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THE FIRST YEAR RESULTS OF A SUBSTITUTION PROCESS IN TWO HORNBEAM COPPICES FROM NORTHERN ROMANIA

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Abstract: *This paper describes the results achieved in two hornbeam coppice stands one year after the beginning of the substitution process in bands. The bands created by harvesting the hornbeam sprouts were planted with European beech, sessile oak and pedunculate oak seedlings using a diamond planting scheme with a density of about 1000 seedlings per hectare.*
The assessment of planted seedlings' state at the end of the first growing season shows a good development especially for pedunculate and sessile oak seedlings which were obtained in nursery and some development difficulties in the case of beech (about 34% of beech seedlings died in the first year) which were taken from natural regeneration. Additionally, some technical recommendations are presented for a successful application of the substitution process in bands.

Key words: *forest substitution, coppice conversion, afforestation.*

1. Introduction

Substitution is a method of ecological restoration that involves replacing the inappropriate species in stands composition (considering their ecological requirements) with species able to better valorize the site conditions [1]. The improvement of the forest state is a traditional practice in Romanian forestry, numerous studies being focused on the improvement of the substitution process. Thus, Marcu [8], Hanganu [6], Lupe [7] and Popa [10] brought important contributions to the substitution of low productive forest stands. Dănescu et al. [3] studied the importance of forest site analysis for the appropriate substitution of the black locust (*Robinia pseudoacacia* L.) stands in the forest steppe. Ştefănescu [11] and Urechiatu [13] analyzed the substitution of degraded European beech stands and the stability of the stands arising from the substitution thereof.

Other studies have been directed towards technical descriptions of the substitution process. Therefore, Petrescu [9] shows the way in which plantations and seeding are to be carried out under the canopy, Dămăceanu [2] and Ştefănescu [12]

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describe the technique of substitution through plantations and seeding in gaps or in corridors and Hanganu [6] talks about the technique of plantations and seeding after clear cuttings.

1. Objectives

The goal of this paper arose from the need to adapt the technique of the forest substitution process to the local peculiarities of species corresponding to natural forest types. Thus, this article aims: *i*) to describe the results obtained after one year from beginning of the substitution process in stripes of two hornbeam coppice stands, *ii*) to identify the difficulties of seedlings development (introduced in place of hornbeam) with respect to species and *iii*) to outline practical recommendations for a proper implementation of substitution in stripes for similar situations to the ones under analysis.

3. Material and Methods

Through the analysis of management plans of the forest districts Pătrăuți and Adâncata (Suceava Forest Department, Romanian Forest Administration) (Figure 1), the hornbeam-dominated stands (the hornbeam has at least 80% in stand composition on basal area) were identified.

Selection then went on in regard with the regeneration type and stand age and thus two similar coppice stands were identified (one in each forest district) in which hornbeam has a higher share. Both selected coppice stands went through illegal cuttings shortly after forest ownership restoration in 1996. In these coppices (the) hornbeam is regenerated from sprouts and accounts for over 90% in the composition, taking the place of European beech and oak improperly harvested.

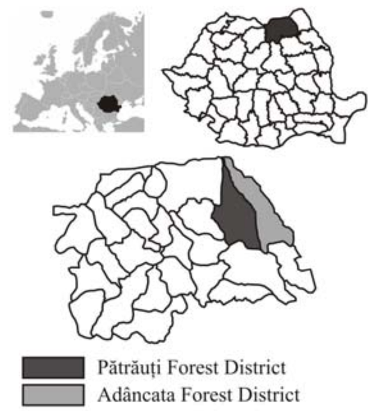

Fig. 1. *Study location*

In February 2011, in the selected coppice stands, two experimental plots were installed (Table 1).

In both experimental plots the hornbeam was extracted in stripes whose width varies between 4 and 7 m. The width of the stripes was determined according to the average height of hornbeam sprouts.

When the stripes were positioned, the azimuth of the sample plot was taken into account, together with the overall aspect, slope and water supply capacity of the soil. Considering these, the stripes were positioned as follows:

- from NE to SW in the Adâncata (*AD*) sample plot, as the slope is 0°;
- from east to west in the Pătrăuți (*PT*) sample plot due to the southern slope, in order to reduce the water loss through evapo-transpiration and drainage on slope.
- In the created stripes, small seedlings (h ≈ 0.4 m) were planted. The same afforestation composition was used in the stripes of both sample plots: 40% European beech (*Fagus sylvatica* L.), 40% sessile oak (*Quercus petraea* Mattuschka) and 20% pedunculate oak (*Quercus robur* L.).

Table 1

The main characteristics of selected stands before installing the sample plots

Plot name	Adâncata (*AD*)	Pătrăuți (*PT*)
Area [ha]	1,0	1,0
Forest district	Adâncata	Pătrăuți
Production unit	VI	III
Stand	34%	30A%+30C%
Elevation [m]	405	400-420
Aspect	-	South
Slope [°]	-	12
Regeneration type	Coppice	Coppice
Stand age [years]	15	15
Stand composition*	98%*HB*, 2% other species	94% *HB*, 6% other species
Average *dbh* [cm]	3,9	4,0
Average height	5,4	5,5
Number of *HB* trees per hectare	26030	22410

* *HB* – hornbeam (*Carpinus betulus* L.); other species: beech (*Fagus sylvatica* L.), sessile oak (*Quercus petraea*), aspen (*Populus tremula* L.), birch (*Betula pendula* Roth.), willow (*Salix caprea* L.);

The European beech seedlings were taken from natural regeneration of adjacent stands, and those of sessile oak and pedunculate oak were obtained in nurseries. The planting scheme is shown in Figure 2, and the density of the planted seedlings in the stripes is:

- 450 trees per hectare in the *AD* plot (or 918 trees per hectare if the inner-stripes are excluded);
- 468 trees per hectare in the *PT* plot (respectively 1074 trees per hectare).

The planting distance from the remained hornbeam inner-stripes was determined with respect to the width of the stripe (Table 2). Considering this distance and the width of the stripe, the planting distance (*a*) between the two outer seedling lines of the stripes was determined (Figure 2). The planting scheme was conceived considering the shade tolerance of the species from the target composition. The European beech seedlings were placed in the shaded part of the stripe (to reduce the effects of exposure to sun), and the sessile and pedunculate oak seedlings were placed in the sunlit part (Figure 2):

- in the *AD* plot the line with European beech seedlings was placed on the north-eastern side of the stripe;
- in the *PT* plot, the European beech line was located on the southern side of the band.

In September 2011, the state of the planted seedlings was assessed and the results are presented.

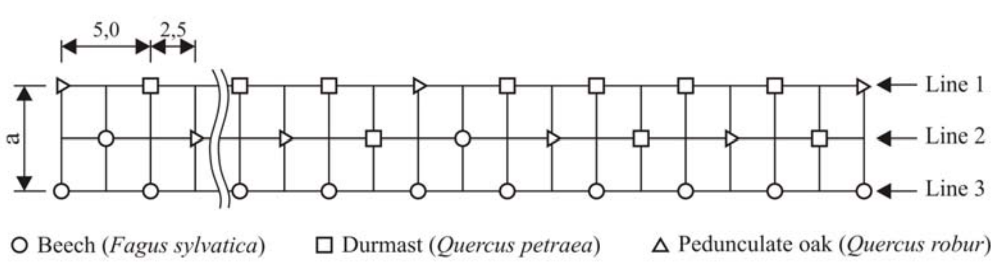

Fig. 2. *The planting scheme used in the bands*

Planting design in the bands Table 2

Width of the band [m]	Number of bands in plot area …		Length of the bands in plot area … [m]		Planting distance from the hornbeam inner-bands [m]	Distance (*a*) between the seedlings from the exterior lines of the band [m]
	AD	*PT*	AD	PT		
4	1	3	175	66	0.5	3.0
5	1	3	175	66	0.6	3.8
6	2	3	175	66	0.8	4.4
7	1	3	175	66	1.0	5.0

4. Results and Discussions

The distribution by species of the planted seedlings is: 366 European beech seedlings, 366 sessile oak and 186 pedunculate oak seedlings. Their distribution in the two plot areas was the same and it depended on the afforestation composition described above.

At the end of the growing season the development state of planted seedlings was assessed, and the main results are presented in Figure 3.

The biggest losses were recorded in the *PT* plot, where 21.4% of planted seedlings dried compared to the *AD* plot where only 17.8% of planted seedlings dried.

In both plots the biggest losses were recorded by European beech (33.9% in *AD* plot and 34.9% in *PT* plot). Although it is a shade tolerant species and should be favoured by protection of remaining hornbeam trees in the inner-stripes, the beech recorded significant losses probably due to the fact that it was taken from natural regeneration. Unlike the sessile and pedunculate oak seedlings taken from the nursery, the European beech seedlings received a long time protection from the mature stands. The transplantation and the significant change in site conditions caused significant loses to beech seedlings. The main reason for drying was caused by exposure to sun.

Oak species behaved very well in the first year after planting, out of the total number of seedlings planted in both sample areas there were identified 89.3% healthy sessile oak seedlings and 91.9% pedunculate oak healthy seedlings. Thus, the pedunculate oak has recorded the lowest losses and it was observed that these losses are correlated with the stripe width for all the analysed species. These aspects are more obvious for the *AD* plot. Here the pedunculate oak has recorded no losses and, in the case of European beech and sessile oak seedlings, it was found that losses were reduced with increasing stripe width, and consequently with the planting distance from hornbeam inner-bands (see Table 2), thus:

- from 44.4% (stripe width of 4 m) to 22.2% (7 m stripe wide) for European beech seedlings;
- from 22.2% (stripe of 4 m) to 5.6% (7 m) in the case of sessile oak seedlings.

In the *PT* plot, these aspects are less obvious in the case of European beech. Here the losses increased with the stripe width increase from 4 to 6 m, while in the case of 7 m stripes losses have dropped below those recorded in stripes of 4 m.

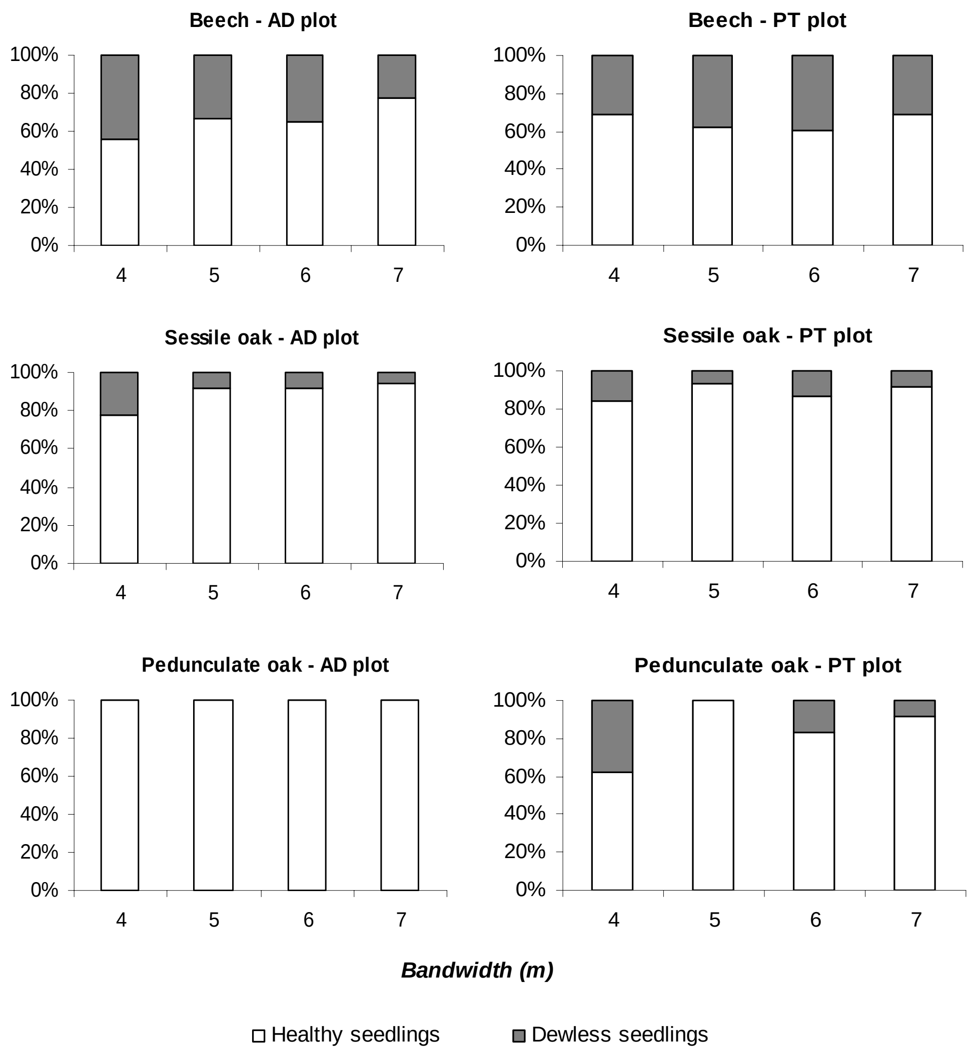

Fig. 3. *The response of planted seedlings to local site conditions*

In the case of sessile oak the results are similar to the ones from *AD* plot: the number of seedlings which dried being reduced with the width of the stripe increase from 15.6% in stripes of 4 m to 8.3% for the 7 m ones. In the *PT* plot, the pedunculate oak recorded significant losses of (15.6% of seedlings dried), but the amount of these losses is reduced by increasing the width of the stripe.

In the *PT* plot, both in the case of sessile and pedunculate oak, there are deviations from the trends reported for the 5 m wide stripe in the sense that here the losses are much lower compared to 4 and 6 m stripes.

This is due to some local peculiarities of the original hornbeam coppice stand in the 5 m stripe, which had a fluctuating canopy closure and gaps that led to changes in structural parameters needed for this study.

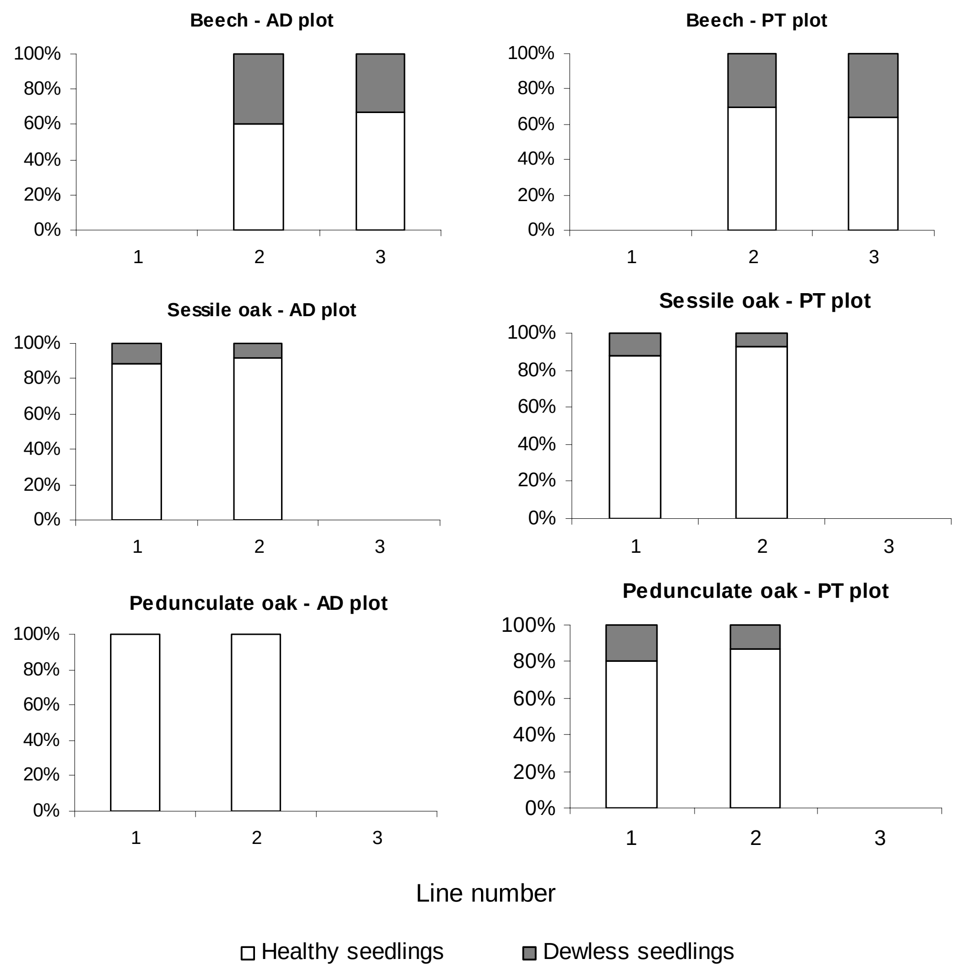

Fig. 4. *The influence of line location inside the band on the surviving rate of seedlings*

Differences between the obtained results in the two sample plots are due to the specific features of the plots described in Table 1 and, corroborating with this, to the different way the stripes were located:

- in the *AD* plot the field is horizontal and the stripes were located from NE to SW. Thus, the radiation penetration was allowed only during the midday;

- in the *PT* plot the field is sloping therefore the water supply for seedlings is reduced on the one hand due to drainage on slope and, on the other hand, due to the field aspect that facilitates the evapo-transpiration. For this reason the stripes were located from W to E, but the seedlings benefited from a higher amount of light and heat compared with *AD* plot.

The response of seedlings was then analyzed according to the position of the line (inside the stripe) where they were planted (Figure 4). It is clear that line 1 receives the largest amount of radiation, and line 3 is the most shaded (see Figure 2).

Except for the beech, in the *PT* plot it was generally found that the number of healthy seedlings increases according to the more protection they get from inner-stripes trees. In the case of sessile and pedunculate oaks, which were planted only in lines 1 and 2, higher losses were recorded in line 1.

In the case of European beech, which was planted only in lines 2 and 3, there are differences between the two sample areas: in the *AD* plot, higher losses were recorded in the central line and fell in the third line where seedlings were less exposed to sun; however, in the *PT* plot, the biggest losses were recorded in the third line.

It thus confirms those noted above: in the case of European beech the general aspect of the slope and the orientation of the stripes influence the success of plantation. Additionally, the shade management is important for the growth of beech seedlings which is lower in dense shelterwood [4]. Also, in the case of *AD* plot, it was confirmed that it was a good choice to plant oaks in sunny lines of the stripes and beech in shaded stripes. Thus, the experience that the seedlings from the central lines of the stripes (in pure plantation) are most vigorous [2], [12] was considered. There were also considered the findings of Gubka [5] who showed that, after plantation, the biggest losses of sessile oak seedlings occurred on the southern site edges.

5. Conclusions

Given the results it might be recommended for the horizontal fields in the studied area that the substitution process of young hornbeam coppice stands should be made by placing stripes from NE-SW. The sessile and pedunculate oak should be planted on the sunny lines of the stripe and the European beech on the shaded line. For better success, the European beech seedlings in the central line may be replaced with pedunculate oak.

For land with southern aspect, if stripes are located from E to W, the seedlings in the sunny side of the stripe suffer from too much light and heat, while seedlings in the shaded side suffer from lack of ecological factors mentioned above. For this reason this study should be completed with an analysis of how the seedlings of the three species behave in completely uncovered field and under shelter. In addition, further clarification through new case studies will be necessary to determine the most appropriate direction of stripes in fields with various aspects.

As for the width of the stripe it was found that best results were obtained in stripes of 7 m width. Moreover, greater stripe width and greater planting distance from the hornbeam inner-stripes in the *PT* plot have reduced shading in the line of European beech and brought a much better success rate of the plantation. However, it is recommended that the stripe width should be about 1.3 times higher than the average height of the coppice stand to be substituted. It is also advisable that the planting distances related to the inner-stripes should be greater in the shaded side of the stripe compared with the sunny one. When adopting the stripe width, the further development of species in the inner-stripes must be taken into consi-deration. If the height growth of these species is more active, the stripe width will be greater and the number of tending works will be higher both in stripes and inner-stripes. Since it was found that European beech seedlings taken from natural regeneration suffer a major transplanting stress (especially due to the change of shelter conditions), it is advisable to collect them from larger gaps in the regenerating stands, where the seedlings have access to light in a similar manner they have in the stripes where they will be planted.

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