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Experimental research in ageing holm oak (*Quercus ilex* L.) coppices: preliminary results

Orazio la Marca*, Pasquale A. Marziliano, Nicola Moretti

Istituto di Assestamento e Tecnologia forestale (IATF), Università di Firenze, Via S. Bonaventura n° 13 - I-50145, Florence, Italy

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Abstract – The initial data of a long-term research programme aimed at determining the silvicultural choices for management of ageing holm oak coppices are reported. The various treatments being tested are the following: treatments A and B, respectively, with 50 and 250 reserve trees per hectare, all of the same age; treatment C with 140 reserve trees per hectare, with three different ages; treatment D, conversion into high forest; and treatment E, natural evolution (the control). A total of 15 permanent plots were established (five treatments × three replicates) and the experimental design used is that of randomized blocks. The results presented regard the structural development of the coppice during the first 2 years after coppicing. Regeneration from seed showed a significant correlation with treatment. Data relative to the characteristics of the stands existing before the various interventions also are given. Such preliminary results need further periodical observations. (© Inra/Elsevier, Paris.)

Quercus ilex L. / **coppice / regeneration / cutting method / snow breakage**

Résumé – Expérimentation concernant les taillis vieillis de chêne vert (*Quercus ilex* L) : premiers résultats. Les résultats obtenus et ici présentés font partie d'un projet de recherche dont l'intention est d'individualiser des possibles options de culture pour les taillis de chêne vert vieillis. On a confronté les cinq thèses suivantes (avec trois répétitions) : les thèses A et B avec respectivement 50 et 250 réserves par hectare ayant toutes le même âge ; la thèse C avec 140 réserves par hectare, ayant trois âges différents ; la thèse D, conversion en futaie ; la thèse E, évolution naturelle. Les résultats exposés concernent l'évolution du peuplement pendant les deux premières années du cycle productif. Pour ce qui concerne la regénération, la présence des semis semble être favorisée par un couvert pas trop excessif des réserves. Il s'agit malgré tout de résultats préliminaires qui dérivent de parcelles d'échantillonage permanentes où, chaque année, on réalisera des reliefs. (© Inra/Elsevier, Paris.)

Quercus ilex L. / **taillis / regénération / méthode de coupe / bris de neige**

* Correspondence and reprints
E-mail: IATF@cesit 1.unifi.it

1. INTRODUCTION

In ancient times the holm oak was considered a sacred tree. Reverence for this tree probably derives from its importance to the economy, uncommon vigour and longevity as well as its modest requirements when grown both as a coppice or high forest. As noted by Pavari [19], and still today, many place names in Italy are in reference to this species. Holm oak wood was considered as an optimum fuel, as it still is today, and also was used to make tools and other objects subject to considerable wear. Its bark was used in the tanning industry, and the acorns and brushwood were used for food and bedding in the breeding of both wild and domestic animals.

Holm oak woods have played and continue to play a key role in soil conservation in protecting the soil from excessive insolation, leaching and erosion, even in extremely difficult geomorphological conditions.

In spite of the human intervention of replacing the holm oak with other species where pedological and geomorphological conditions allow, due to its uncommon resilience in unfavourable conditions and its capacity to colonize the most impervious areas, the holm oak justly remains one of the species characteristic of the Mediterranean landscape. As observed by Pignatti [20], in a broad area of the Mediterranean region, holm oak stands represent the potential natural vegetation. In addition, these stands also represent a rare example of equilibrium in the interaction between natural factors and anthrophic activity.

On the Gargano headland (south-eastern Italy), in addition to colonizing the low-lying areas at the edges of agricultural land, holm oak also tends to colonize the internal areas on sunny exposures up to relatively high elevations (> 800 m above sea level [a.s.l.]). Taking into consideration the spread of this species over the last 40 to 50 years, it is believed that the surface area covered by holm oak woods is increasing. On the Gargano headland, holm oak coppices form units, often of considerable extension, which in general coincide with highly degraded soils. In some particularly impervious areas, the holm oak is the dominant species. This species can be found isolated or in small groups on slopes with a southern exposure up to the highest elevations of the Gargano headland (around 1 000 m a.s.l.).

Until 40 to 50 years ago, the most common management method for the holm oak was coppicing with few reserve trees per hectare, in order to satisfy the high demand for fuelwood and for charcoal production. The coppicing, carried out at short intervals (the rotation period was 15 years), together with the practice of grubbing (to increase the quantity of wood to be removed at the end of each cycle), resulted in some zones in a notable degradation.

With the decrease in anthropic pressure and due to the considerable capacity of regeneration characteristic of this species, the general situation of holm oak coppices has improved considerably as regards canopy closure and growing stock, and in the best edaphic conditions in regard to biodiversity.

The main problem to be confronted in forestry regarding management practices concerns the choice of silvicultural methods suitable for the new economic and environmental situations in which holm oak coppices are found, in particular within the National Park of the Gargano.

Few references appear in the research literature regarding holm oak formations. Interesting studies on holm oak carried out in France do provide management indications of general application [2, 8–13, 21]. Studies on biomass estimation equations for individual holm oak were developed in Spain [6, 7] and in Italy [4, 5]. A survey on the potential wood production and coppice rotations of holm oak has been carried out by Hermanin and Pollini [16] in Tuscany, Italy. A research on vegetative regeneration during the first 3 years after coppicing of *Quercus ilex* in the Maremma Nature Park (Tuscany, Italy) has been studied by Giovannini et al. [15]. More recently in Italy, within the MEDCOP project (*Improvement of coppice forests in the Mediterranean region*), other research on holm oak coppices has been carried out [1, 14, 17].

The present study in the Gargano headland, initiated in 1993, is aimed at providing experimental results on which to base silvicultural choices (natural evolution, conversion into high forest, coppice management) regarding the management of ageing holm oak coppices at more or less maximal density. The effects of reserve trees (from 50 to 250) on the development of seedlings and shoots during the first 2 years after coppicing are examined here. The treatments to be confronted are suitable for the new economic and environmental situations (national park) in which these holm oak coppices are found.

The wind storm that occurred in Gargano at the end of August 1994 (wind speed around 150 km·h), and the exceptional snowfall at the beginning of January 1995 (over 120 cm of snow with density between 0.25 and 0.30 g·cm^{-3}), offered the opportunity to value the mechanical resistance of studied stands to the meteoric events of extraordinary intensity.

2. MATERIALS AND METHODS

The holm oak coppice used for the present study is located in Monte S. Angelo (Promontory of the Gargano in southern Italy on a peninsula of the Adriatic coast). The holm oak stands cover about 2 500 ha. The coppice is found at an altitude of around 650 m a.s.l. on a slope with a southern exposure where calcareous outcrops frequently occur. According to the FAO classification, the soils belong to Chromic cambisols. The climate is of Mediterranean type, with precipitations close to 650–700 mm/year, high rates of atmospherical humidity and 3 months of summer aridity (sensu Bagnouls-Gaussen). The coppice is located on steep slopes (around 40 % inclination). The experimental plots delineated for this study were chosen in an ageing coppice around 45 years old which, during the summer months, was normally used as pasture land. The coppice was dominated by holm oak with a sporadic presence of flowering ash (*Fraxinus ornus*) and European hophornbeam (*Ostrya carpinifolia*). The traditional management had a short rotation period (15 years) and release of 60–70 reserve trees per hectare. Before the silvicultural interventions (February 1993), the holm oak stand had a high density of stems of resprout origin (mean stand density 6 300 stems/ha, of which about 70 reserve trees). The number of shoots per stump was 5.5. The diameter at breast height of shoots was 9.5 cm; basal area 44 m^2·ha^{-1} and volume about 200 m^3·ha^{-1}.

Undergrowth in the study area is represented mainly by *Asplenium onopteris*, *Asplenium trichomanes*, *Cyclamen neapolitanum* and *Ruscus aculeatus*, all species typically found in stands of holm oak.

The main objective of the study (in the long term) is to compare various types of management methods applied to ageing holm oak coppice.

The experimental design adopted is that of randomized blocks. The treatments compared are: *treatment A:* coppice with 50 even-aged (40 years old) reserve trees per hectare; *treatment B:* coppice with 250 even-aged (40 years old) reserve trees per hectare; *treatment C:* coppice with 140 uneven-aged reserve trees per hectare, of three different ages – 80 of 40 years and 60 from 55 to 70 years; *treatment D:* conversion into high forest, obtained with the release of a great number (about 2 000) of trees to gain a transition high forest; *treatment E:* natural evolution (control).

In February 1993, a total of 15 permanent plots were established (five treatments x three replicates). The plots were square in shape, each with a surface area of 1 600 m^2. They were separated from each other by a distance of around 10 m on all sides in order to avoid a 'border effect.'

Before cutting (i.e. the silvicultural intervention), the inventory of the tree populations in each of the 15 plots was taken. The height/diameter relationship was determined on the basis of measurements carried out on 100 trees, selected on the basis of representative criteria from among all the diameter classes. These trees have been used also to determine a single-entry volume table, showing the volumes and the fresh and dry weight of the trees up to 3 cm in diameter (excluding brushwood).

The choice of the reserve trees to be left standing was based on good development and shape of the tree (this criterion led to decreasing 'quality' as their number increased).

After coppicing (March 1993), all of the plots relative to treatments A, B and C were surrounded by barbed wire to protect the young shoots from free-roaming livestock.

In August 1993 a planimetric drawing showing the position of each reserve tree (*figure 1*) was made for each of the plots in which

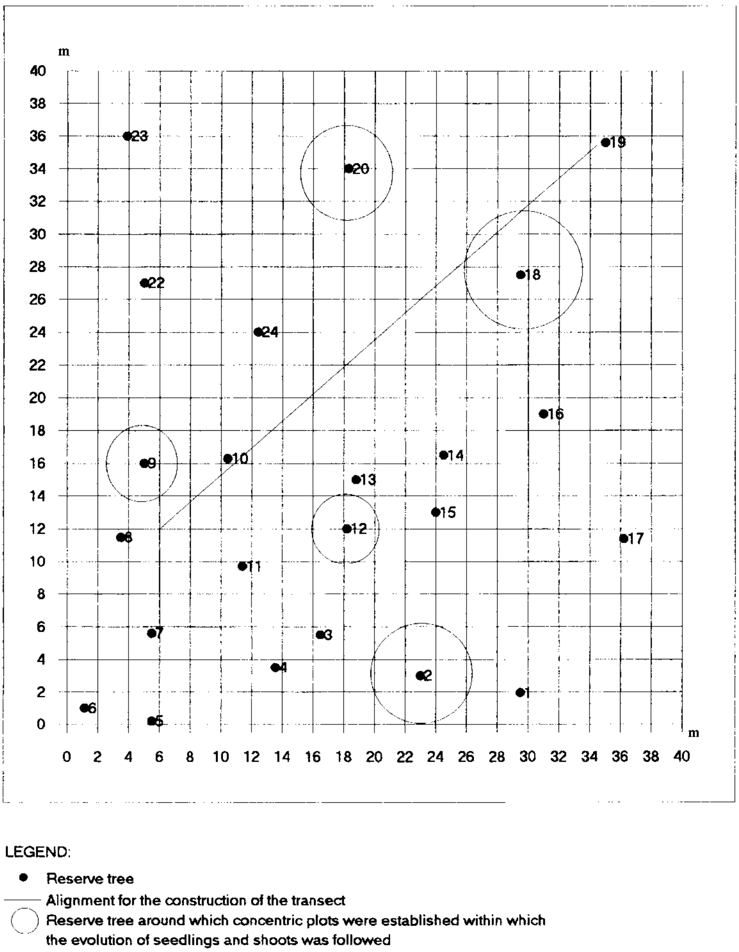

Figure 1. Example of the planimetric drawings showing the position of each reserve tree and the construction of the transect. This drawing is for management treatment C with 140 reserve trees per hectare, 80 of which have an age of one rotation period and 60 of two rotation periods.

treatments A, B and C were adopted. In each plot a transect diagonal with a NE–SW direction (20-m long and 1-m wide) was drawn and mapped. For each species, the positions of all the seedlings and stumps in each transect were indicated so that their evolution over the period of the study could be followed, including the effect of the shading potential of the reserve trees. In this regard, in the treatment plots A, B and C, 30 reserve trees of different ages were selected around which concentric plots were drawn, each having a radius up to three times that of the radius of the canopy of the reserve tree. A detailed inventory of the seedlings and shoots in these concentric areas was also made so that their evolution could be followed *(figure 1)*.

The data collected on the coppice after cutting concerned the seed and vegetative regeneration. The inventory on the seed regeneration was carried out both for the 20-m^2 transects and the concentric plots. In December 1993 and November 1994, various dendrometric features (collar diameter in mm and height in cm) were measured on all the seedlings present in the transects and in the concentric plots. In the course of the second sampling (November 1994), a check was also made to see if there were any new seedlings and whether any of the seedlings noted in the first sampling had died. The location of each seedling in the concentric plots was related to the projection of the canopy of the reserve tree. This was accomplished by specifying classes of distance from the edge of the projection of the canopy, each 1-m wide; the increasing distances outward from the edge of the canopy were indicated with positive numbers, while those under the canopy going inward towards the tree were indicated with negative numbers *(figure 2)*.

Data on vegetative regeneration were collected for all the stumps present in the transect and in the concentric plots. The number of stumps per hectare were determined, in August 1993, from the complete census of each plot. The position of each stump in the concentric plots was related to the projection of the canopy of the reserve tree, in order to evaluate any possible differences in growth or mortality of the shoots. In December 1993 and November 1994, the number of shoots per stump, the collar diameter of all the shoots and the total height of 15 shoots for each stump were determined. The sampling done in the 2nd year (November 1994) determined the mortality occurring among the shoots. In fact, in December 1993 all the shoots were marked at the base with indelible paint, so that it was possible to note on each stump if there were any new shoots from the growing season following the first.

3. RESULTS

The main dendrometric parameters before and after the cutting together with the entity of the mass removed are shown in *tables I, II* and *III* for each plot.

The analysis of variance (ANOVA) carried out on the data for the number of stumps, total number of shoots per ha and number of shoots per stump before the silvicultural intervention show that there were no significant differences in any of these parameters. The average values for the number of stumps, total number of shoots per hectare and number of shoots per stump are given in *table IV* for each treatment together with the relative statistical indices calculated from the collected data.

3.1. Construction of volume table

Using the measurements carried out on a sample of 100 trees, the following semi-logarithmic equation was employed to calculate the height curve *(figure 3)* of the sampling stand before the various silvicultural interventions:

$$H[\mathrm{m}] = 4.547468 + 1.786606 * \ln (D_{130})$$

where H = height and D_{130} = diameter at breast height in cm.

The volumes of the shoots taken in the sample are a function of their diameter at breast height (130 cm). The volume curve *(figure 4)* was calculated from the following model:

$$V[\mathrm{m}^3] = 0.00031 * (D_{130})^{2.10184}$$

where V = volume and D_{130} = diameter at breast height in cm.

This equation expresses the volume, including the bark, of the shoots (trees) in m^3 (with a 3-cm topping) as a function of their diameter at breast height, expressed in cm. The correlation coefficient obtained was very good ($R^2 = 0.967$).

Finally, the volume table *(table V)* was transformed into a weight determination table. The ratio between the weight of the timber and its volume was calculated for 300 samples collected from 100 trees at different heights (at the base of the tree,

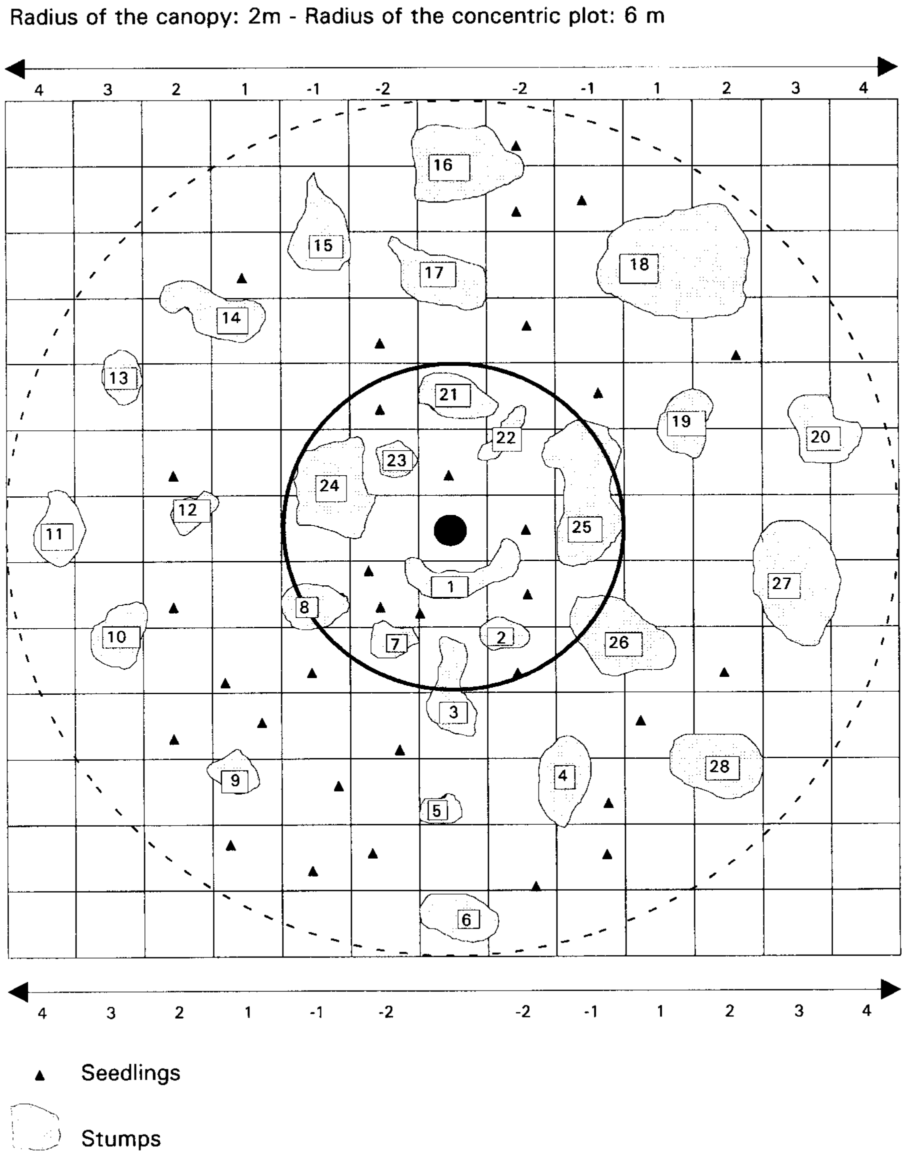

Figure 2. Planimetric drawing of a concentric plot around a tree where the location of each seedling and stump in the concentric plot is related to the projection of the canopy of the tree.

Table I. Main dendrometric parameters before and after adoption of the various treatments to be tested in the first block of plots (data per hectare).

Dendrometric parameters	Treatments				
	A (50 trees/ha) Plot 1.1	B (250 trees/ha) Plot 1.2	C (140 trees/ha) Plot 1.3	D (conversion) Plot 1.4	E (control) Plot 1.5
No. of shoots before intervent.	7 188	7 081	7 994	7 263	7 650
No. of shoots removed	7 138	6 831	7 854	4 838	0
No. of trees after intervention	50	250	140	2 425	7 650
No. of stumps	1 100	1 200	1 338	1 225	1 238
No. of shoots/stump	6.5	5.9	6.0	5.9	6.2
G before intervention (m^2)	38.95	39.64	45.37	45.69	53.06
G removed (m^2)	38.16	36.77	43.38	23.61	0
G after intervention (m^2)	0.79	2.87	1.99	22.09	53.06
Dg before intervention (cm)	8.31	8.44	8.50	8.95	9.40
Dg trees removed (cm)	8.25	8.28	8.39	7.88	—
Dg trees remaining (cm)	14.19	12.09	13.48	10.77	9.40
Volume before interv. (m^3)	190.72	194.41	222.69	225.46	263.10
Volume removed (m^3)	186.73	179.97	212.61	114.99	0
Volume after interv. (m^3)	4.00	14.44	10.08	110.47	263.10

G: basal area; Dg: average diameter.

Table II. Main dendrometric parameters before and after adoption of the various treatments to be tested in the second block of plots (data per hectare).

Dendrometric parameters	Treatments				
	A (50 trees/ha) Plot 2.1	B (250 trees/ha) Plot 2.2	C (140 trees/ha) Plot 2.3	D (conversion) Plot 2.4	E (control) Plot 2.5
No. of shoots before intervent.	5 163	4 581	4 556	5 313	5 781
No. of shoots removed	5 113	4 331	4 416	3 231	0
No. of trees after intervention	50	250	140	2 081	5 781
No. of stumps	1 144	956	831	1 069	963
No. of shoots/stump	4.5	4.8	5.5	5.0	6.0
G before intervention (m^2)	39.68	33.99	48.53	37.88	40.45
G removed (m^2)	38.39	30.62	45.20	16.01	0
G after intervention (m^2)	1.29	3.36	3.33	21.88	40.45
Dg before intervention (cm)	9.89	9.72	11.65	9.53	9.44
Dg trees removed (cm)	9.78	9.49	11.42	7.94	—
Dg trees remaining (cm)	18.15	13.08	17.41	11.57	9.44
Volume before interv. (m^3)	197.79	169.10	245.96	188.12	200.66
Volume removed (m^3)	191.11	152.00	228.60	78.03	0
Volume after interv. (m^3)	6.68	17.10	17.35	110.08	200.66

G: basal area; Dg: average diameter.

Table III. Main dendrometric parameters before and after adoption of the various treatments to be tested in the third block of plots (data per hectare).

Dendrometric parameters	Treatments				
	A (50 trees/ha) Plot 3.1	B (250 trees/ha) Plot 3.2	C (140 trees/ha) Plot 3.3	D (conversion) Plot 3.4	E (control) Plot 3.5
No. of shoots before intervent.	7 194	7 019	6 706	4 688	6 938
No. of shoots removed	7 144	6 769	6 566	3 100	0
No. of trees after intervention	50	250	140	1 588	6 938
No. of stumps	1 231	1 188	1 225	1 219	1 275
No. of shoots/stump	5.8	5.9	5.5	3.8	5.4
G before intervention (m^2)	45.27	47.47	46.97	44.69	52.56
G removed (m^2)	44.35	44.39	42.95	22.80	0
G after intervention (m^2)	0.92	3.08	4.03	21.89	52.56
Dg before intervention (cm)	8.95	9.28	9.44	11.02	9.82
Dg trees removed (cm)	8.89	9.14	9.13	9.68	—
Dg trees remaining (cm)	15.32	12.53	19.14	13.25	9.82
Volume before interv. (m^3)	223.36	235.11	233.05	225.24	261.82
Volume removed (m^3)	218.66	219.50	212.33	113.42	0
Volume after interv. (m^3)	4.70	15.61	20.72	111.82	261.82

G: basal area; Dg: average diameter.

Table IV. Average values for the number of stumps, total number of shoots and number of shoots per stump for each plot together with the relative statistical indices calculated from the data collected (data per hectare before application of the treatments).

Treatments	No. of stumps	No. of shoots/ha	No. of shoots/stump
A	1 158	6 515	5.6
B	1 115	6 227	5.6
C	1 131	6 419	5.7
D	1 171	5 754	4.9
E	1 158	6 790	5.9
Statistical coefficients			
Between treatments			
$F_{4/8}$	0.152	0.862	1.071
$F_{0.05}$	3.839	3.839	3.839
P	0.956	0.526	0.431
Blocks			
I	1 220	7 435	6.1
II	993	5 079	5.2
III	1 228	6 509	5.3
Statistical coefficients			
Between blocks			
$F_{2/8}$	8.531	13.630	3.510
$F_{0.05}$	4.459	4.459	4.459
P	0.010	0.002	0.080

G: basal area; Dg: average diameter.

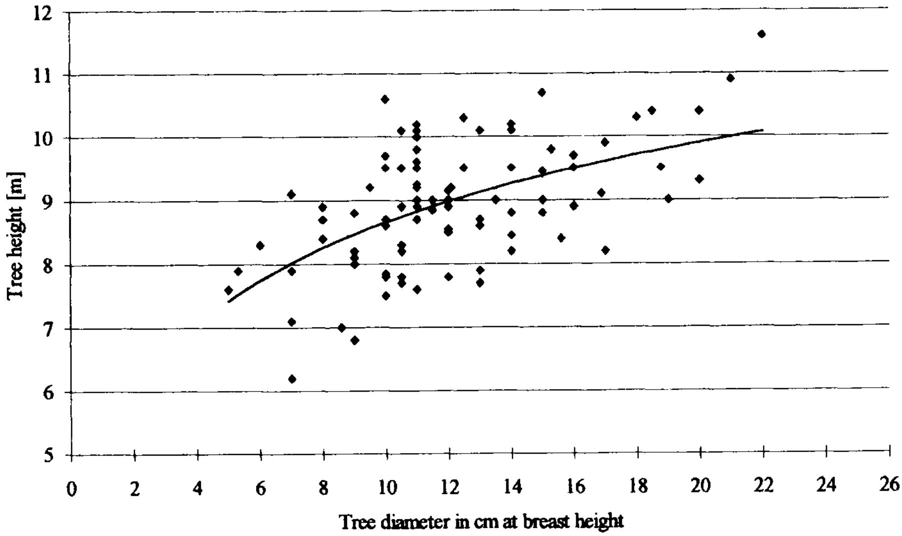

Figure 3. Relationship between diameter and height of the trees in the study site before adoption of the various treatments to be tested.

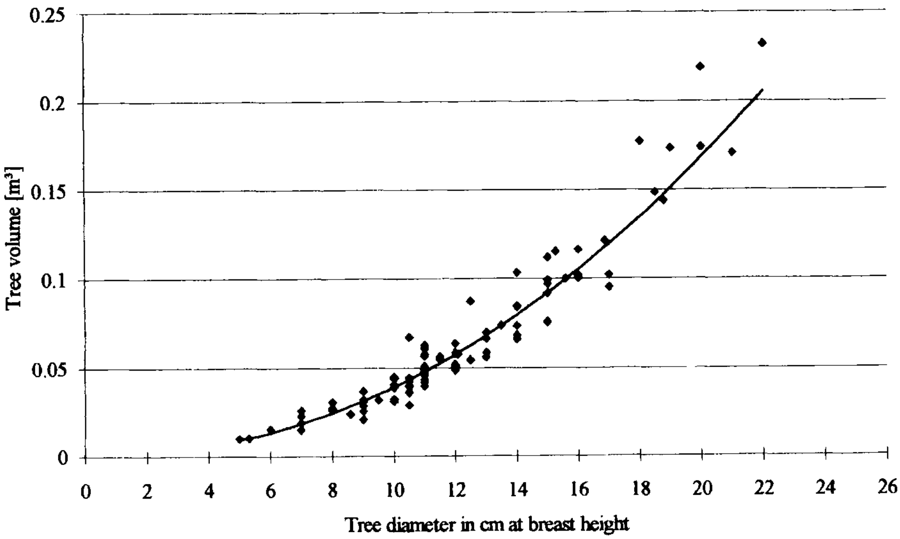

Figure 4. Relationship between diameter and volume of the trees in the study site before adoption of the various management methods to be tested.

Table V. Determination of the volumes and weights of the holm oak coppices in the locality of Inversa di Spigno (Monte S. Angelo, Apulia, Italy).

$D_{1.30}$ (cm)	H indicative (m)	Volume (m^3)	Fresh weight (kg)	Dry weight (kg)
5	7.4	0.009	11	7
6	7.7	0.013	15	10
7	8.0	0.019	22	14
8	8.2	0.024	28	18
9	8.5	0.031	36	23
10	8.7	0.039	46	29
11	8.8	0.048	56	36
12	9.0	0.058	68	43
13	9.1	0.068	79	51
14	9.3	0.079	92	59
15	9.4	0.092	108	69
16	9.5	0.105	123	78
17	9.6	0.120	140	90
18	9.7	0.135	158	101
19	9.8	0.151	177	113
20	9.9	0.168	196	125
21	10.0	0.186	217	139
22	10.1	0.206	241	154

D_{130}, diameter at breast height; H, height.

at half-height and at the top of the tree). Both the volumetric mass (ratio between fresh weight and fresh volume) and the basic density (ratio between the dry weight and the fresh volume) were calculated. The fresh weights were those measured on the same day as the cutting (February 1993), while the dry weights were those determined by drying the samples to constant weight in an oven at 85 °C.

The volumetric mass was 1.169 $g{\cdot}cm^{-3}$ and the basic density was 0.746 $g{\cdot}cm^{-3}$. The weight determination table *(table V)*, therefore, was derived from the preceding volume table simply by multiplying the volume values by 1 169 and 746, respectively. In this way, one obtains the fresh and dry weights expressed in kilograms as a function of tree diameter.

3.2. Gamic and vegetative regeneration

The data collected on seed regeneration made it possible to determine the mortality among seedlings, the number of seedlings per hectare in the various treatments during the first 2 years after the silvicultural interventions (together to preexistent seedlings). In addition to the seedlings recorded in the first years, approximately 1 000 were noted in the following year. ANOVA was conducted on all parameters considered. The number of seedlings per hectare, diameter at the collar and their height are shown in *table VI*. Mortality was found to be 11.0 % in treatment A, 13.5 % in treatment B and 7.3 % in treatment C. ANOVA showed significant differences ($P = 0.05$) in the number of seedlings between treatments A and C

Table VI. Number and growth in yield data of seedlings (average values per hectare) and relative statistical indices calculated from the collected data.

Treatments	No. of seedlings		Mortality	Collar diameter (mm)		Height (cm)	
	1993	1994	93-94	1993	1994	1993	1994
A	27 333	24 333	11.0 %	4.3	5.4	20.9	28.7
B	24 667	21 333	13.5 %	3.3	4.8	16.8	27.8
C	20 500	19 000	7.3 %	3.7	5.3	15.1	20.6
Statistical coefficients							
$F_{2/4}$	11.698	32.283	1.586	6.449	0.382	5.207	4.324
$F_{0.05}$	6.944	6.944	6.944	6.944	6.944	6.944	6.944
P	0.021	0.003	0.311	0.056	0.705	0.077	0.085

Table VII. Distribution of the seedlings as a function of their distance from the edge of the projection of the canopy of the tree (coppice age: 2 years in 1994).

Distance from edge of canopy (m)	Treatment A (seedlings/m^2)	Treatment B (seedlings/m^2)	Treatment C (seedlings/m^2)	Avg. of the 3 treatments (seedlings/m^2)
–3	3	0	2	2
–2	9	5	4	6
–1	9	7	5	7
+1	9	5	6	7
+2	6	7	6	6
+3	5	6	5	5
+4	4	6	5	5
+5	3	5	5	4
+6	2	2	1	2
Total [20 m^2]	49	43	38	43
Seed/m^2	2.43	2.13	1.90	2.16

in both the 1st and 2nd years, while no significant differences in the dimensions of the seedlings were found between the various treatments. The study on the presence of seedlings in relation to the distance from the canopy of the reserve trees *(table VII)* has so far revealed no significant datum. However, the greatest concentration of seedlings seems to be found (in all treatments) around the edge of the canopy.

The data collected on vegetative regeneration made it possible to determine the average diameter and height of the shoots and the number of shoots per stump in 1993 and 1994.

The average number of stumps per hectare, after cuttings, was found to be 1 108 for treatment A, 865 for treatment B and 991 for treatment C. After the silvicultural interventions, since treatments A, B and C differ in the number of reserve trees per hectare, clearly the number of stumps left for vegetative regeneration is obtained by subtracting the number of reserve trees from the total number of stumps.

Two years after the cutting, almost all of the stumps were found to have living shoots. Some stumps without living shoots (four stumps per hectare) were found only with treatment A. The number of shoots per stump, in 1994, was 35.8 for treatment A, 31.2 for treatment B and 27.8 for treatment C *(table VIII)*. About 35 % of the holm oak shoots present in the 1st year following felling died *(table IX)*. Generally, the dead shoots were found under the canopy and growing in anomalous directions. At the start of the second vegetative season, a fresh production of shoots occurred on the stumps (an average of about 11 shoots per stump). During the next survey these new shoots will be observed, with their modest dimension (the fact that they are dwarfed by other shoots), to determine whether they are in a condition to develop or are destined to fail.

Analysis of variance revealed that, at a distance of 2 years from coppicing, the number of shoots per hectare in treatment A is still significantly higher than that in other treatments, while there are no significant differences between the height of shoots and their diameters for the various treatments.

The data collected in the concentric plots made it possible to determine possible differences in diameter and number of shoots between the areas falling under the canopy of the reserve tree (shoots shaded by the tree) and those falling outside the influence of the canopy (free shoots). The total number of stumps surveyed in the 30 concentric plots was 364.

The processed data *(table X)* show that, where diameters are concerned, values slightly increasing from the trunk of the reserve trees outwards as far as the edge of the canopy projection, from the edge of the canopy outwards the findings take on a random character.

3.3. Damage from meteoric events

Table XI indicates the number of trees per hectare and the average diameter of the trees standing before the two meteoric

Table VIII. Number of shoots per hectare, number of shoots per stump, growth in yield data at 1st and 2nd years after the adoption of the various treatments (average values per hectare), together with the relative statistical indices calculated from collected data.

Treatments	No. of shoots/ha		No. of shoots/stump		Avg. diameter (mm)		Average height (cm)	
	1993	1994	1993	1994	1993	1994	1993	1994
A	40 553	39 666	36.6	35.8	8.1	13.5	71	132
B	27 680	26 988	32.0	31.2	6.7	11.6	55	112
C	30 325	27 550	30.6	27.8	6.6	11.9	59	120
Statistical coefficients								
$F_{2/4}$	8.319	22.049	2.340	11.552	1.686	1.793	0.667	0.686
$F_{0.05}$	6.944	6.944	6.944	6.944	6.944	6.944	6.944	6.944
P	0.038	0.006	0.212	0.022	0.294	0.278	0.562	0.554

Table IX. Mortality of 1-year-old shoots and new shoot production during the 2nd year.

	Treatment A			Treatment B			Treatment C		
	Shoot/ stump	Dead	Born	Shoot/ stump	Dead	Born	Shoot/ stump	Dead	Born
1993	36.6			32.0			30.6		
		13.1	12.4		11.2	10.5		10.9	8.1
1994	35.8			31.2			27.8		
Mortality		35.9 %			35.1 %			35.7 %	

Table X. Average number of shoots per stump ($No._{avg.}$) and average diameter of the shoots ($D_{avg.}$) at the different distances from the edge of the projection of the canopy of the trees for the various treatments.

Distance from edge of canopy (m)	Treatment A		Treatment B		Treatment C	
	$No._{avg.}$	D_{avg} (mm)	$No._{avg.}$	$D_{avg.}$ (mm)	$No._{avg.}$	$D_{avg.}$ (mm)
–3	50.7	14.1	0		58.2	12.9
–2	45.2	14.8	47.2	13.8	49.9	16.1
–1	42.4	18	44.4	14.5	48	17.1
+1	48.9	14.5	48.7	13.6	32.7	14.8
+2	50.2	15.8	49.2	13	39.6	14.2
+3	34.3	17	50.2	14	39.7	15.1
+4	26.5	16.6	31.3	16.8	42.7	14.1
+5	32.5	16.8	0		8.6	13.1
+6	28.4	24	0		21	16.9
Average	39.9	16.8	30.1	14.3	37.8	14.9

Table XI. Number of trees per hectare and average diameter ($D_{avg.}$) of the trees standing before two very severe meteoric events together with the total number, average diameter and percentage of trees uprooted or broken per hectare and the remaining number and average diameter of the trees per hectare after the said events.

Treatment	Before meteoric events		Trees damaged & uprooted					Remaining trees	
	No of trees	$D_{avg.}$	No. of trees	%	Average %	Dg	Vol. m^3	No. of trees	$D_{avg.}$
A	50	14.2	38	75.00		14.0		12	14.6
A	50	18.1	6	12.50	37.50	16.0	1.592	44	18.4
A	50	15.3	13	25.00		14.4		37	15.8
B	250	12.1	131	52.50		11.9		119	12.3
B	250	13.1	75	30.00	49.17	12.0	7.011	175	13.5
B	250	12.5	163	65.00		12.0		87	13.4
C	140	13.3	13	8.70		11.5		127	13.5
C	140	17.2	6	4.35	11.60	13.0	1.390	134	17.3
C	140	18.9	31	21.74		15.6		109	19.7
D	2 425	10.8	338	13.94		13.1		2 087	10.4
D	2 081	11.6	531	25.52	20.90	12.4	27.385	1 550	11.3
D	1 588	13.3	369	23.24		13.2		1 219	13.3
E	7 650	9.4	250	3.27		11.7		7 400	9.3
E	5 781	9.4	106	1.83	2.81	11.4	11.366	5 675	9.4
E	6 938	9.8	231	3.33		12.7		6 707	9.7

events cited earlier, together with the number of trees uprooted or broken per hectare and the remaining number of trees per hectare after the said events. The data show that the intensity of the damage varied considerably depending on the treatment chosen (number of reserve trees per hectare). In both absolute and relative terms, the greatest damage was found in the plots in which treatment B (250 reserve trees per hectare) was used. On the average, more than 50 % of the reserve trees were broken or uprooted, with an average volumetric loss of 7 $m^3 \cdot ha^{-1}$.

In the plots in which treatment A (50 reserve trees per hectare) was adopted, an average of 37 % of the trees were broken or uprooted during the two meteoric events. It should be pointed out, however, that this percentage of damage is mainly the result of that occurring in a single plot where the diameters of the trees were small (in this plot 75 % of the trees were damaged). The average volumetric loss is 1.59 $m^3 \cdot ha^{-1}$.

In both cases, treatments A and B, the damaged trees belonged to the lowest diameter classes. With respect to the average diameter of the trees in the individual plots, the damaged trees always had a lower diameter.

Damage in the plots where treatment C (reserve trees of different ages) was used also was relatively low (12 % of the trees), with a volumetric loss of 1.39 $m^3 \cdot ha^{-1}$.

The damage caused by the two meteoric events in the plots where treatments D and E (conversion to high forest and the control, in percent) were used was not high (20 % and 3 %, respectively, of the standing trees). In absolute terms, instead, the loss was of 413 unity (27.38 $m^3 \cdot ha^{-1}$) for the conversion into high forest and of 196 unity (11.37 $m^3 \cdot ha^{-1}$) for the control.

The height/diameter ratio of the broken trees ranged from 68 to 75, while that of the trees still standing ranged from 57 to 70. On the basis of these observations, in first approximation, the critical value of the height/diameter ratio for the shoots of holm oak is around 70.

4. DISCUSSION AND CONCLUSION

The emergence and growth of the seedlings took place chiefly in the year of cutting and during the first vegetative season of the coppice. The number of seedlings emerging in the course of the 2nd vegetative year proved to be rather small.

Regeneration from seed, which is still abundant in all treatments (on average there are over 20 000 seedlings per hectare), showed a significant correlation with the treatment used. In treatment A (50 reserve trees per hectare), a larger number of seedlings was noted as compared with the other treatments. A higher proportion of reserve trees, therefore, did not make for the emergence of a larger number of seedlings. Most likely, many reserve trees in the stand have a negative effect on the survival of the young seedlings, due perhaps to excessive shading. Little is known about the performance of holm oak seedlings as a function of the cover made by the canopy of the reserve trees, the latter being well spread out and stratified – insufficient research has been done on this point. Holm oak seedlings under cover from deciduous trees seem to have a fair resistance because they have the benefit of ample light during the winter [3]. As the experimental work proceeds a detailed study will be made of the influence of the canopy of the reserve trees on the mortality and dimensional development of seedlings.

Another interesting fact is the low mortality among seedlings emerging in the coppice with uneven-aged reserve trees. In this connection, certain authors [3, 18, 19] suggest that this form of management seems to favour the regeneration of holm oak, since cutting the trees releases a large amount of the acorns capable of germinating and becoming established.

Vegetative regeneration tends to regain upper-air levels very quickly. By the 2nd year, shoot height will exceed 120 cm, and contacts between the canopies of shoots from different stumps are already observable. In 2 years time, the shoots will be entirely under cover.

Coppices with fewer reserve trees have produced a greater number of shoots, the latter also having an average diameter and average height greater (though not to any significant extent) than in other treatments. A coppice with uneven-aged reserve trees produces the lowest number of shoots per stump, and the average diameters will be smaller.

At a distance of 2 years from the beginning of this research, therefore, it seems that, wherever a smaller number of reserve trees has been, more shoots have become established and vegetative regeneration has resulted in greater increments. Two years from coppicing it becomes clear that a high reserve tree-to-coppice ratio makes for excessive shading and does nothing to increase regeneration from seed.

It may be worth repeating, however, that the practice of leaving a large number of reserve trees inevitably entails accepting less rigour in the choice of trees to be left standing; and this can prove highly dangerous when one considers the damage to the coppice caused by poor weather conditions.

In conclusion, this study on management options conducted in a holm oak stand in the Gargano has made it possible, albeit in strictly provisional terms, to discern differences among the effects of the respective management practices.

The 'coppice problem' can, as a general rule, be approached via differing management formulas: coppice with reserve trees; conversion into high forest; and allowing natural evolution to proceed unhindered.

Apart from these considerations, this study represents a contribution to the task of acquiring an exact understanding of silvicultural techniques that are best suited to the achievement of a specific purpose, and of the effects of operations conducted in stands. Given the socio-economic conditions obtained in the tract of country considered, it is evident that coppice management for the production of fuelwood not only constitutes the traditional forest use in these parts but supplies a commodity for which there is still a market demand.

The holm oak coppice has undoubtedly been an important component of the Gargano landscape since ancient times. Coppices consisting of this species have been in centuries-long equilibrium with the environment – indeed, have characterized that environment. For this reason, too, even a partial return to this form of management is desirable. 'Every forest,' said Patrone, 'has its story.' Within the area now declared a national park, it is essential to respect history and to turn this history to good account. In any case, Framework Law No. 394/91, the Parks Act, creates incentives for, and in other ways promotes, traditional activities carried on by man in the tract of country that has been declared a park.

The results show that the holm oak coppice meets all the requirements for continuing with this form of management. The number of reserve trees to be left standing should also be governed by the shoot-bearing capacity of the stumps and by the abundance and frequency of acorn production. In this respect, the holm oak has excellent characteristics both in terms of agamic regeneration and in terms of fruiting.

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