

Growth effects of thinning operation in an umbrella pine (*Pinus pinea* L.) stand in central Italy

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Introduction

Intermediate cut is a practice during the period between seeding and maturity. It is done to improve the existing stand and regulate its growth without any effort directed at regeneration.

The main goals are enhancing ecosystem functioning and species diversity, increasing individual tree diameter, reducing water loss caused by interception of rainfall specially in environments more susceptible to drought, increasing net primary production, saving management costs, and mitigation of the effects of drought in the Mediterranean basin due to the climatic change (De las Heras et al. 2013, Mazza et al. 2011, Pasho et al. 2012, Seiwa et al. 2012).

In Italy currently the timber from first thinning in broadleaf stands has a developed firewood market (Lo Monaco et al. 2011, Picchio et al. 2011b), nevertheless in coniferous forests the thinning produces unappreciated materials, but with ascertained good energetic characteristics for fuelwood (Picchio et al. 2012c). Mechanized harvesting techniques have been increasingly improved productivity and reduced logging costs (Picchio et al. 2011b, Maesano et al. 2013). During thinning operations, logging injury to the remaining trees may lead to serious economic losses of timber quality at the final harvest. Behjou (2012) found a 39% loss of log values losses of damaged trees and tree growth reduction (Behjou & Mollabashi 2011, Vasiliauskas, 2001). The level of damage in residual trees, seedlings and timber products was significantly affected by the timber harvesting techniques. In spruce forests Eroglu et al. (2009) found in Turkey that the higher mechanization level is adopted lower are the damages to residual stand. Although equal stand conditions may often be difficult to replicate, Granhus & Fjeld (2009) have reached opposite conclusions, in multistoried spruce stands in southeast Norway. On the Mediterranean area few studies have been concerned with damage to remaining trees. Some studies have taken into account both coppiced and high forests, species and sites characteristics, different forestry treatment as well as machines and work methods which may have different impacts on the trees and on forest soil (Spinelli et al. 2010, Picchio et al. 2011a, 2012a, 2012b, Tsioras & Liamas 2011, Magagnotti et al. 2012, Pinard & Putz 1996). Kiser (2011) and Ezzati & Najafi (2009) observed that wounds inflicted during thinning operations deteriorate the timber quality and stated a loss of volume and value of timber. Nevertheless the interesting issue, few authors have studied the relationship between the damage and the radial growth. Picchio et al. (2011a) reported that no difference was recorded in growth between damaged and undamaged trees of *Pinus laricio* Poiret planted on hill of central Italy, in moist temperate climate. Umbrella pine (*Pinus pinea* L.) is one of the most important Italian Mediterranean pine. It has been cultivated traditionally for the production of both wood and pine nuts. On the Tyrrhenian coastline these plantations have assumed higher recreational and landscape value. This study aimed to evaluate the impact of thinning and the wound influence in terms of ring growth on the remaining trees 11 years after the operation in a typical Mediterranean pine plantation.

Materials and methods

During the winter 2000-2001 a first thinning was carried out in an Umbrella pine plantation, located at Riotorto in the municipality of Piombino (LI), Central Italy (Fig. 1). The thinning was

predominantly geometric, cutting a row every two, and selective on the row. The geometric scheme was not always met due to the presence of dead, unhealthy or poorly shaped trees.



Figure 1: The study area localization

For this reason the results were not uniform and different thinning intensities were observed. Based on the dendrometric data, detected during the survey in spring 2012, the area was divided into two particles due to the different tree density. Each particles was divided in two macro-plots characterized by different tree diameter at breast high (DBH) (Fig.2).

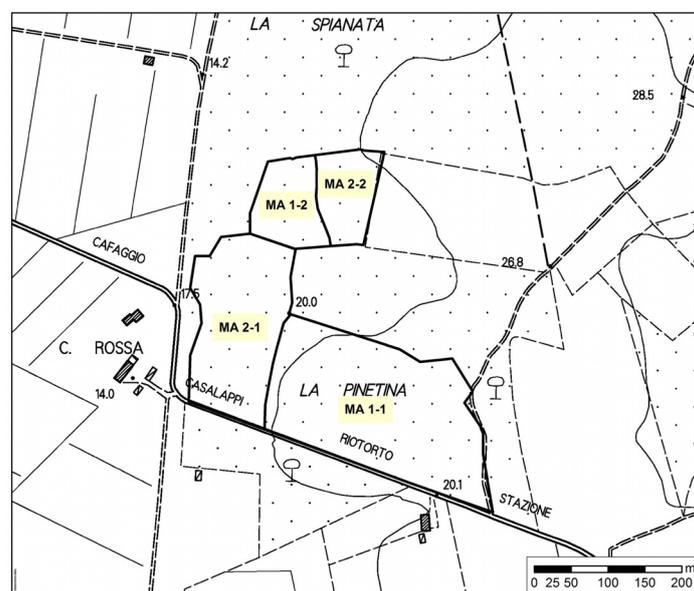


Figure 2: The particles and the macro-plots (MA1-1 and MA2-1 particle 1; MA1-2 and MA2-2 particle 2)

The macro-plots were subjected to different thinning intensity, ranged from 30 to 60 % of basal area removed. Logging operations were carried out with a semi-mechanized logging systems: felling was performed by chainsaw, extraction was by skidding with a tracked agricultural tractor driving in the inter-rows. The short wood system was applied.

Damages to standing trees were investigated in the thinned macro-plots in 2012. The following parameters were recorded (Concerted Action N° AIR3-CT94-2097, 1997): number of damaged trees, DBH; crown class, i.e. dominant, co-dominant, and dominated; type of damaged tissues, i.e.

bark, bast, wood fibres; cause of damage, i.e. felling or bunching/skidding; location of wounds; size of wounds. Trees damaged in several parts were classified on the basis of the most severe damage. The agent of damage (felling, skidding) was inferred on the basis of the position and size of the wound, following Picchio et al. (2011a).

Stem cores were collected at breast height, both in damaged and undamaged trees to evaluate the effect of thinning and injuries on radial growth. Ring width were measured and recorded by CATRAS (Aniol 1983).

Factorial ANOVA was applied to the ring widths, considering the growth year, the status of damage, and the combination of these, restricted to the last eleven years after the thinning. A t test for independent samples was applied to check differences between average ring width of the eleven years before and after the thinning, to check differences between average ring width of the eleven years before and after the thinning.

Results

In spring 2012 the survey showed different density in term of tree/ha and different average DBH (Tab. 1).

Table 1: The main dendrometric parameters of thinning

Macro Plot	Before thinning			After thinning			11 years after thinning		
	trees (n/ha)	DBH (cm)	Basal area (m ² /ha)	trees (n/ha)	DBH (cm)	Basal area (m ² /ha)	DBH (cm)	Basal area (m ² /ha)	Thinning intensity (%)
MA1-1	535	19.0±2.1	15.2	214	22.2±1.9	8.3	34.8±2.2	20.3	45
MA2-1	513	19.2±1.9	14.8	154	28.6±2.1	9.9	38.3±2.0	17.7	33
MA1-2	990	16.0±4.1	19.9	276	22.8±1.1	11.3	31.0±1.2	20.8	43
MA2-2	1109	17.1±2.8	25.5	276	20.0±3.1	10.5	27.5±1.8	19.8	59

Mortality after thinning was 6% and no statistical difference was recorded among the macro-plots. Damage frequency ranged from 9 to 14 % and wound severity was related with the higher frequency of wound occurrence (Tab. 2).

Table 2: Damage frequency and severity

Macro-plot	Damaged trees n./ha	Damaged trees %	Seriously wounded trees %
MA1-1	30	14	61
MA2-1	18	12	46
MA1-2	25	9	33
MA2-2	33	10	33

The main cause of the injuries inflicted to the trees, was due to felling operations, mostly in the plots with high trees density. The passage of tractor follows as cause of damage located at the base of the trees. The short wood system applied, although inappropriate to the type of intervention, is deeply ingrained in the practices of local workers, as common in Italy.

In order of evaluating the effect of injuries on radial growth, factorial ANOVA and t test were applied. In Parcel 1, on both macro plot 1 and 2, factorial ANOVA (Tab. 3) shows significant differences in "year" and "tree status", but not in the combination of these, in the last eleven years after the thinning.

Table 3: The effect of injuries on radial growth on parcell 1

Variable	Macro-plot MA1-1			Macro-plot MA2-1		
	Ring (n.)	fd	p-value	Ring (n.)	fd	p-value
Year	220	10	<0.01	220	10	<0.01
Trees status		1	<0.01		1	<0.05
Year x Trees status		10	>0.05		10	>0.05

In Parcel 2, factorial ANOVA (Tab. 4) shows significant differences only in "year" for macro plot MA1-2, but not in "tree status" and in the combination of these, in the last eleven years after the thinning. In macro plot MA2-2 there are no significant differences for each variables.

Table 4: The effect of injuries on radial growth on parcell 2

Variable	Macro-plot MA1-2			Macro-plot MA2-2		
	Ring (n.)	fd	p-value	Ring (n.)	fd	p-value
Year	43	10	<0.05	36	10	>0.05
Trees status		1	>0.05		1	>0.05
Year x Trees status		10	>0.05		6	>0.05

However the t test shows a significant increase of the average radial growth after the thinning in the parcel 1 - macro-plot 1 (MA1-1) and 2 (MA2-1) - (Tab. 5), and in the parcel 2 only in macro plot 2 (MA2-2) (Tab. 6). In macro plot 1 (MA1-2) of the parcel 2 (Tab.6) no-significant increase of average radial growth was observed.

Table 5: Parcel 1: t test on ring growth widths before and after the thinning in damaged trees

Macro-plot	Average growth after thinning	Average growth before thinning	fd	p-value	Rings number after thinning	Rings number before thinning
MA1-1	2.35	1.86	438	<0.01	220	220
MA2-1	2.5	2.28	482	<0.05	242	242

Table 6: Parcel 2: t test on ring growth widths before and after the thinning in damaged trees

Macro-plot	Average growth after thinning	Average growth before thinning	fd	p-value	Rings number after thinning	Rings number before thinning
MA1-2	2.51	3.04	64	>0.05	33	33
MA2-2	1.67	2.85	42	<0.05	22	22

Thus, significant differences in radial growth between damaged and no-damaged trees were not recorded. In order to better understand the effect of the thinning, the intensity was expressed as a percentage decrease of basal area due to the thinning (Tab.7). It is in some way proportional to the

percentage increase of the annual growth. At lower intensity of thinning, the radial growth decreases, while at higher intensity the DBH is significantly lower.

*Table 7: Thinning intensity and growth recovery expressed as basal area. *Note: only in this case, the t test shows a no-significant increase of the average radial growth after the thinning in parcel 2 macro-plot 1.*

<i>Macro-plot</i>	<i>Increased growth after thinning (%)</i>	<i>Thinning intensity (%)</i>
<i>MA1-1</i>	28	45
<i>MA2-1</i>	9	33
<i>MA1-2*</i>	20	43
<i>MA2-2</i>	64	59

The recovery in basal area was higher in the intensive thinned macroplots. The average DBH was higher in weakly thinned areas compared to the intensively thinned ones. The recovery of the total basal area in the macro plots indicates that the thinning intensity, which seems to provide the best results in terms of mass and stability of the stand, is around 45%.

Discussion

In 2012 differences in the main dendrometric parameters were found in the parcels and in the macro-plots and correspond in part to those that were found immediately after the thinning. After thinning the average DBH and height in the macro-plots increased and basal area decreased, as effect of thinning (Roberts and Harrington, 2008), due to the different number of stems and the cutting of the smaller diameter trees (Mäkinen and Isomäki, 2004).

The wounds were due to the felling operations and harvesting system (SWS). Similar results were observed by Magagnotti et al. (2012) reporting 5 % of wounded trees in a 35 year old pine stand removing 36% of trees, but the whole tree system were applied. Spinelli et al. (2010) and Picchio et al. (2011a) found damages to the 14 % of residual pine trees, but in pine plantations much more fertile, with basal area also double of that found in this study. Total injury (injured + dead) to saplings in a multistoried spruce stands in southeast Norway were observed to vary from 17 to 76% and with a mortality varying from 5 to 51% (Granhus and Fjeld, 2001). Tsioras & Liamas, 2010 in a mixed beech and oak stand observed that one fifth (19.7%) of the monitored trees were damaged. Eroglu et al. (2009) studied the impacts of timber harvesting techniques (manpower, skidder, and skyline) on residual trees, seedlings, and timber products in natural oriental spruce stands in Turkey. The degree of damage was significantly affected by the timber harvesting techniques, with more than 80% of the residual trees damaged by manpower and skidder harvesting techniques, but less than 35% of the residual trees by skyline method. Athanassiadis (1997) recorded residual stand damage during harvesting operations using a farm tractor in two conifer stands. Damaged tree percentage was up to 6.5%.

Behjou et al. (2012) highlighted that logging system and slope gradient had a significant impact on damages.

Growth effects of thinning injuries were not recorded, as noted in a Corsican pine (*Pinus laricio* Poiret) stand in central Italy (Picchio et al. 2011a).

The effect of the thinning, assessed as basal area, was revealed by the DBH that was higher in weakly thinned areas compared to the intensively thinned ones. Seiwa et al. (2012) obtained similar results in a *Cryptomeria japonica* plantation managed with different thinning intensity (33% weak thinned treatment, and 67% intensive thinned treatments).

Conclusions

- This study confirms the effect of thinning on growth rate for the considered period, although significant differences in radial growth between damaged and no-damaged trees were not recorded. However the quality of the final harvest will not be uniform.
- In addition, the macro-plot 2- parcel 1 (MA2-1) thinned with lower intensity, just eleven years after, the incremental effects are very low (about 9%). The macro-plot 1- parcel 2 (MA1-2) thinned with medium intensity, just eleven years after, the incremental effects are no statistically significant, compared to the previous period, in terms of average radial growth, due to the thinning that in this plot has released mainly dominant trees. In the macro-plot 2- parcel 2 (MA2-2) thinned with high intensity, just eleven years after, the incremental effects are statistically significant and they are very high (about 65%), compared to the previous period, in terms of average radial growth, due to the thinning that in this plot has released mainly co-dominant and rarely dominated trees. This is also the only case in which the average basal area did not reach the “before thinning” value.
- The percentage increase of the annual growth is in some way proportional to the thinning intensity.
- The recovery of the total basal area in the macro plots MA1-1, MA2-1 and MA1-2 indicates that the thinning intensity, which seems to provide the best results in terms of mass and stability of the stand, is around 45% of basal area. At lower intensity of thinning, the radial growth decreases, while at higher intensity the DBH is significantly lower.
- To limit damages on the remaining trees and to increase the positive thinning effect on the trees growth it is important a correct intervention planning supported by an appropriate logging system.
- Better understanding the effects of silvicultural operations can direct the management to a different intervention planning to limit damage to the remaining trees. Analyzing the injuries to the trees, management can judge whether and to what degree the actions undertaken have achieved the design expectations.

References

- Aniol, R.W. (1983): Tree-ring analysis using Catras. *Dendrochronologia* 1, 45–53.
- Athanassiadis, D. (1997): Residual stand damage following cut-to-length harvesting operations with a farm tractor in two conifer stands. *Silva Fennica* 31(4): 461-467.
- Behjou, F. K. (2012): Economic analysis on log damage during logging operation in Caspian Forests. *Journal of Forestry Research* 23 (4): 699-702.
- Behjou, F.K., Mollabashi, O.G. (2011): Selective logging and damage to unharvested trees in a Hyrcanian forest in Iran. *BioResource* 7 (4): 4867- 4874.
- De las Heras, J., Moya, D., Lopez-Serrano, F.R., Rubio, E. (2013): Carbon sequestration of naturally regenerated Aleppo pine stands in response to early thinning. *New Forests* 44:457–470.
- Eroglu, H., Öztürk, U. O., Sönmez, T., Tilki, F. and Akkuzu, E. (2009): The impacts of timber harvesting techniques on residual trees, seedlings, and timber products in natural oriental spruce forests. *African Journal of Agricultural Research* 4 (3): 220-224.
- Ezzati, S., et Najafi, A. (2009): Long-Term Impact Evaluation of Ground-Base Skidding on Residual Damaged Trees in the Hyrcanian Forest, Iran. Hindawi Publishing Corporation International *Journal of Forestry Research*. 2010: 1-8 doi:10.1155/2010/183735
- Granhus, A. and Fjeld, D. (2001): Spatial distribution of injuries to Norway spruce advance growth after selection harvesting. *Can. J. For. Res.* 31: 1903–1913.
- Kiser, J. (2011): Histochemical and geometric alterations of sapwood in coastal Douglas-Fir following mechanical damage during commercial thinning. *Silva Fennica* 45(4):729-741

- Lo Monaco, A., Todaro, L., Sarlatto, M., Spina, R., Calienno, L., Picchio, R. (2011): Effect of moisture on physical parameters of timber from Turkey oak (*Quercus cerris* L.) coppice in Central Italy. *For. Stud. China* 13: 276–284.
- Magagnotti, N., Spinelli, R., Guñdner, O., Erler, J. (2012): Site impact after motor-manual and mechanised thinning in Mediterranean pine plantations. *Biosystems engineering* 113: 140-147.
- Mazza, G., Amorini, E., Cutini, A., Manetti, M. C. (2011): The influence of thinning on rainfall interception by *Pinus pinea* L. in Mediterranean coastal stands (Castel Fusano-Rome). *Annals of Forest Science* 68:1323–1332.
- Maesano, M., Picchio, R., Lo Monaco, A., Neri, F., Lasserre, B. and Marchetti, M. (2013): Productivity and energy consumption in logging operation in a Cameroonian tropical forest. *Ecological Engineering* 57: 149-153.
- Mäkinen, H., Isomäki, A., 2004. Thinning intensity and growth of Scots pine stands in Finland. *Forest Ecology and Management* 201: 311–325.
- Pasho, E., Camarero, J. J., de Luis, M., Vicente-Serrano, S. M. (2012): Factors driving growth responses to drought in Mediterranean forests. *Eur. J. Forest. Res.* 131:1797–1807.
- Picchio, R., Magagnotti, N., Sirna, A., Spinelli, R. (2012): Improved winching technique to reduce logging damage. *Ecological Engineering* 47: 83– 86.
- Picchio, R., Neri, F., Maesano, M., Savelli, S., Sirna, A., Blasi, S., Baldini, S., Marchi, E. (2011a): Growth effects of thinning damage in a Corsican pine (*Pinus laricio* Poiret) stand in central Italy. *Forest Ecology and Management* 262(2): 237-243.
- Picchio, R., Neri, F., Petrini, E., Verani, S., Marchi, E., Certini, G. (2012b): Machinery-induced soil compaction in thinning two pine stands in central Italy. *Ecological Engineering* 47: 83– 86.
- Picchio, R., Spina, R., Maesano, M., Carbone, F., Lo Monaco, A. and Marchi, E. (2011b): Stumpage value in the short wood system for the conversion into high forest of a oak coppice. *Forestry Studies in China* 13(4): 252-262.
- Picchio, R., Spina, R., Sirna, A., Lo Monaco, A., Civitarese, V., Del Giudice, A., Suardi, A. and Pari, L. (2012c): Characterization of woodchips for energy from forestry and agroforestry production. *Energies* 5(10): 3803-3816.
- Pinard M.A. Putz F.E. (1996): Retaining biomass by reducing logging damage. *Biotropica* 28(3): 278-295.
- Roberts, S.D., Harrington, C.A. (2008): Individual tree growth response to variable density thinning in coastal Pacific Northwest forests. *Forest Ecology and Management* 255: 2771–2781.
- Seiwa, K., Eto, Y., Hishita, M., Masaka, K. (2012): Effects of thinning intensity on species diversity and timber production in a conifer (*Cryptomeria japonica*) plantation in Japan. *J. For. Res.* 17: 468–478.
- Spinelli, R., Magagnotti, N., Nati, C. (2010): Benchmarking the impact of traditional small-scale logging systems used in Mediterranean forestry. *Forest Ecology and Management* 260: 1997–2001.
- Vasiliauskas, R. (2001): Damage to trees due to forestry operation and its pathological significance in temperate forests: a literature review. *Forestry* 74 (4): 319–336.
- Tsioras, P. A. and Liamas, D. K. (2011): Hauling damages in a mixed beech oak stand. FORMEC 2010 Forest Engineering: Meeting the Needs of the Society and the Environment July 11 – 14, 2010, Padova – Italy.