond & Keeley, 2005; Moretti *et al.*, 2006; Verdú & Pausas, 2007), and it provides important evolutionary pressure on plant traits (Keeley *et al.*, 2011; Çatav *et al.*, 2012). In fire-prone environments, seed germination of many plants is triggered by fire-related cues (i.e., heat, smoke) (Mazzoleni, 1989). The positive effects of such heat-shock treatment on germination in species with water-impermeable seed coats is well known (Rundel, 1981; Trabaud & Oustric, 1989; Thanos *et al.*, 1992; Doussi & Thanos, 1994; Rivas *et al.*, 2006; Moreira *et al.*, 2010; Santos *et al.*, 2010).

Such effects have also been reported for a species that strongly characterises the area of Calalunga (Peschici, FG, southern Italy): *Calicotome villosa* (Poiret) Link. This is a circum-Mediterranean component of lowland shrub vegetation in open woodlands (Greuter *et al.*,

1984-89), where it sometimes forms almost monospecific shrublands (Arroyo *et al.*, 2008). *C. villosa* is often associated with disturbance processes, particularly those caused by cattle browsing, and to a lesser extent by fire and slashing. This species is very digestible by cattle (Anmar *et al.*, 2005), and thus it occurs in open sites with low or no tree cover and extensive cattle and goat management. However, *C. villosa* is relatively resilient to serious damage, because of its strong spiny branches and profuse regeneration by seed (Arroyo *et al.*, 2008). The tolerance of *C. villosa* is promoted by strong resprouting after damage. *C. villosa* is potentially dispersed by cattle when browsed during the fruiting season. Humans might also facilitate its dispersal, because *C. villosa* is more frequent along roadsides and paths. Furthermore, *C. villosa* can survive the dry summer period because of its summer-deciduous habit (De Lillis & Fontanella, 1992; Yiotis *et al.*, 2008).

This study was aimed at an investigation of: (i) the seed germination behaviour of *C. villosa*, and its reproductive strategy in relation to fire events and endo-

zoochorous seed dispersal; and (ii) the vegetation that grows after a fire in the forestry communities, whereby *C. villosa* is one of the first aspects of the dynamic succession, together with the vegetation dominated by cysts. Over time, this will lead to the reconstitution of the forest that was set on fire.

### The Gargano promontory and the study area

The study area was Calalunga (Peschici, Province of Foggia, southern Italy), on the eastern side of a small valley that opens onto the Adriatic and is situated in the peninsula of Gargano. Gargano is a southern area on the Adriatic (eastern) side of the Italian peninsula (Fig. 1). It has an area of around 2,000 km<sup>2</sup>, and a geological matrix that is exclusively limestone. In geological terms, the Gargano massif is essentially formed of limestone and dolomite rock from the Mesozoic, with frequent inclusions of flint (i.e., nodules, slabs) and covered with thin layers of calcarenites (from the Tertiary). In some stretches (e.g., lake and coastal zones) there are marine and watercourse deposits (from the Quaternary) (Lopez, 2003). The limestone matrix has a strong influence on the morphology of the promontory, through the extensive karst phenomena that at the same time enormously reduces the hydrographic characteristics, such that in the whole of the territory there are no surface-water courses, except for the Asciatizzo seasonal river (Torrente Asciatizzo). Indeed, it has been calculated that around three-quarters of the rain that falls on the Gargano promontory penetrates into the soil.

According to the European biogeographic classification proposed by Rivas-Martínez *et al.* (2001), the Gargano is part of the Apulia Subprovince, Adriatic Province, east Mediterranean subregion of the Mediterranean region. According to the ecoregions map of Italy (Blasi *et al.*, 2014), the Gargano belongs to the Gargano Subsection, Adriatic Province, and Mediter-



Fig. 1 - The Calalunga study area of the Gargano promontory. Inset: location of the Gargano promontory within Italy.

anean Division.

On the basis of the closest thermopluviometric station (Vieste: 25 m a.s.l.; observation period, 1966–1996) the annual mean temperature is 17 °C, and the annual mean precipitation is 571 mm (Fig. 2; Hydrographic Annals of the Hydrographic and Mareographic Service of Bari). The study area is in the Mediterranean pluviseasonal oceanic bioclimate, of the meso-Mediterranean thermotype and upper dry ombrotype horizon, according to the classification proposed by Rivas-Martínez *et al.* (2011), and as applied to the thermopluviometric station of Vieste (Fig. 2) and to the bioclimate map of Italy (Pesaresi *et al.*, 2014).

### Vegetation of the study area

The study area was mainly covered by an Aleppo pine forest of the association *Pistacio lentisci–Pinetum halepensis* De Marco, Veri & Caneva 1984 (De Marco *et al.*, 1984). There was a *Juniperus phoenicea* subsp. *turbinata* micro-wood on limestone cliffs closest to the sea that belonged to the same association as for the eastern Adriatic coast: *Pistacio lentisci–Juniperetum turbinatae* Trinajstić ex Asensi, Díaz-Garretas & Quézel 2007.

Along the narrowest part of the Calalunga Valley, the Aleppo pine wood made contact with the holm oak wood association *Cyclamino hederifolii–Quercetum ilicis* Biondi, Casavecchia & Gigante 2003. In the transition zone between *Pistacio lentisci–Pinetum halepensis* and *Cyclamino hederifolii–Quercetum ilicis* there was a two-layered forest of *Quercus–Pinetum halepensis* Loisel 1971, the dominant layer of which was *Pinus halepensis*, and the dominated layer was *Quercus ilex*. This forest had arisen from forest management. According to the potential natural vegetation, the area occupied by the forest belonged to the association *Cyclamino hederifolii–Quercetum ilicis*. Following the vegetation series described in Biondi *et al.* (2010), the study area was characterised by:

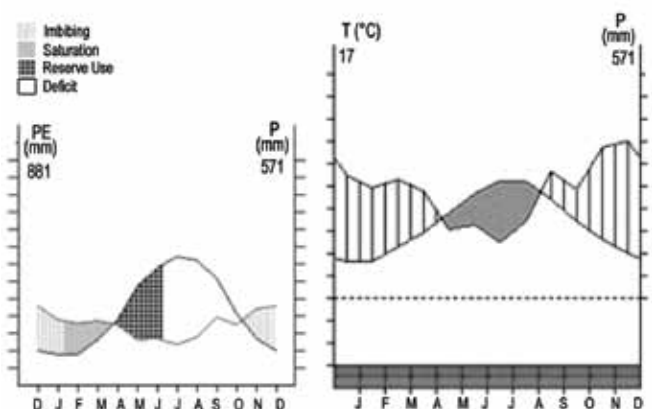


Fig. 2 - Bioclimatic and evapotranspiration diagrams for Vieste, Gargano (from Rivas-Sáenz, 2009).

- central Mediterranean calcicolous *P. halepensis* series (*Pistacio lentisci*–*Pino halepensis* sigmetum);
- peninsular neutro-basiphilous *Q. ilex* (*Cyclamino hederifolii*–*Quercu ilicis* sigmetum).

The post-fire succession dynamics began very early with a therophytic community that was dominated by *Trifolium pallidum* and *Ononis pusilla* and that covered the whole burnt area. This vegetation occurs on the deposits of fire ash. The surveys carried out 4 years after the fire led to the identification of shrub formations of rockroses and *C. villosa*.

On July 24, 2007, a violent fire occurred in the study area that spread to the north-east sector of the Gargano mountain, included the areas between Peschici and Vieste. In a few hours, the fire caused the destruction of more than 4,500 ha of forest and Mediterranean brushland that covered the coastal areas and the foothills of the internal mountains. The arson was favoured by the exceptional climatic conditions, as it was particularly hot, with air temperatures of over 40 °C, combined with the Sirocco wind of up to 1.5 km/h. At first, the fire was oblique, and of low intensity, and mainly affected the herbaceous layer and shrub layer typical of the Mediterranean scrub. Then, the fire evolved when it got the canopies of the Aleppo pine woods, holm oak woods, and Mediterranean maquis and olive groves, developing into a crown fire of catastrophic proportions, with flames several metres high.

## Materials and Methods

### Seed collection

Ripe fruits were collected from wild populations of *C. villosa* in Calalunga (X = 587843; Y = 4643800) during the summer of 2010, according to the description of seed collection protocols (Bacchetta *et al.*, 2006; International Seed Testing Association, 2006). Following this harvesting, the seeds were extracted from the fruit and processed using a blower, to remove empty and poorly developed seeds (Agriculex CB1 Column Seed Cleaner, T.A. Baxall and Co., Ltd). Afterwards, the seeds were dried and stored in a dry room at 15 °C and 15% relative humidity, before being used for the germination study and morphological analysis.

### Seed macromorphological analysis

Ten samples of fifty air-dried seeds of each seed lot were weighed on a four decimal places balance (BCA120, PBI International) with a precision of 0.1 mg. The lengths and widths of 20 randomly selected seeds were measured with a Nikon SMZ800 stereoscope.

### Germination tests

The seeds were sown on 1% distilled water agar in 9-cm-diameter transparent polyethylene Petri dishes.

The germination rates were determined using programmable environmental chambers with controlled temperature and illumination. Germination responses to different pretreatments that can act on physical dormancy were tested: (1) control; (2) seed immersion in boiling water for 30 s (Doussi & Thanos, 1994); (3) chemical scarification by seed immersion in H<sub>2</sub>SO<sub>4</sub> (95%) for 60 min, and for (4) 120 min; (5) physical seed scarification achieved by chipping the seed coat with a scalpel; and (6) direct exposure of seeds to an oxydric flame for a few seconds, i.e. until the seed coat was completely burnt (Vuillemin & Bulard, 1981; Morbidoni *et al.*, 2008).

The germination rates were also determined according to temperature, which were evaluated at five constant temperatures between 5 °C and 25 °C. The seeds used for these tests were scarified by immersion in boiling water prior to the tests. Illumination was provided for 12 h each day, by 30 W cool white fluorescent lighting.

Four replicates of 25 seeds were used in each germination test. The seeds were monitored daily until the main germination period was over, and then they were monitored progressively less frequently, for at least 30 days after sowing. The germinated seeds were removed when radicle was at least 1 mm long (Bacchetta *et al.*, 2006).

These germination tests were considered finished when no additional seeds germinated over a period of at least 15 days. At the end of each germination test, the seeds that had not germinated were dissected (i.e., the cut-test) to determine whether they were viable (e.g., fresh), non-viable (e.g., mouldy) or empty.

### Data analysis

The seed volumes were calculated according to Equation (1):

$$VOL = 0,46753 VOL_{LW} + 2,65493 \times 10^{-5} VOL_{LW}^2 \quad (1),$$

where VOL is the seed volume, L is the length and W the width (Dias & Ganhão, 2012). Means  $\pm$  standard deviation were calculated for the seed volumes and the seed weights. Mean germination rates, expressed as percentages, and mean germination time (MGT) were determined. The MGT was calculated according to Equation (2) (Ellis & Roberts, 1980):

$$MGT = \sum (n d) / \sum N \quad (2),$$

where n is the number of seeds that germinated on day d, and N is the total number of seeds that had germinated at the end of the test. The final germination percentages were calculated and arcsine-transformed, and the levels of significance (P < 0.05) were obtained by analysis of variance (ANOVA). One-way ANOVA

was used to analyse the influence of temperature and pretreatment on the breaking of the seed dormancy. In this last case, homogeneous groups were determined using Tukey's tests. Statistical analysis of MGT was also carried out using the same methods. The tests at different temperatures allowed the determination of  $T_{50}$ ; i.e. the days to achieve 50% germination. The reciprocal of  $T_{50}$  was then regressed using a linear model, to estimate the base temperature ( $T_{base}$ ) below which the germination rate was zero (Hardegee, 2006). All of these analyses were carried out using the SPSS 15.0 software.

### Vegetations analysis

The study of the plant communities was carried out according to the phytosociological method of the Sigmatis School of Zurich-Montpellier, as proposed by Braun-Blanquet (1964), and successively integrated (Rivas-Martínez, 2005; Géhu, 2006; Biondi, 2011; Blasi et al., 2011; Blasi & Frondoni, 2011; Pott, 2011). The International Code of Phytosociological Nomenclature (Weber et al., 2000) was used for the description of new syntaxa. The syntaxonomic classifications follow the Prodrome of Vegetation of Italy (Biondi et al., 2014; <http://www.prodromo-vegetazione-italia.org/>). For the taxonomic nomenclature, we examined the studies of Pignatti (1982) and Conti et al. (2005, 2007), and the following websites were consulted: <http://www.anarchive.it/> (Lucarini et al., 2014) and <http://www.theplantlist.org/>.

Four phytosociological relevés on *C. villosa* vegetation were carried out in the Calalunga study area (Fig. 1). Also, 64 published surveys with coverage value of *C. villosa* of at least 3 (according to the scale of Braun-Blanquet, 1964) were collected. The published surveys referred to the associations *Pistacio lentisci-Calicotometum villosae* Biondi, Filigheddu & Farris, 2001, described for north-west Sardinia (Biondi et al., 2001) and found in several Italian locations, and *Phagnalo annotici-Calicotometum villosae* Mossa, Curreli & Fogu 2000, described for southern Sardinia (Mossa et al., 2000) (Appendix III).

Principal component analysis (PCA) ordering was performed on the *C. villosa* vegetation data matrix of the 68 phytosociological relevés, with the Braun-Blanquet (1964) abundance values converted in the scale of Van der Mareel (1979) and Hellinger-transformed (Legendre & Gallagher, 2001), in order to: (i) determine the positions of the unpublished plots of Gargano compared with those published in the Hellinger multivariate space; (ii) verify and validate the attributions of the mentioned associations; and (iii) recognize eventual new associations. Indicator species analysis (ISA) using the  $\phi$  coefficient (Chytrý et al., 2002) was carried out to identify the diagnostic species (i.e., characteristic, differential) of the different plant com-

munities. Species with  $\phi > 0.4$  (with significance at  $P < 0.05$ ) are considered diagnostic.

All of the vegetation analyses were carried out using the R software (R Core Team 2012), with the following packages: 'VEGAN' (Oksanen et al., 2013) and 'indic-species' (De Cáceres & Legendre, 2009).

### Results: seed analysis

#### Seed macromorphological analysis

The *C. villosa* seeds were reniform according to the classification of Martin (1946) and Werker (1997), although they have also been described as 'lens oblong' or 'wedge-shaped' (Kirkbride et al., 2003). The ripened seeds were brown in colour. The seed coat was smooth and shiny, and was relatively simple in this species, without any cuticular sculptures or secondary wall thickening (Fig. 3).

The mean weight of the air-dried seeds was  $6.68 \text{ mg} \pm 0.199 \text{ mg}$ , the mean seed length was  $2.15 \text{ mm} \pm 0.25 \text{ mm}$ , and the mean seed width was  $2.15 \text{ mm} \pm 0.25 \text{ mm}$ . The mean seed volume was  $3.3 \text{ mm}^3 \pm 1.06 \text{ mm}^3$ .

#### Germination tests

The mean germination rate of the untreated seeds was only 10%, with increases in the final germination rates in all of the other tests with the scarified seeds (Table 1, Fig. 4). The best results for the germination rates were obtained with mechanic scarification (seeds chipped with a scalpel: 97% germination). High germination rates were also obtained with seed boiling (88% germination) and chemical scarification with the seeds immersed in  $\text{H}_2\text{SO}_4$ , although only with the longer duration of treatment of 120 min. The other two treatments provided only slight increases in the germination rates (Table 1, Fig. 4).

The analysis of variance shows that the differences in final germination rates obtained with the different pretreatments were statistically significant ( $F = 65.212$ ;  $P < 0.001$ ). Tuckey's HSD tests allowed the means to be separated into three homogeneous subsets, as reported in Table 1.



Fig. 3 - *Calicotome villosa* seed observed under a stereo microscope.

For the speed of germination, the seeds chipped with a scalpel showed the lowest MGT, while seeds exposed to the oxydric flame showed the highest (Table 1, Fig. 4).

For the germination responses to different temperatures, the final germination rates were between 84% (at 15 °C) and 94% (at 5 °C) (Table 2, Fig. 5). The analysis of variance showed that the differences in germination rates are not statistically significant ( $F = 0.548$ ;  $P = 0.659$ ). Conversely, significant differences

were found for MGT ( $F = 111.905$ ;  $P < 0.001$ ) and  $T_{50}$  ( $F = 630.71$ ;  $P < 0.001$ ). The speed of germination was thus maximal at 15 °C and 20 °C, and minimal at 5 °C, in terms of both MGT and  $T_{50}$  (Table 2, Fig. 5).

The linear model applied to the reciprocal of the  $T_{50}$  values shows that these data are significantly correlated with temperature ( $F = 143.134$ ;  $P < 0.001$ ), with an  $R^2$  value of 0.911. According to this model, the  $T_{base}$  is  $-0.15$  °C for this species (Fig. 6).

Tab. 1 - Germination of the *C. villosa* seeds according to the different pretreatments applied, and the homogeneous subsets of the data obtained with Tuckey's HSD tests ( $P < 0.05$ ).

Pretreatment	Germination rate (%)	Homogeneous groups for germination rates	Mean germination time (days)	Homogeneous groups for mean germination time
Control	10 ±6.9	c	13.6 ±3.68	b
Seeds boiled for 30 s	88 ±8.6	a	9.7 ±2.94	bc
Immersion in H <sub>2</sub> SO <sub>4</sub> for 60 min	20 ±7.3	c	9.6 ±2.46	bc
Immersion in H <sub>2</sub> SO <sub>4</sub> for 120 min	65 ±6.8	b	9.0 ±1.43	bc
Seed chipped with a scalpel	97 ±3.8	a	5.1 ±0.70	c
Exposure to oxydric flame	27 ±8.9	c	20.4 ±0.63	a

Tab. 2 - Germination percentage, MGT and  $T_{50}$  at different temperatures and homogeneous subset of data obtained with Tuckey's HSD test ( $P < 0.05$ ).

Germination temperature (°C)	Germination rate (%)	Mean germination time (days)	Homogeneous groups for mean germination time	Days to achieve 50% germination ( $T_{50}$ )	Homogeneous groups for $T_{50}$
5	94 ±5.2	31.0 ±1.14	a	27.3 ±0.47	a
10	92 ±5.7	15.9 ±1.93	b	12.2 ±1.11	b
15	84 ±14.2	10.0 ±0.69	c	7.1 ±0.33	c
20	88 ±8.6	9.8 ±2.94	c	6.6 ±0.90	c

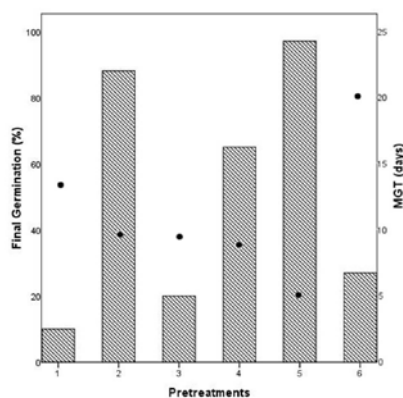


Fig. 4 - Final germination rates (bars) and mean germination time (MGT; dots) for *Calicotome villosa* seeds after the different pretreatments: 1, control; 2, immersion in boiling water for 30 s; 3, chemical scarification by immersion in H<sub>2</sub>SO<sub>4</sub> (95%) for 60 min; 4, chemical scarification by immersion in H<sub>2</sub>SO<sub>4</sub> (95%) for 120 min; 5, scarification by chipping seed coat with a scalpel; 6, direct exposure to an oxydric flame.

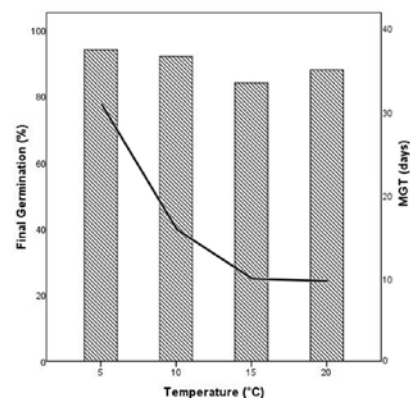


Fig. 5 - Final germination rates (bars) and mean germination time (MGT; lines) of boiled *Calicotome villosa* seeds, for germination at the different temperatures.

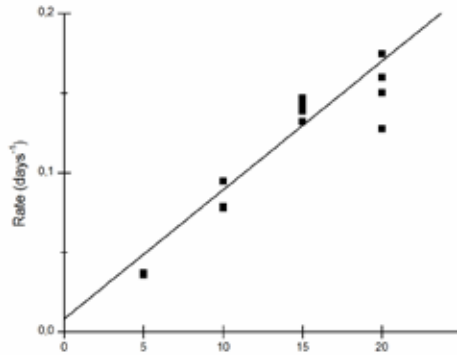


Fig. 6 - Germination rate ( $1/T_{50}$ ) regressed on temperature for seeds of *Calicotome villosa*.

### Discussion: seed analysis

This study has confirmed that *C. villosa* seeds have a physical dormancy, with the germination barrier only consisting of the tegument, due to its water resistance, as usually occurs in most *Fabaceae* (Baskin & Baskin, 1989). Indeed, intact seeds showed a germination rate of just 10%. This confirms the report of Doussi & Thanos (1994), who obtained a germination rate of 8% under the same conditions. However, the data obtained with the more efficient scarification techniques demonstrate the high vitality of these seeds.

Nevertheless, the data obtained in this study also demonstrate that *C. villosa* seeds have considerable heterogeneity in their germination behaviour, as observed for other species in the same environments, such as some *Cistus* species (Thanos & Georghiou, 1988). Indeed, some seeds that germinated without any treatment were found, and also water-impermeable seeds do not respond in the same way towards certain pretreatments. This suggests that under natural conditions, a certain number of seeds (soft seeds) can still germinate during non-fire years, which will contribute to the maintenance of the populations, whereas most of the seeds (hard seeds) will accumulate in the soil seed bank. Thus, when a fire takes place, there will always be a high number of seeds in the soil that can then germinate as they are released from their dormancy by the fire.

Therefore, *C. villosa* can be said to show an opportunistic strategy of seed germination, in close agreement with its essential role in post-fire regeneration processes in the Mediterranean ecosystems where it grows. Generally, plants in fire-prone regions have evolved characteristics that allow them to take advantage of the predictable prevalence of favourable conditions after each fire (i.e., increased availability of water, light and nutrients, and thus decreased competition; Doussi & Thanos, 1994).

For *C. villosa*, the impermeability of the seed coat generally prevents germination, until selective dama-

ge to the lens or some other region of the seed coat allows water uptake. Fire appears to be the most important factor in providing this damage, and thus in overcoming the seed-coat impermeability. In some hard-seeded species, heat generated by fire satisfies the scarification requirements of the seeds (Doussi & Thanos, 1994), although for *C. villosa*, the positive effects of fire on germination appear to be exclusively due to the selective damage caused to the seed coat. Indeed, seeds germinated at high rates also when they were chemically scarified and after being chipped with a scalpel, so without heating. Interestingly, it was this scalpel treatment that promoted the highest final germination rate and the highest speed of germination (i.e., the lowest MGT), and thus this is the treatment that is recommended for multiplication protocols for *C. villosa*.

For the chemical scarification, the duration of the treatment was also crucial. Indeed, seeds scarified by immersion in 95%  $H_2SO_4$  for 1 h showed a considerably lower germination rate than those scarified in this way for 2 h. This suggests that in the first case, this scarification duration was not long enough to provide adequate damage to the seed coat (i.e., after 1 h). Moreover, it is possible that scarification duration in 95%  $H_2SO_4$  of longer than 2 h will result in higher germination rates. However, it must also be taken into account that acid scarification can often result in the destruction of the seed coat integrity over a substantial proportion of the seed surface, so these scarified seeds are more vulnerable to deterioration (Doussi & Thanos, 1994). Thus, the positive effects of possible deeper scarification might be frustrated by increased vulnerability to pathogen attack. In any case, the positive effects of chemical scarification on the germination rates appear to confirm that *C. villosa* can take advantage of endozoochory seed dispersal. Indeed, the passage through the goat or cattle digestive systems might also be effective for softening of the *C. villosa* seed coat, and therefore promote an improvement in the germination rates (Grande *et al.*, 2013; Myers *et al.*, 2004).

However, a safer, more rapid, and easier method of seed softening in laboratory experiments is seen in seed immersion in boiling water (Doussi & Thanos, 1994). This method has to be preferred to the previous described treatments when heat treatment is required to break the dormancy of hard-seeded species. Although an effect of high temperatures on seed germination was not found in *C. villosa*, the seed boiling can still be considered a suitable method for breaching the impermeability of the seed coat. Indeed, the boiled *C. villosa* seeds showed high germination rates, which were only surpassed by the chipped seeds with their slightly higher germination rate, although this difference did not reach statistical significance between the means obtained with these two methods.

Exposure of the *C. villosa* seeds to a naked flame was aimed at reproducing the action of fire, which can be considered as quite a common event in the habitat where *C. villosa* grows (habitat 5330, Thermo-Mediterranean and Pre-Desert Scrub), due to its climatic, pedological and vegetation characteristics. However, the action of a flame on seeds is a relatively random effect that is difficult to reproduce in the laboratory (Morbidoni *et al.*, 2008).

Previous studies have demonstrated that the actions of high temperatures on seed germination of *Fabaceae* growing in Mediterranean climates show strong interspecific variations (Herranz *et al.*, 1997; Hanley *et al.*, 2001). In almost all of the cases studied, an increase in germination rates has been seen with exposure of seeds to temperatures between 70 °C and 150 °C for various periods of time. However, with many species from environments that are exposed to frequent fires, exposure to temperatures of 110 °C to 120 °C would lead to embryo death, even if it is only for 4 min (Auld & O'Connell, 1991). The treatment applied in this study might have been lethal for the embryo of some of these *C. villosa* seeds, as the germination rate was lower than for the other pretreatments. However, the tests carried out in this study clearly demonstrate that *C. villosa* seeds do not need exposure to high temperatures in order to germinate. Conversely, the embryo showed high sensitivity to high temperatures. Therefore, the ecological benefit derived from the passage of fire will only be the indirect factors described above. As *C. villosa* seeds have a primary dormancy that is imposed by the seed coat, whereby in the natural environment this dormancy can be eventually released massively by wildfires, this often results in prolific dense stands, as observed by Thanos *et al.* (1992) in some *Cistaceae*. This seed-coat impermeability constitutes a control mechanism for germination, which will prevent the seeds from germinating under unfavourable conditions, and which will also generally inhibit and delay the germination process (Morbidoni *et al.*, 2008). The presence of this germination barrier allows us to hypothesise that in nature there will be an accumulation of a considerable reserve of seeds in the ground with time (Bewley & Black, 1985; Guardia *et al.*, 2000). This is an important adaptive aspect, as it is evident that in a difficult environment like the Mediterranean ecosystems, the availability of an important seed reserve in itself constitutes an important factor for species survival. Therefore, this study has shown the capacity of *C. villosa* to act as a seeder after a fire has occurred. However, another study demonstrated that *C. villosa* is also a resprouter (Arroyo *et al.*, 2008); thus, *C. villosa* is not an obligate seeder, but it can take advantage of both of these survival strategies.

Finally, it is interesting to note that for the temperature within the range considered in this study, there were

no effects on germination, and  $T_{base}$  was around 0 °C. This confirms what has been hypothesised from various studies (Thompson, 1970; Thanos & Georghiou, 1988); i.e., that Mediterranean species generally show high and rapid germination at low temperatures due to an adaptation to the relatively low temperatures that prevail during the rainy season (i.e., October-May) in Mediterranean type ecosystems. This hypothesis appears to be consistent with the results of the present study and with the pattern of germination and seedling establishment in *C. villosa* post-fire regeneration in natural environments. More precisely, fires generally occur in the dry season (i.e., July-August) and after their release from dormancy, the seeds germinate during the rainy season, when there is sufficient moisture in the soil, irrespective of the temperature.

This evidence clearly demonstrates that fire is the most important factor in releasing *C. villosa* seeds from dormancy and in activating their germination.

### Results: vegetation analysis and syntaxonomy

The PCA ordering of the Hellinger abundance vegetation data clearly identified the main turnover floristic gradients that characterise and determine the different plant communities of *C. villosa* (Fig. 7). The first three PCA axes explain about 35% of the total variation. The relevé groups represent the different phytosociological tables published by the authors and considered here.

The ISA identified 21 species that are diagnostic for different plant communities summarised in the synoptic table (Table 3).

*PISTACIO LENTISCI-CALICOTOMETUM VILLOSAE* Biondi, Filigheddu & Farris 2001

*ROSMARINETOSUM OFFICINALIS* Biondi & Bagella 2005

*PHILLYREETOSUM ANGUSTIFOLIAE* Biondi & Bagella 2005

Groups 1 and 2 in Table 4 are, respectively, the phytocoenoses of *Pistacio lentisci-Calicotometum villosae* Biondi, Filigheddu & Farris 2001, subassociation *rosmarinetosum officinalis* Biondi & Bagella 2005, that develops on the limestone formations of Nurra (north-west Sardinia), and *Pistacio lentisci-Calicotometum villosae*, subassociation *phillyreetosum angustifoliae* Biondi & Bagella 2005, that develops on granitic substrates of the La Maddalena Archipelago (north-eastern Sardinia).

*SPARTIO JUNCEI-CALICOTOMETUM VILLOSAE* (Foggi, Cartei, Pignotti, Signorini, Viciani, Dell'Olmo & Menicagli 2006) Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nov. et stat. nov. hoc loco* (*Holotypus* rel. 546 of Tab. 34 in Foggi *et al.*, 2006)

Basionym: *Pistacio lentisci-Calicotometum villosae*



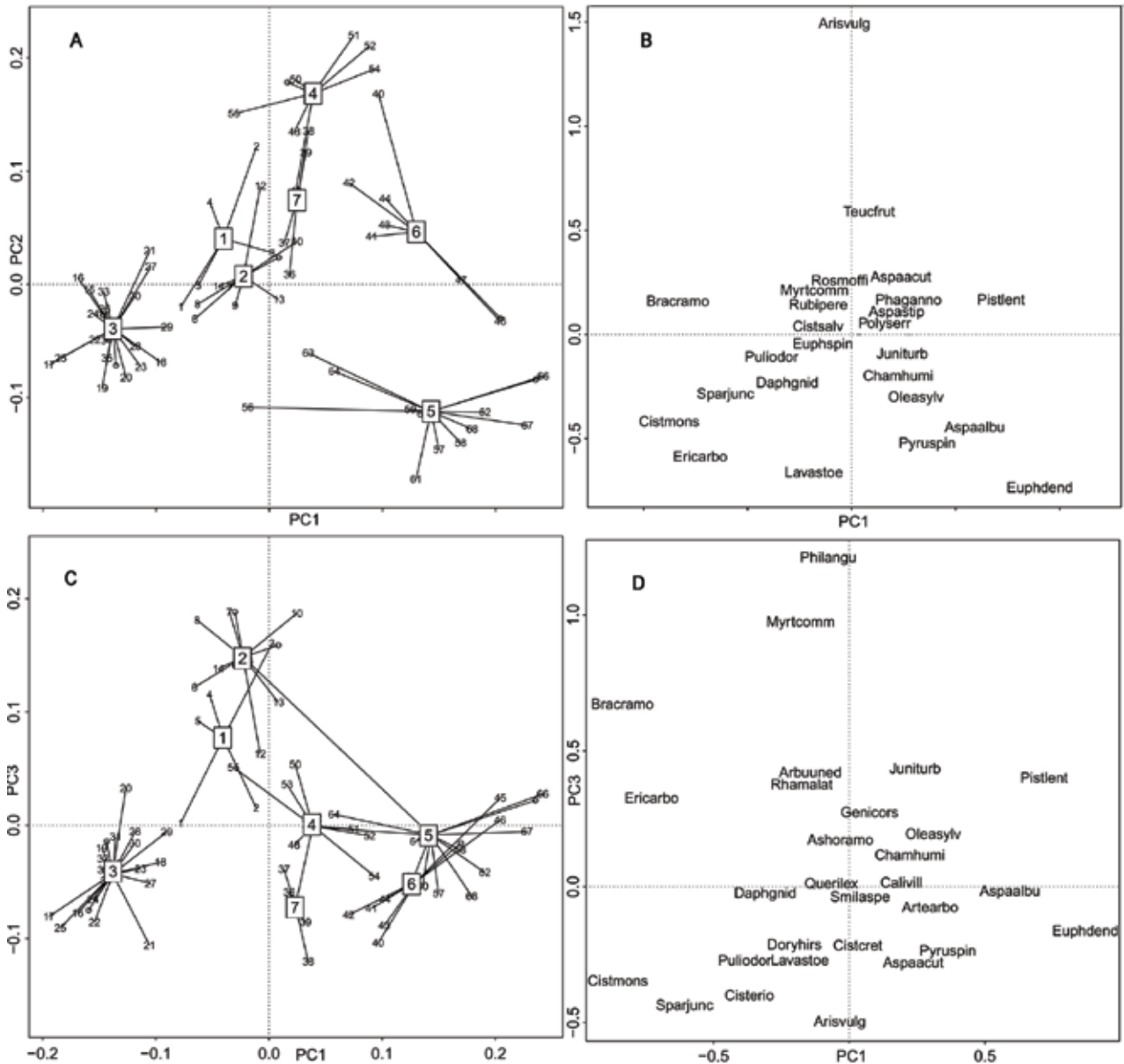


Fig. 7 - Principal component analysis ordering plots of the Hellinger-transformed abundance for the *Calicotome villosa* vegetation data. (A, B) Plots of the site and species scores of PCA axes 1 and 2. (C, D) Plots of the site and species scores of PCA axes 1 and 3. The percentages of variance in the data explained by PCA axes 1, 2 and 3 are 17%, 10% and 8%, respectively. The small numbers represent the sampling sites (plot numbers). Species: Arbuuned, *Arbutus unedo*; Arisvulg, *Arisarium vulgare*; Artearbo, *Artemisia arborescens*; Ashoramo, *Asphodelus ramosus*; Aspaacut, *Asparagus acutifolius*; Aspaalbu, *Asparagus albus*; Aspastip, *Asparagus stipularis*; Bracramo, *Brachypodium ramosum*; Calivill, *Calicotome villosa*; Chamhumi, *Chamaerops humilis*; Cistcret, *Cistus creticus creticus*; Cisterio, *Cistus creticus eriocephalus*; Cistmons, *Cistus monspeliensis*; Cistsalv, *Cistus salvifolius*; Daphgnid, *Daphne gnidium*; Doryhirs, *Dorycnium hirsutum*; Ericarbo, *Erica arborea*; Euphdend, *Euphorbia dendroides*; Euphspin, *Euphorbia spinosa*; Genicors, *Genista corsica*; Juniturb, *Juniperus phoenicea turbinata*; Lavastoe, *Lavandula stoechas*; Myrtcomm, *Myrtus communis*; Oleasylv, *Olea europaea sylvestris*; Phaganno, *Phagnalon saxatile*; Philangu, *Phillyrea angustifolia*; Pistlent, *Pistacia lentiscus*; Polyserr, *Polypodium cambricum serrulatum*; Puliodor, *Pulicaria odora*; Pyruspin, *Pyrus spinosa*; Querilex, *Quercus ilex*; Rhamalat, *Rhamnus alaternus*; Rosmoffi, *Rosmarinus officinalis*; Rubipere, *Rubia peregrina*; Sparjunc, *Spartium junceum*; Teucfrut, *Teucrium fruticans*. Group number ('spiders'): 1, *Pistacio lentisci-Calicotometum villosae rosmarinetosum*; 2, *Pistacio lentisci-Calicotometum villosae phillyreetosum angustifoliae*; 3, *Spartio juncei-Calicotometum villosae*; 4, *Teucrio fruticantis-Calicotometum villosae*; 5, *Euphorbio dendroidis-Calicotometum villosae*; 6, *Phagnalo saxatili-Calicotometum villosae typicum* and *Phagnalo saxatili-Calicotometum villosae asparagetosum stipularis*; 7, *Pino halepensis-Calicotometum villosae*.

*cistetosum monspeliensis* Foggi, Cartei, Pignotti, Signorini, Viciani, Dell'Olmo & Menicagli 2006 (Foggi *et al.*, 2006: 54).

Group 3 in Table 5 is the plant community *Pistacio lentisci–Calicotometum villosae* Biondi, Filigheddu & Farris 2001, *cistetosum monspeliensis* Foggi *et al.*, 2006, as described in a study of the plant landscape of Elba Island (Isola d'Elba, Tuscan Archipelago) (Foggi *et al.*, 2006). However, as Foggi *et al.* (2006) indicated, the PCA shows how this group 3 is clearly distinct and dissimilar from groups 1 and 2 (Fig. 7A), and that it has its own flora autonomy, as confirmed by the diagnostic species identified by ISA.

A new association is therefore proposed with the epithet *Spartio juncei–Calicotometum villosae*, with the characteristic species of: *Spartium junceum*, *Pulicaria odora* and *Daphne gnidium*. The differential species are: *Dorycnium hirsutum*, *Lavandula stoechas* and *Cistus creticus* subsp. *eriocephalus*. The five phytosociological relevés of *Pistacio lentisci–Calicotometum cistetosum monspeliensis* of Giglio Island of Foggi & Pancioli (2008) were not taken into consideration here, as *C. villosa* had a cover value <3. Indeed, these are *Cistus monspeliensis* dominated formations and they are attributable to *Lavandulo stoechadis–Cistetum monspeliensis* Arrigoni, Di Tommaso, Camarda & Satta 1996.

**TEUCRIO FRUTICANTIS–CALICOTOMETUM VILLOSAE** Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nov. hoc loco* (*Holotypus* rel. 55 of Tab. 3 in Foggi & Pancioli, 2008)

Group 4 in Table 6 corresponds to the vegetation found on the island of Giglio (Foggi & Pancioli, 2008), in the Tuscan Archipelago, and attributed by Foggi & Pancioli (2008) to the association *Pistacio lentisci–Calicotometum villosae rosmarinetosum officinalis* Biondi & Bagella 2005. The PCA and ISA (Figure 7, Table 3) show low affinity for this group 4 with the association *Pistacio lentisci–Calicotometum villosae* (groups 1 and 2) and with the new association *Spartio juncei–Calicotometum villosae* (group 3), and show clearly original flora composition. Therefore, the new association *Teucrio fruticantis–Calicotometum villosae* *ass. nova* is proposed, with the characteristic species of: *Teucrium fruticans* and *Arisarum vulgare*.

**EUPHORBIO DENDROIDIS–CALICOTOMETUM VILLOSAE** (Farris, Secchi & Filigheddu 2007) Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nov. et stat. nov. hoc loco* (*Holotypus* rel. 153 of Tab. 16 in Farris *et al.*, 2007)

Basionym: *Pistacio lentisci–Calicotometum villosae euphorbietosum dendroidis* Farris, Secchi & Filigheddu 2007 (Farris *et al.*, 2007: 74)

Group 5 in Table 7 constitutes the relevés attributed

by Farris *et al.* (2007) to *Pistacio lentisci–Calicotometum villosae* subass. *euphorbietosum dendroidis* in their study of the shrub and pre-forest communities of the effusive substrata of north-western Sardinia. According to the PCA ordering plots, this subassociation should be raised to the rank of an association, with the epithet of *Euphorbio dendroidis–Calicotometum villosae* *stat. nov.* Indeed, it is the most thermophilic phytocoenosis, and floristically, it is far from those mentioned above (Fig. 7A, C). The diagnostic species in the ISA are in agreement with those highlighted by Farris *et al.* (2007), and they are: *Asparagus albus*, *Euphorbia dendroides*, *Artemisia arborescens*, *Chamaerops humilis*, *Pyrus spinosa* and *Lavandula stoechas*. Only relevés 1, 2, 3 of Table 7 (56, 63, 64 in Fig. 7A, B) do not have *Euphorbia dendroides* and *Artemisia arborescens*, and thus tend to greater similarity with groups 1, 2 and 3.

**PHAGNALO SAXATILI–CALICOTOMETUM VILLOSAE** Mossa, Curreli & Fogu ex Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nova hoc loco* subass. **TYPICUM** Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *subass. nova hoc loco* (*Holotypus* rel. 8 of Tab. 8)

subass. **ASPARAGETOSUM STIPULARIS** Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *subass. nova hoc loco* (*Holotypus* rel. 2 of Tab. 8)

Group 6 in Table 8 represents the relevés carried out for Carbonara Cape (southern Sardinia) that have been attributed to the association *Phagnalo saxatili–Calicotometum villosae* Mossa, Curreli & Fogu 2000 (Table 14 in Mossa *et al.*, 2000). This name is invalid (art. 3f) because *Phagnalon saxatile* is not indicated in the original diagnosis (Table 14 in Mossa *et al.*, 2000). Indeed in the Flora of Capo Carbonara, Camarda & Ballero (1981) reported that *Phagnalon saxatile* is common in the area whereas they did not indicate the presence of *Phagnalon rupestre* subsp. *annoticum*. For this reason in Table 14 in Mossa *et al.* (2000) *Phagnalon rupestre* subsp. *annoticum* has been replaced with *Phagnalon saxatile* (Tab. 8).

Albeit that on average group 6 is separated from the others (Fig. 7) and characterised by the species *Phagnalon saxatile*, *Asparagus stipularis* and *Asparagus albus* (Table 3), it shows floristic heterogeneity. Relevés 1, 2 and 3 of Table 8 (47, 46, 45 in Fig. 7) tend to the association *Euphorbio dendroidis–Calicotometum villosae*, as proposed above, and they differentiate a particularly thermophilic sub-association, called *Phagnalo saxatili–Calicotometum villosae* subass. *asparagetosum stipularis* subass. *nova*. The differential species are: *Euphorbia dendroides*, *Polypodium cambricum* subsp. *serrulatum*, *Asparagus stipularis* and *Asparagus albus*. The *typicum* aspect is characterised by the species *Phagnalon saxatile* and *Prasium majus*.

Tab. 3 - Synoptic frequency table (percentage) of *Calicotome villosa* vegetation with diagnostic species as identified in the indicator species analysis (ISA; Significance: 0 \*\*\* 0.001 \*\* 0.01 \* 0.05). Tyrrhenian coenoses (number 1-6) and Adriatic coenoses (number 7). 1, *Pistacio lentisci-Calicotometum villosae rosmarinetosum officinalis*; 2, *Pistacio lentisci-Calicotometum villosae phillyreetosum angustifoliae*; 3, *Spartio juncei-Calicotometum villosae*; 4, *Teucrio fruticantis-Calicotometum villosae*; 5, *Euphorbio dendroidis-Calicotometum villosae*; 6a, *Phagnalo saxatili-Calicotometum villosae typicum*; 6b, *Phagnalo saxatili-Calicotometum villosae asparagetosum stipularis*; 7, *Pino halepensis-Calicotometum villosae*.

Phytocoenosis	3	4	1	2	6a	6b	5	7	ISA	
									phi	p.value
<i>Spartio juncei-Calicotometum villosae</i>										
<i>Spartium junceum</i> L.	71								0.82	0.001***
<i>Pulicaria odora</i> (L.) Rchb.	62								0.76	0.001***
<i>Daphne gnidium</i> L.	43			11			8		0.50	0.035*
<i>Lavandula stoechas</i> L.	67	12		11			62		0.47	0.026*
<i>Dorycnium hirsutum</i> (L.) Ser.	29							33		
<i>Cistus creticus</i> L. subsp. <i>eriocephalus</i> (Viv.) Greuter & Burdet	43	25								
<i>Teucrio fruticantis-Calicotometum villosae</i>										
<i>Teucrium fruticans</i> L.		62							0.75	0.002**
<i>Arisarum vulgare</i> Targ.-Tozz.	48	100	40	22	80			33	0.62	0.003**
<i>Pistacio lentisci-Calicotometum villosae rosmarinetosum officinalis</i>										
<i>Rosmarinus officinalis</i> L.		12	100	22				33	0.81	0.002**
<i>Cistus salvifolius</i> L.	19		60		20				0.52	0.032*
<i>Helichrysum italicum</i> (Roth) Don ssp. <i>microphyllum</i> (Willd.) Nyman			40						0.60	0.026*
<i>Pistacio lentisci-Calicotometum villosae phillyreetosum angustifoliae</i>										
<i>Phillyrea angustifolia</i> L.				100			8		0.97	0.001***
<i>Phagnalo saxatili-Calicotometum villosae typicum</i>										
<i>Prasium majus</i> L.	24			11	60		15	17	0.5	0.016**
<i>Phagnalon saxatile</i> (L.) Cass.					80	100			0.6	0.009**
<i>Phagnalo saxatili-Calicotometum villosae asparagetosum stipularis</i>										
<i>Polypodium cambricum</i> L. subsp. <i>serrulatum</i> (Schinz ex Arcang.) Pic. Serm.		25				100			0.91	0.001***
<i>Asparagus stipularis</i> Forsskal					20	100			0.78	0.002**
<i>Euphorbia dendroides</i> L.						100	77		0.74	0.001***
<i>Asparagus albus</i> L.				11	40	67	69		0.48	0.019*
<i>Euphorbio dendroidis-Calicotometum villosae</i>										
<i>Pyrus spinosa</i> Forssk.							69	17	0.7	0.002**
<i>Artemisia arborescens</i> L.							38		0.6	0.013*
<i>Chamaerops humilis</i> L.							31		0.5	0.025*
<i>Pino halepensis-Calicotometum villosae</i> and <i>Cisto cretici-Ericion manipuliiflorae</i>										
<i>Cistus creticus</i> ssp. <i>creticus</i> L.								100	1	0.001***
<i>Pinus halepensis</i> Miller (juvenile)								100	1	0.001***
<i>Ericion arboreae, Pistacio lentisci-Calicotomenion villosae</i>										
<i>Arbutus unedo</i> L.	14		40	22			8			
<i>Myrtus communis</i> L.	14	38	60	56			8			
<i>Erica arborea</i> L.	71		80	56			38			
<i>Cistus monspeliensis</i> L.	100	62	80	100	60		77	83		
<i>Asparagus acutifolius</i> L.	10		20	44	100	33	15	83		
<i>Calicotome villosa</i> (Poiret) Link	100	100	100	100	100	100	100	100		
<i>Pistacia lentiscus</i> L.	76	100	80	100	60	100	100	100		
<i>Genista corsica</i> (Loisel.) DC.			20	22			8			
<i>Clematis cirrhosa</i> L.							23			
<i>Upper units</i>										
<i>Rhamnus alaternus</i> L.	33	12		56			23			
<i>Olea europaea</i> L. var. <i>sylvestris</i> Brot.				20	22	40	54			
<i>Juniperus phoenicea</i> L. subsp. <i>turbinata</i> (Guss.) Nyman				60	22	33	23			

<i>Smilax aspera</i> L.			11	20		50
<i>Lonicera implexa</i> Aiton	10				31	17
<i>Rubia peregrina</i> L.	24	80				33
<i>Quercus ilex</i> L.	14		11		8	
<i>Allium subhirsutum</i> L.	10					17
<i>Phillyrea latifolia</i> L.	14					
<i>Rosa sempervirens</i> L.					23	
<i>Other species</i>						
<i>Brachypodium ramosum</i> (L.) R. et S.	100	75	80	100	100	8 67
<i>Asphodelus ramosus</i> L. subsp. <i>ramosus</i>	5		22	20	8	
<i>Reichardia picroides</i> (L.) Roth	5		20			33
<i>Piptatherum miliaceum</i> (L.) Coss.	5					67
<i>Cytinus hypocistis</i> (L.) L.	52			20		
<i>Briza maxima</i> L.	14	50				
<i>Carlina corymbosa</i> L.	10		80			
<i>Rubus ulmifolius</i> Schott	19	12				
<i>Coleostephus myconis</i> (L.) Cass. ex Rchb.fil.	5	25				
<i>Lysimachia arvensis</i> (L.) U. Manns et Anderb.	5	25				
<i>Dittrichia viscosa</i> (L.) Greuter	14					17
<i>Daucus carota</i> L.	14					33
<i>Dactylis glomerata</i> L.	29					
<i>Geranium molle</i> L.					100	
<i>Mercurialis annua</i> L.		38				
<i>Ampelodesmos mauritanicus</i> (Poiret) Dur. et Sch.	24					
<i>Euphorbia spinosa</i> L.	24					

#### PINO HALEPENSIS-CALICOTOMETUM VILLOSAE

Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nova hoc loco* (*Holotypus* rel. 3 of Tab. 9)

Group 7 in Table 9 refers to the unpublished relevés carried out in the Calalunga (Gargano). The analyses show the floristic originality of these relevés, as mainly differentiated in the PCA3 axis (Fig. 7A, C). The vegetation is similar structurally to *Pistacio lentisci-Calicotometum villosae*, but it differs from this significantly by the presence of *Pinus halepensis*, although in juvenile parts, and *Cistus creticus* subsp. *creticus*. These two species are characteristic of the new association *Pino halepensis-Calicotometum villosae* *ass. nova hoc loco*. The Fig. 8 shows the structural increase of the thick maquis dominated by *C. villosa* four and eight years after the fire. Currently, *C. villosa* is about 2.5 m tall, and the young trees of *P. halepensis* are 3.5 m tall, all with pine cones. This maquis has developed in the upper part of the hill-side investigated, on sub-flat morphologies where the soils are deeper than in the area dominated by the vegetation formed by rockroses (*Cistus creticus* subsp. *creticus*, *C. salvifolius*, *C. monspeliensis*). Moreover, this association shows some similarities with the association *Erico-Calicotometum infestae* Horvatić 1958, described for southern Croatia in the area of Dubrovnik. The dominant species of this latter association are *Erica manipuliflora* Salisb. (= *Erica verticillata* Forssk.) and *Calicotome infesta* (C. Presl) Guss., which were chosen for the construction of its name (Table 3 in Horvatić, 1958). These two

species do not occur in the Gargano area, as do other strictly Balkan species. In the phytosociological table (Table 3 in Horvatić, 1958), *P. halepensis* occurs in 10 relevés out of 12, and this supports the concept that the association *Erico-Calicotometum infestae* has the same dynamic role in the recovery after fire as a *P. halepensis* pine wood in the Calalunga area (Gargano) before the fire.

#### Syntaxonomical discussion

The majority of the considered vegetation (groups 1, 2, 3, 4, 5, 6) refer to the Tyrrhenian area, and in particular to the Sardinian sector and the Tuscan Archipelago. This is represented and described mainly by the PCA1 and PCA2 axes. Otherwise, the only vegetation referred to the Adriatic sector (group 7) is mainly differentiated by the PCA3 axis (Fig. 7A, C).

The attribution of the described association to upper syntaxonomical categories appears to be relatively difficult, as this kind of vegetation is traditionally framed into two different classes: the class *Quercetea ilicis* and the class *Cisto cretici-Micromerietea julianae* Oberdorfer ex Horvatić 1958. The first class groups together the maquis of *C. villosa* that occurs in the western part of the Mediterranean basin, while for the eastern side, the *C. villosa* coenoses are considered as recovery stages of chamaephytic and nanophanerophytic communities. Therefore, the *C. villosa* vegetation that occurs for the Tyrrhenian coastal and subcoastal areas of Sardinia and the Tuscany Archipelago should be

attributed to the order *Pistacio lentisci–Rhamnetalia alaterni* Rivas-Martínez 1975, and to the alliance *Ericion arboreae* Rivas-Martínez (1975) 1987. This alliance groups together maquis and garrigues that occur in the western Mediterranean, and that extend as far as the Tyrrhenian sector of the Italian islands and peninsula (Biondi et al., 2014).

**PISTACIO LENTISCI–CALICOTOMENION VILLOSAE** Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *suball. nova hoc loco* (Holotypus: *Pistacio lentisci–Calicotometum villosae* Biondi, Filigheddu & Farris 2001)

This suballiance includes all the maquis with *Calicotome villosa* and *C. spinosa*, that occur in the Western Mediterranean area. These maquis are included in the alliance *Ericion arboreae* and they represent the came-

phytic and nanophanerophytic stages that follow the phases characterised by the species belonging to the classes *Rosmarinetea officinalis* and *Cisto-Lavanduletea*. In the Tyrrhenian area, these classes are represented by the alliance *Cisto eriocephali–Ericion multiflorae* Biondi 2000 (*Rosmarinetea officinalis*) and *Calicotomo villosae–Genistion tyrrhenae* Biondi 2000 respectively. The last alliance does not occur in Sardinia and in Corse where it is replaced by the alliance *Teucrium mari* Gamisans & Murraciale 1984 (*Cisto-Lavanduletea*). The communities related to the new suballiance are complex because they are constituted by both fast resprouting species (*Pistacia lentiscus*, *Erica arborea*, *Myrtus communis* and *Arbutus unedo*) and regenerative species by seed (*Calicotome villosa*, *C. spinosa*, *Cistus* sp.pl., *Pinus halepensis* etc.).

On the basis of the analysis carried out, the new su-

Tab. 4 - *Pistacio lentisci-Calicotometum villosae* Biondi, Filigheddu & Farris 2001, *rosmarinetosum officinalis* Biondi & Bagella 2005, *phillyreetosum angustifoliae* Biondi & Bagella 2005.

Group n.	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	Presences
Rel. n.	1	2	3	4	5	6	7	8	9	10	11	12	13	14				
Rel. n. in Fig. 7	1	5	4	2	3	6	8	14	7	9	12	13	11	10				
Original rel. n. (1-5 Tab. 59 in Biondi, Filigheddu & Farris 2001 6-14 Tab 74 in Biondi & Bagella 2005)	1	5	4	2	3*	1	3	9	2	4	7	8	6	5*				
<hr/>																		
Charact. of ass.																		
Calicotome villosa (Poirot) Link	4.5	4.4	5.5	3.4	4.5	5.5	4.5	5.5	5.5	5.5	5.5	5.5	4.4	4.5	14			
Pistacia lentiscus L.	.	+	+2	1.2	2.3	1.2	2.2	1.2	3.3	2.3	1.2	2.3	1.2	2.3	13			
Diff. of subass. <i>rosmarinetosum officinalis</i>																		
Rosmarinus officinalis L.	2.3	1.1	1.2	2.2	2.2	.	.	.	.	+2	.	.	1.2	.	7			
Cistus salvifolius L.	3.3	+	.	2.3	.	.	.	.	.	.	.	.	.	.	3			
Helichrysum italicum (Roth) Don ssp. microphyllum (Willd.) Nyman	+	.	.	1.2	.	.	.	.	.	.	.	.	.	.	2			
Diff. of subass. <i>phillyreetosum angustifoliae</i>																		
Phillyrea angustifolia L.	.	.	.	.	.	2.3	1.2	3.3	2.3	1.2	2.3	2.3	3.3	3.3	9			
<hr/>																		
Charact. and diff. of <i>Ericion arboreae</i> and <i>Pistacio lentisci-Calicotomenion villosae</i>																		
Cistus monspeliensis L.	1.2	3.4	1.2	+	.	2.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	+2	13			
Erica arborea L.	2.3	+	+2	.	+	1.2	2.2	2.2	+2	+	.	.	.	.	9			
Myrtus communis L.	.	+	2.2	.	+	.	2.2	1.2	1.2	1.2	.	.	.	1.2	8			
Arbutus unedo L.	.	+	+2	.	.	.	2.2	.	+2	.	.	.	.	.	4			
Genista corsica (Loisel.) DC.	.	.	.	1.2	.	.	.	.	.	.	.	.	2.2	1.2	3			
Daphne gnidium L.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1			
Charact. and diff. of upper units																		
Rhamnus alaternus L.	.	.	.	.	.	.	1.2	.	1.1	1.2	2.2	+	.	5				
Juniperus phoenicea L. subsp. turbinata (Guss.) Nyman	.	+	+	.	1.1	.	.	.	.	.	.	.	+2	+2	5			
Asparagus acutifolius L.	.	+	.	.	.	.	.	.	.	.	+2	+	1.2	+2	5			
Arisarum vulgare Targ.-Tozz.	.	.	+	1.1	.	.	.	1.2	.	.	1.2	.	.	4				
Rubia peregrina L.	1.2	.	1.2	+	1.2	.	.	.	.	.	.	.	.	4				
Olea europaea L. var. sylvestris Brot.	.	.	.	.	+2	.	.	.	.	1.1	1.2	.	.	3				
Asparagus albus L.	.	.	.	.	.	.	.	.	+	.	.	.	.	1				
Prasium majus L.	.	.	.	.	.	.	.	.	.	.	.	+	.	1				
Quercus ilex L.	.	.	.	.	.	.	1.2	.	.	.	.	.	.	1				
Smilax aspera L.	.	.	.	.	.	.	.	.	.	.	.	.	1.2	1				
Osyris alba L.	.	.	.	.	.	.	.	.	.	.	.	.	.	+2	1			
Other species																		
Brachypodium ramosum (L.) R. et S.	.	+	+	+	3.3	1.2	1.2	+2	1.2	1.2	1.2	1.2	1.2	1.2	13			
Carlina corymbosa L.	+	+	.	+	+	.	.	.	.	.	.	.	.	.	4			
Sporadic species	1	0	0	2	1	1	0	2	0	0	1	0	3	1				

Tab. 5 - *Spartio juncei-Calicotometum villosae* (Foggi, Cartei, Pignotti, Signorini, Viciani, Dell'Olmo & Menicagli 2006) Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nov. et stat. nov. hoc loco* (*Holotypus* rel. 546 of Tab. 34 in Foggi *et al.*, 2006).

Group n.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	Presences
Rel. n.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Rel. n. in Fig. 7	17	25	16	15	24	22	19	32	33	26	34	35	31	20	30	28	23	21	27	18	29
Original rel. n. (Tab. 34 in Foggi <i>et al.</i> , 2006)	737	742	736	708	740	311	501	545	546*	514	547	507	746	537	706	544	310	500	707	738	747
Charact. and diff. of ass.																					
Spartium junceum L.	1	1	.	+	+	1	1	2	2	+	.	.	+	1	.	1	2	1	1	.	15
Pulicaria odora (L.) Rchb.	.	.	+	1	.	.	.	+	+	+	+	.	.	+	+	r	+	+	.	1	13
Daphne gnidium L.	+	.	.	r	.	.	1	.	1	r	1	1	.	1	.	.	.	.	.	+	9
Lavandula stoechas L.	1	.	.	.	.	.	1	+	.	+	2	.	+	+	1	+	1	1	+	+	14
Cistus creticus L.subsp. eriocephalus (Viv.) Greuter & Burdet	1	+	1	1	+	+	1	.	.	.	.	.	.	.	.	.	.	.	1	.	9
Dorycnium hirsutum (L.) Ser.	.	+	.	.	+	.	+	.	.	.	+	+	.	.	.	.	.	1	.	.	6
Charact. and diff. <i>Ericion arboreae</i> and <i>Pistacio lentisci-Calicotomenion villosae</i>																					
Calicotome villosa (Poirot) Link	4	3	4	4	3	3	4	5	4	4	3	3	4	4	4	4	4	4	4	4	21
Cistus monspeliensis L.	3	4	3	3	4	3	2	2	2	3	3	4	2	3	2	2	3	3	2	3	21
Pistacia lentiscus L.	.	.	.	+	.	.	1	1	1	+	1	+	1	1	+	1	+	1	1	1	16
Erica arborea L.	2	+	2	1	.	2	1	1	2	2	2	2	1	+	1	.	.	.	.	+	15
Cistus salvifolius L.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	1	.	.	+	.	.	4
Myrtus communis L.	.	.	.	.	+	.	.	r	.	.	.	.	.	1	.	.	.	.	.	.	3
Arbutus unedo L.	.	.	.	.	.	.	.	.	r	.	.	1	.	.	.	.	.	.	.	r	3
Charact. and diff. of upper units																					
Arisarum vulgare Targ.-Tozz.	r	.	+	+	.	.	.	+	+	1	+	.	.	.	.	.	.	1	+	.	10
Rhamnus alaternus L.	.	.	.	.	.	.	+	+	.	1	.	.	.	1	+	1	1	.	.	.	7
Rubia peregrina L.	.	.	.	.	+	.	.	+	.	.	r	.	.	.	.	.	.	.	+	.	5
Prasium majus L.	.	.	.	.	1	.	.	+	.	.	.	.	+	r	+	.	.	.	.	.	5
Quercus ilex L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	r	1	.	3
Phillyrea latifolia L.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	1	.	3
Asparagus acutifolius L.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	2
Allium subhirsutum L.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	1	.	.	2
Lonicera implexa Aiton	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	2
Pinus pinaster Aiton	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1
Other species																					
Brachypodium ramosum (L.) R. et S.	1	+	1	1	+	+	2	2	2	1	3	1	3	1	3	4	1	2	3	+	3
Cytinus hypocistis (L.) L.	r	+	+	+	.	.	.	.	.	+	2	.	.	.	.	.	.	.	+	.	11
Dactylis glomerata L.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	+	6
Euphorbia spinosa L.	.	.	.	.	.	.	.	1	.	.	+	.	.	.	.	+	1	.	.	r	5
Ampelodesmos mauritanicus (Poirot) Dur. et Sch.	.	.	.	.	.	.	2	1	.	2	.	.	.	1	.	r	.	.	.	.	5
Rubus ulmifolius Schott	.	.	+	.	1	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	4
Dittrichia viscosa (L.) Greuter	.	.	.	.	.	.	r	+	.	.	+	.	.	.	.	.	.	.	.	.	3
Daucus carota L.	.	.	r	.	r	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	3
Briza maxima L.	.	+	.	.	r	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	3
Sporadic species	0	0	1	0	2	0	4	1	0	8	4	1	0	0	1	2	0	5	0	1	0

Tab. 6 - *Teucrio fruticantis-Calicotometum villosae* Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nova hoc loco* (*Holotypus* rel. 55 of Tab. 3 in Foggi & Pancioli, 2008).

Group n.	4	4	4	4	4	4	4	Presences	
Rel. n.	1	2	3	4	5	6	7	8	
Rel. n. in Fig. 7	55	53	48	50	49	51	52	54	
Original rel. n. (Tab. 3 in Foggi & Pancioli, 2008)	84	55*	73	70	63	27	28	29	
Charact. and diff. of ass.									
Arisarum vulgare Targ.-Tozz.	1	2	2	2	1	4	3	4	8
Teucrium fruticans L.	2	2	.	.	.	2	2	r	5
Charact. and diff. of <i>Ericion arboreae</i> and <i>Pistacio lentisci-Calicotomenion villosae</i>									
Calicotome villosa (Poirot) Link	4	3	2	3	4	3	4	2	8
Pistacia lentiscus L.	1	3	3	1	3	3	3	5	8
Cistus monspeliensis L.	1	+	r	.	1	.	.	r	5
Myrtus communis L.	+	+	.	1	.	.	.	.	3
Cistus creticus L.subsp. eriocephalus (Viv.) Greuter & Burdet	.	.	+	.	2	.	.	.	2
Rhamnus alaternus L.	.	.	.	.	r	.	.	.	1
Other species									
Brachypodium ramosum (L.) R. et S.	3	1	r	1	.	+	r	.	6
Briza maxima L.	.	r	+	+	+	.	.	.	4
Sporadic species	6	1	6	2	5	2	0	0	

Tab. 7 - *Euphorbia dendroidis-Calicotometum villosae* (Farris, Secchi & Filigheddu 2007) Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nov. et stat. nov. hoc loco* (*Holotypus* rel. 153 of tab. 16 in Farris *et al.*, 2007).

Group n.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	Presences
Ril. n.	1	2	3	4	5	6	7	8	9	10	11	12	13			
Rel. n. in Fig. 7	56	63	64	59	61	60	57	58	68	62	67	65	66			
Original rel. n. (Tab. 16 in Farris <i>et al.</i> , 2007)	144	151	152	147	149	148	145	146	156	150	155	153*	154			
Charact. and diff. of ass.																
<i>Euphorbia dendroides</i> L.	.	.	.	1.2	1.2	1.1	2.2	1.1	+2	1.1	3.3	2.3	2.3	10		
<i>Asparagus albus</i> L.	1.1	.	.	.	+	.	+2	1.1	1.1	+	+2	+	+2	9		
<i>Pyrus spinosa</i> Forssk.	.	+	+	1.2	+	2.3	1.2	1.2	1.2	+2	.	.	.	9		
<i>Lavandula stoechas</i> L.	1.1	.	.	+	+	+2	+	+	+	.	+	.	.	8		
<i>Artemisia arborescens</i> L.	.	.	.	1.2	.	.	.	.	2.2	+	1.2	+	.	5		
<i>Chamaerops humilis</i> L.	1.1	.	.	.	.	.	.	.	.	.	+2	1.2	1.2	4		
Charact. and diff. of <i>Ericion arboreae</i> and <i>Pistacio lentisci-Calicotomenion villosae</i>																
<i>Calicotome villosa</i> (Poiret) Link	3.3	4.5	4.4	4.4	4.5	3.4	4.4	4.5	3.4	4.4	3.4	3.4	4.4	13		
<i>Pistacia lentiscus</i> L.	1.2	2.3	2.3	2.3	3.3	3.3	2.3	3.3	3.4	2.2	1.2	1.2	2.3	13		
<i>Cistus monspeliensis</i> L.	1.2	+2	+2	1.2	1.2	1.2	+2	+	+2	+2	.	.	.	10		
<i>Erica arborea</i> L.	+	1.2	1.2	.	+	.	+	.	.	.	.	.	.	5		
<i>Clematis cirrhosa</i> L.	.	.	.	.	+2	+2	.	.	+	.	.	.	.	3		
<i>Arbutus unedo</i> L.	1.1	.	.	.	.	.	.	.	.	.	.	.	.	1		
<i>Myrtus communis</i> L.	+2	.	.	.	.	.	.	.	.	.	.	.	.	1		
<i>Phillyrea angustifolia</i> L.	1.1	.	.	.	.	.	.	.	.	.	.	.	.	1		
<i>Daphne gnidium</i> L.	+	.	.	.	.	.	.	.	.	.	.	.	.	1		
<i>Genista corsica</i> (Loisel.) DC.	.	.	.	.	.	.	.	.	.	.	.	+	.	1		
Charact. and diff. of upper units																
<i>Olea europaea</i> L. var. <i>sylvestris</i> Brot.	+2	.	1.1	.	+	.	+	+2	.	1.2	.	.	.	+2	7	
<i>Lonicera implexa</i> Aiton	1.3	.	.	.	+2	.	+2	.	1.2	.	.	.	.	4		
<i>Juniperus phoenicea</i> L. subsp. <i>turbinata</i> (Guss.) Nyman	.	.	.	.	.	.	.	.	.	.	1.2	+2	+	3		
<i>Rhamnus alaternus</i> L.	+2	.	.	.	+	.	.	+2	.	.	.	.	.	3		
<i>Rosa sempervirens</i> L.	.	.	.	.	.	.	+2	+	+2	.	.	.	.	3		
<i>Asparagus acutifolius</i> L.	.	.	.	.	.	.	1.1	.	+2	.	.	.	.	2		
<i>Prasium majus</i> L.	.	.	.	.	.	1.2	.	.	+	.	.	.	.	2		
<i>Quercus ilex</i> L.	.	+	.	.	.	.	.	.	.	.	.	.	.	1		
Sporadic species	2	0	0	0	0	0	0	0	0	0	0	1	1			

Tab. 8 - *Phagnalo saxatili-Calicotometum villosae* Mossa, Curreli & Fogu ex Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nova hoc loco* (*Holotypus* rel. 8), subass. *typicum* Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *subass. nova hoc loco* (*Holotypus* rel. 8), subass. *asparagetosum stipularis* Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *subass. nova hoc loco* (*Holotypus* rel. 2).

Group n.	6	6	6	6	6	6	6	6	6	6	Presences
Ril. n.	1	2*	3	4	5	6	7	8			
Rel. n. in Fig. 7	47	46	45	42	41	40	43	44			
Original rel. n. (Tab. 14 in Mossa <i>et al.</i> , 2000)	8	7	6	3	2	1	4	5			
Charact. and diff. of ass. and subass. <i>typicum</i>											
<i>Phagnalon saxatile</i> (L.) Cass.	+	+	+	.	1.1	1.1	+	+			7
<i>Prasium majus</i> L.	.	.	.	.	1.1	.	+	1.1			3
<i>Arisarum vulgare</i> Targ.-Tozz.	.	.	.	1.1	.	2.2	+	+			4
Diff. of subass. <i>asparagetosum stipularis</i>											
<i>Euphorbia dendroides</i> L.	2.3	2.3	2.3	.	.	.	.	.			3
<i>Asparagus stipularis</i> Forsskal	1.1	1.2	+2	.	.	2.2	.	.			4
<i>Polypodium cambricum</i> L. subsp. <i>serrulatum</i> (Schinz ex Arcang.) Pic. Serm.	+	+	+	.	.	.	.	.			3
<i>Asparagus albus</i> L.	.	2.2	1.2	+2	.	.	+	.			4
Charact. and diff. of <i>Ericion arboreae</i> and <i>Pistacio lentisci-Calicotomenion villosae</i>											
<i>Calicotome villosa</i> (Poiret) Link	3.4	3.3	4.3	4.5	5.5	5.5	4.5	4.5			8
<i>Pistacia lentiscus</i> L.	1.2	3.3	3.3	+	.	.	2.2	3.2			6
<i>Cistus monspeliensis</i> L.	.	.	.	+	.	.	1.2	1.2			3
Charact. and diff. of upper units											
<i>Asparagus acutifolius</i> L.	+	.	.	+	1.1	+	1.2	+2			6
<i>Olea europaea</i> L. var. <i>sylvestris</i> Brot.	.	.	.	.	.	.	+	1.2			2
<i>Juniperus phoenicea</i> L. subsp. <i>turbinata</i> (Guss.) Nyman	.	.	+	.	.	.	.	.			1
<i>Smilax aspera</i> L.	.	.	.	.	.	.	.	+2			1
Sporadic species	3	2	2	2	2	2	1	1			

Tab. 9 - *Pino halepensis-Calicotometum villosae* Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia ass. nova *hoc loco* (*Holotypus* rel. 3)

Group n.	7	7	7	7	7	7		
Rel. n.	1	2	3*	4	5	6		
Rel. n. in Fig. 7	37	36	39	38	-	-		
Coverage (%)	100	100	100	100	100	100		
Area (m <sup>2</sup> )	300	300	300	200	250	200		
Exposure	-	-	-	S	E	W	Presences	
H veg. (m)	2,5	2,2	2,2	2,5	2	2,5		
Altitude (m a.s.l)	122	76	70	70	-	146		
Slope (°)	0	0	0	10	3	5		
Charact. and diff. of ass.								
<i>Calicotome villosa</i> (Poiret) Link	5.5	5.5	5.5	5.5	5.5	5.5		6
<i>Pinus halepensis</i> Miller (juvenile)	2.2	+	2.3	2.3	1.2	1.2		6
<i>Cistus creticus</i> ssp. <i>creticus</i> L.	1.2	2.2	2.3	2.2	1.2	3.4		6
Charact. and diff. <i>Cisto cretici-Ericion manipuliflorae</i> and upper units								
<i>Cistus monspeliensis</i> L.	2.3	3.4	3.4	3.4	.	2.2	5	
<i>Dorycnium hirsutum</i> (L.) Ser.	.	1.2	.	.	.	2.2	5	
<i>Rosmarinus officinalis</i> L.	.	.	+	.	.	2.3	5	
<i>Lonicera implexa</i> Aiton	.	.	.	.	+	.	1	
<i>Cistus creticus</i> L. subsp. <i>eriocephalus</i> (Viv.) Greuter & Burdet	.	.	.	.	+	.	1	
<i>Micromeria graeca</i> (L.) Benth	.	.	.	.	.	1.2	1	
Charact. and diff. <i>Pistacio-Rhamnetalia</i>								
<i>Pistacia lentiscus</i> L.	2.3	3.4	2.3	2.3	2.2	2.3	6	
<i>Asparagus acutifolius</i> L.	+	1.2	1.2	1.2	1.2	.	5	
<i>Smilax aspera</i> L.	.	1.2	+2	.	1.2	.	3	
<i>Quercus ilex</i> L. (seedling)	.	1.2	.	.	1.1	.	2	
<i>Clematis flammula</i> L.	.	2.3	.	.	2.2	.	2	
<i>Rubia peregrina</i> L.	.	.	1.2	+	.	.	2	
<i>Arisarum vulgare</i> Targ.-Tozz.	.	.	1.2	3.3	.	.	2	
<i>Pistacia terebinthus</i> L.	.	1.2	.	.	.	.	1	
<i>Euphorbia characias</i> L.	.	2.2	.	.	.	.	1	
<i>Phillyrea media</i> L.	.	2.2	.	.	.	.	1	
<i>Allium subhirsutum</i> L.	.	+	.	.	.	.	1	
<i>Prasium majus</i> L.	.	.	.	+	.	.	1	
Other species								
<i>Brachypodium ramosum</i> (L.) R. et S.	+	+2	.	.	1.2	1.2	4	
<i>Piptatherum miliaceum</i> (L.) Coss.	.	.	2.3	2.3	+	1.2	4	
<i>Daucus carota</i> L.	1.2	1.1	.	.	.	.	2	
<i>Andropogon distachyus</i> L.	1.2	2.2	.	.	.	.	2	
<i>Bituminaria bituminosa</i> (L.) C.H. Stirt.	+	1.2	.	.	.	.	2	
<i>Reichardia picroides</i> (L.) Roth	.	.	+	+	.	.	2	
Sporadic species								
	0	7	1	0	2	2		

balliance *Pistacio lentisci-Calicotomenion villosae* can be described, which belongs to the alliance *Ericion arboreae*. This new suballiance groups together all of the Tyrrhenian associations considered in this study. The *typus* of the new suballiance is the association *Pistacio lentisci-Calicotometum villosae* Biondi, Filigheddu & Farris 2001. The characteristic species of the suballiance *Pistacio lentisci-Calicotomenion villosae* are *C. villosa*, *C. spinosa*, *Pistacia lentiscus*, *Myrtus communis*, *Asparagus acutifolius* and *Daphne gnidium* while the differential species are, *Cistus albidus*, *C. salvifolius*, *C. creticus* subsp. *eriocephalus*, *C. monspeliensis*.

On the contrary, the association described at Gargano should be attributed to the order *Cisto cretici-Ericetalia manipuliflorae* Horvatić 1958, grouping the garrigues that are indifferent to the chemical nature of the substratum and that grow from the coastal to the mon-

tane sectors (Biondi *et al.*, 2014). This order ranges from the eastern Balkan peninsula to the south-eastern part of the Italian peninsula, and from the central-eastern Adriatic sector to the Ionian, including eastern Sicily. The alliance *Cisto cretici-Ericion manipuliflorae* Horvatić 1958, to which the association *Pino halepensis-Calicotometum villosae* belongs, has a similar distribution range in Italy.

## Conclusions

Fire has a primary role in the diffusion of *C. villosa*. Indeed, it eliminates the plants that compete with this species for water, light and nutrients, and it promotes the germination of seeds of *C. villosa* through scarification of their water-impermeable coat. Therefore, the major proportion of the seeds accumulate in the soil seed bank and can germinate *en masse* after a fire



occurs.

The studied vegetation, and the other kinds of vegetation observed in Gargano, represents important phases in the recovery series of potential vegetation of different Mediterranean woodlands. When a fire occurs in a pine forest, large quantities of calories are released, and pyrophyte shrubs have an essential role in the vegetation recovery. Indeed, these plants produce a considerable amount of seeds in restricted periods that accumulate in the soil and can maintain their ability to germinate for decades.

The Aleppo pine has serotinous cones that open du-

ring a fire, with the spreading of the seeds, and these crucially contribute to woodland reconstruction. For the classification of the studied vegetation, we believe that the suballiance *Pistacio lentisci-Calicotomenion villosae* is very important in the western Mediterranean hierarchical system. Indeed, the communities belonging to the new suballiance are formed by both fast resprouting species (*Pistacia lentiscus*, *Erica arborea*, *Myrtus communis* and *Arbutus unedo*) and regenerative species by seed (*Calicotome villosa*, *C. spinosa*, *Cistus* sp. pl., *Pinus halepensis* etc.).

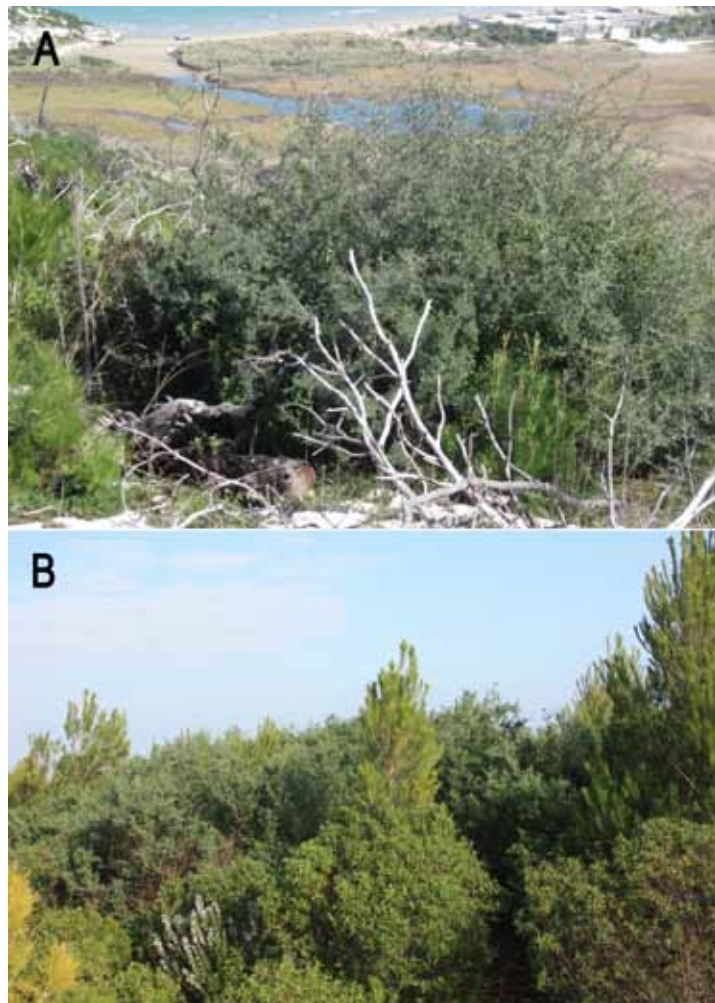


Fig. 8 - *Calicotome villosa* maquis (ass. *Pino halepensis-Calicotometum villosae*) in the Calalunga area, 4 years (A) and 8 years (B) after the fire that destroyed the Aleppo pine wood (Pictures by E. Biondi).

### Syntaxonomic scheme

The syntaxonomical scheme includes the *C. villosa* vegetation studied that is attributed in the different vegetation contexts, in agreement with the traditional proposals from different studies. For this reason, the Tyrrhenian coenoses are included in the class *Quercetea ilicis*, while the Adriatic coenosis is attributed to the class *Cisto-Micromerietea*.

i) *Calicotome villosa* vegetation, Tyrrhenian zone:

QUERCETEA ILICIS Br.-Bl. in Br.-Bl., Roussine & Négre 1952

*PISTACIO LENTISCI-RHAMNETALIA ALATERNI* Rivas-Martínez 1975

**Ericion arboreae** Rivas-Martínez (1975) 1987

**Pistacio lentisci-Calicotomenion villosae** *suball. nova hoc loco*

*Pistacio lentisci-Calicotometum villosae* Biondi, Filigheddu & Farris 2001

*rosmarinetosum officinalis* Biondi & Bagella 2005

*phillyreetosum angustifoliae* Biondi & Bagella 2005

*Spartio juncei-Calicotometum villosae* (Foggi, Cartei, Pignotti, Signorini, Viciani, Dell'Olmo & Menicagli 2006)

Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nov. et stat. nov.*

*Teucrio fruticantis-Calicotometum villosae* Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nova hoc loco*

*Phagnalo saxatili-Calicotometum villosae* Mossa, Curreli & Fogu ex Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nova hoc loco*

*subass. typicum* Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *subass. nova*

*subass. asparagosum stipularis* Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *subass. nova*

*Euphorbio dendroidis-Calicotometum villosae* (Farris, Secchi & Filigheddu 2007) Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *stat. nov. et ass. nova hoc loco*

ii) *Calicotome villosa* vegetation: central-southern Adriatic zone:

CISTO CRETICI-MICROMERIETEA JULIANAE Oberdorfer ex Horvatić 1958

*CISTO CRETICI-ERICETALIA MANIPULIFLORAE* Horvatić 1958

**Cisto cretici-Ericion manipuliflorae** Horvatić 1958

*Pino halepensis-Calicotometum villosae* Biondi, Biscotti, Gasparri, Pesaresi & Casavecchia *ass. nova*

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## Appendix I: Sporadic species

Tab. 4 - Rel. 1: *Euphorbia cupanii* Guss. ex Bertol. (+); Rel. 4: *Dactylis hispanica* Roth (+), *Reichardia picroides* (L.) Roth (+); Rel. 5: *Euphorbia characias* L. (+.2); Rel. 6: *Asphodelus ramosus* L. subsp. *ramosus* (1.1); Rel. 8: *Dactylis hispanica* Roth (+), *Lavandula stoechas* L. (+); Rel. 11: *Allium triquetrum* L. (+.2); Rel. 13: *Asphodelus ramosus* L. subsp. *ramosus* (+), *Carex hallerana* Asso (+.2), *Stachys glutinosa* L. (+.2); Rel. 14: *Stachys glutinosa* L. (+).

Tab. 5 - Rel. 3: *Coleostephus myconis* (L.) Cass. ex Rchb. fil. (+); Rel. 5: *Avena fatua* L. (+), *Vitis vinifera* L. (+); Rel. 7: *Carlina corymbosa* L. (+), *Helichrysum italicum* (Roth) Don (+), *Lupinus angustifolius* L. (+), *Teucrium flavum* L. (r); Rel. 8: *Teucrium flavum* L. (r); Rel. 10: *Asphodelus ramosus* L. subsp. *ramosus* (1), *Asterolinon linum-stellatum* (L.) Duby (+), *Hypochoeris achyrophorus* L. (+), *Lotus ornithopodioides* L. (+), *Lysimachia arvensis* (L.) U. Manns et Anderb. (+), *Ornithopus compressus* L. (+), *Serapias vomeracea* (Burm.) Briq. (+), *Vicia disperma* DC. (+); Rel. 11: *Carex flacca* Schreber ssp. *serrulata* (Biv.) Greuter (+), *Centaurium erythraea* Rafn (+), *Crepis leontodontoides* All. (r), *Helichrysum italicum* (Roth) Don (1); Rel. 12: *Odontites luteus* (L.) Clairv. (+); Rel. 15: *Crepis leontodontoides* All. (r); Rel. 16: *Ailanthus altissima* (Miller) Swingle (1), *Carlina corymbosa* L. (+); Rel. 18: *Lupinus angustifolius* L. (+), *Melica minuta* L. (r), *Micromeria graeca* (L.) Bentham (+), *Ornithogalum umbellatum* L. (+), *Reichardia picroides* (L.) Roth (+); Rel. 20: *Piptatherum miliaceum* (L.) Coss. (1).

Tab. 6 - Rel. 1: *Euphorbia pinea* L. (+), *Fumaria capreolata* L. (r), *Leopoldia comosa* (L.) Pari. (r), *Mercurialis annua* L. (+), *Silene gallica* L. (+), *Tuberaria guttata* (L.) Fourr. (1); Rel. 2: *Fumaria capreolata* L. (r); Rel. 3: *Coleostephus myconis* (L.) Cass. ex Rchb. fil. (r), *Lavandula stoechas* L. (r), *Lysimachia arvensis* (L.) U. Manns et Anderb. (+), *Mercurialis annua* L. (r), *Polypodium cambricum* L. subsp. *serrulatum* (Schinz ex

Arcang.) Pic. Serm. (r), *Rosmarinus officinalis* L. (3); Rel. 4: *Avena barbata* Pott ex Link (+), *Coleostephus myconis* (L.) Cass. ex Rchb. fil. (+); Rel. 5: *Avena barbata* Pott ex Link (r), *Lysimachia arvensis* (L.) U. Manns et Anderb. (r), *Polypodium cambricum* L. subsp. *serrulatum* (Schinz ex Arcang.) Pic. Serm. (+), *Rubus ulmifolius* Schott (+), *Silene gallica* L. (+); Rel. 6: *Euphorbia pinea* L. (r), *Mercurialis annua* L. (r). Tab. 7 - Rel. 1: *Asphodelus ramosus* L. subsp. *ramosus* (1.1), *Brachypodium ramosum* (L.) R. et S. (1.1); Rel. 12: *Opuntia ficus-indica* (L.) Miller (+); Rel. 13: *Opuntia ficus-indica* (L.) Miller (2).

Tab. 8 - Rel. 1: *Brachypodium ramosum* (L.) R. et S. (+), *Geranium molle* L. (+), *Solanum dulcamara* L. (+). Rel. 2: *Brachypodium ramosum* (L.) R. et S. (+), *Geranium molle* L. (+). Rel. 3: *Brachypodium ramosum* (L.) R. et S. (+), *Geranium molle* L. (+). Rel. 4: *Cistus salvifolius* L. (2.3), *Convolvulus althaeoides* L. (+). Rel. 5: *Asphodelus ramosus* L. subsp. *ramosus* (+), *Linum tenuifolium* L. (2.1). Rel. 6: *Hypochoeris achyrophorus* L. (1.1), *Lobularia maritima* (L.) Desv. (+). Rel. 7: *Cytinus hypocistis* (L.) L. (+). Rel. 8: *Pseudorhiza pumila* (L.) Grande (+).

Tab. 9 - Rel. 2: *Convolvulus elegantissimus* Miller (2.2), *Hypericum montanum* L. (+), *Melica ciliata* L. (1.2), *Pallenis spinosa* (L.) Cass. (+), *Pyrus spinosa* Forssk. (+), *Tamus communis* L. (+), *Verbascum niveum* Ten. ssp. *garganicum* (Ten.) Murb. (+); Rel. 3: *Hypochoeris radicata* L. (1.2); Rel. 5: *Cyclamen hederifolium* Aiton (1.2), *Melica arrecta* O. Kuntze (1.2); Rel. 6: *Dittrichia viscosa* (L.) Greuter (1.2), *Stipa bromoides* (L.) Dorfl. (1.2).

## Appendix II: Localities and dates of the relevés

Tab. 9 - Rels. 1-2: Calalunga, Peschici, Gargano (02/06/2011); Rels. 3-4: Calalunga, Peschici, Gargano (19/11/2015); Rel. 5: Calalunga, Peschici, Gargano (24/04/2013); Rel. 6: Calalunga, Peschici, Gargano (27/04/2013).

## Appendix III: Origins of the published relevés

Associations	Tab. N.	Relev. N.	Locality	References
<i>Pistacio lentisci-Calicotometum villosae</i> Biondi, Filigheddu & Farris 2001 <i>rosmarinetosum officinalis</i> Biondi & Bagella 2005	59	1-5	Northern Nurra	Biondi E., Filigheddu R. & Farris E., 2001. Il Paesaggio vegetale della Nurra (Sardegna nord-occidentale). <i>Fitosociologia</i> 38 (2) - Suppl. 2: 3-105.
<i>Pistacio lentisci-Calicotometum villosae</i> Biondi, Filigheddu & Farris 2001 <i>phillyretosum angustifoliae</i> Biondi & Bagella 2005	74	1-9	Maddalena Archipelago	Biondi E. & Bagella S., 2005. Vegetazione e paesaggio vegetale dell'Arcipelago di La Maddalena (Sardegna nord-orientale). <i>Fitosociologia</i> 42 (2) - Suppl. 1: 3-99.
<i>Pistacio lentisci-Calicotometum villosae</i> Biondi, Filigheddu & Farris 2001 <i>rosmarinetosum officinalis</i> Biondi & Bagella 2005 <i>cistetosum monspeliensis</i> Foggi et al. 2006	34	all rels. except 52, 552, 556, 518	Elba (Tuscan Archipelago)	Foggi B., Cartei L., Pignotti L., Signorini M.A., Viciani D., Dell'Olmo L. & Menicagli E., 2006. Il paesaggio vegetale dell'Isola d'Elba (Arcipelago Toscano). Studio di fitosociologia e cartografico. <i>Fitosociologia</i> 43 (1) - Suppl. 1: 3-95.
<i>Pistacio lentisci-Calicotometum villosae</i> Biondi, Filigheddu & Farris 2001 <i>cistetosum monspeliensis</i> Foggi et al. 2006	3	all rels. except 7, 8, 57, 76, 74	Giglio Island (Tuscan Archipelago)	Foggi B. & Pancioli V., 2008. Contributo alla conoscenza della vegetazione dell'Isola del Giglio (Arcipelago Toscano, Toscana meridionale) Webbia: <i>Journal of Plant Taxonomy and Geography</i> , 63 (1): 25-48.
<i>Pistacio lentisci-Calicotometum villosae</i> Biondi, Filigheddu & Farris 2001 <i>euphorbietosum dendroidis</i> Farris, Secchi & Filigheddu 2007	16	144-156	NW Sardinia	Farris E., Secchi Z. & Filigheddu R., 2007. Phytosociological study of the shrub and pre-forest communities of the effusive substrata of NW Sardinia. <i>Fitosociologia</i> 44 (2): 55-81.
<i>Phagnalo saxatili-Calicotometum villosae</i> Mossa, Curreli & Fogu 2000	14	all rels. except 1, 2, 3	Cape Carbonara (Southern Sardinia)	Mossa L., Curreli F. & Fogu M.C., 2000. La vegetazione degli habitats terrestri della riserva marina protetta di Capo Carbonara (Sardegna sud-orientale). La vegetazione degli habitats terrestri della riserva marina. <i>Rendiconti Seminario Facoltà Scienze Università Cagliari Supplemento Vol. 70: 163-185.</i>