

PhD thesis

**ROLE OF THE BREEDING IN GROWING-IMPROVEMENT OF THE LEUCE-
POPLAR STANDS GROWING UNDER SANDY SOIL CONDITIONS**

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1. THE AIMS OF THE RESEARCH

Leuce-poplars, above all the white poplar (*Populus alba* L.) and its natural hybrid, grey poplar (*Populus x canescens* SM.) are native stand-forming tree species in Hungary. They are covering 3.4 per cent of the total forested area (64 000 ha).

More than 80 per cent of their stands and plantations can be found on calcareous sandy sites on the Danube-Tisza region, so they play a significant role in the poplar growing of this part of the country.

The white poplar (*Populus alba* L.) was one of the dominant tree species in the Great Hungarian Plain in the past centuries. The control of the rivers, drainage as well as the agricultural production covering more and more lands in the sandy area between rivers Danube and Tisza have caused a drastic decreasing of white poplar's habitat. The white poplar – like the black locust (*Robinia pseudoacacia* L.) – played a significant role in the sand fixation and in the forestation of the region. Leuce-poplar stands are significant not only from forestry but from nature conservation point of view as well. Their stands establish associations with large ecological stability which provide habitat for several protected plant and animal species. They have a significant role in the field of afforestation on salt affected soils since they are able to tolerate the mildly salted heavy soils and the mildly, salty groundwater too. Due to the unchanged seed collection method – seed collection from felled trees – done in the late decades the stands with high genetic value disappeared, which have caused a genetic degradation in the case of Leuce-poplar stands growing under sandy soil conditions. In the course of the investigation it was important for us to select new clones that have good stem form and yield properties and could be suitable for wood production.

During my research the aim was to prove the more favourable yield and stem form properties of promising Leuce-poplar clones produced by micropropagation method and which are suitable for growing under marginal site conditions compared to common white poplar seedlings. On account of official recognition of the promising Leuce-poplar clones the Leuce-poplar cultivar assortment suitable for wood production under marginal site conditions can be expanded.

2. ANTECEDENTS OF THE RESEARCH

Having regard to the antecedent of the research we have to go back until 1974. The research connected to the clone selection of 25 Leuce-poplar hybrids made by our excellent poplar breeder, Ferenc Kopecky have been started in the nursery of Forest Research Institute in Kecskemét at this time. From this collection the most promising species have been continually selected mainly on the basis of their phenotype, height and diameter growth, root emergence, health conditions as well as their tolerance against the extreme sites. The primary aim of the research was to prevent the genetic degradation of Leuce-poplar stands growing under sandy soil conditions between in the rivers of Danube and Tisza. Provenance and variety comparison experiments have been established with clones having the best properties.

3. METHODOLOGY OF THE RESEARCH

In the course of my research I have done the continuous stand survey and detailed evaluation of two variety comparison clone trials (in subcompartment Kecskemét 40A). Besides I also have done the evaluation of a variety comparison clone trial established earlier in subcompartment Szentkirály 40G (*table 1*). The evaluations included not only the growth test but for the health condition of every clone and the analysis of stem quality as well. Besides the stand survey I have done biometrical (statistical) analysis (analysis of variance, discriminant analysis) and annual ring analysis as well.

Table 1. System of the investigated clone trials

| Trial Features | Szentkirály 40G | Balotaszállás 84L | Kecskemét 40A Blokk I. | Kecskemét 40A Blokk II. |
|-------------------------|--|--|--|--|
| Type of trial | Variety comparison clone trial | Native poplar gene collection | Variety comparison clone trial | Variety comparison clone trial |
| Planting time | 1988 | 1987-1991 | 2004 | 2005 |
| Clones | 'Villafranca', white poplar, H-758, H 422-9, H 427-3, H 425-4, | Selection of plus-trees: B-4, B-10, B-25, B-31, B-50 | White poplar, B-10, B-25, B-31, Sz-1, Sz-3 | White poplar, B-31, Sz-3, <i>P. hupehensis</i> K-1, <i>P. alba</i> K-2 (selected in China) |
| Wholetree survey | 1991, 1992, 1993, 1995, 1997, 1998, 2003 | 1997, 1998, 2005 | 2004, 2005, 2006, 2007, 2009, 2010, 2011 | 2006, 2012 |

The late variety comparison clone trials were established in the Danube - Tisza interflow region in spring 2004 and in autumn 2005. According to classification of forest site types, the main ecological characteristics of the studied areas are the following: forest steppe climate zone; humidity of the air is less than 50% in July at 2 pm; during the period at the test area the annual precipitation is between 263.8-560.3 mm, hydrology: free draining; genetic soil type: humous sandy soil with very shallow rootable depth. The latitude and longitude coordinates of the experimental area are *N* 46.883547, *E* 19.588868 (Figure 1).

In the clone trials the clone *H-325* (*P. alba* x *P. grandidentata*), *H-337* (*P. alba* x *P. grandidentata*), *H-384* (*P. alba* x *P. grandidentata*), *H 425-4* (*P. alba* x *P. alba*), *K-1* (*P. hupehensis*), *K-2* (*P. alba* x *P. alba*) as well as white poplar (*P. alba* L.) as control can be found. The experiments were set up with one-year-old micropropagated plants (in case of the clones) and one-year-old seedlings (in case of the control). A randomised block system with three replications was used. The initial spacing was 2.5 x 2.0 m, 30 and 60 plants were planted in every replication. The total experimental area was 0.43 and 0.59 ha.

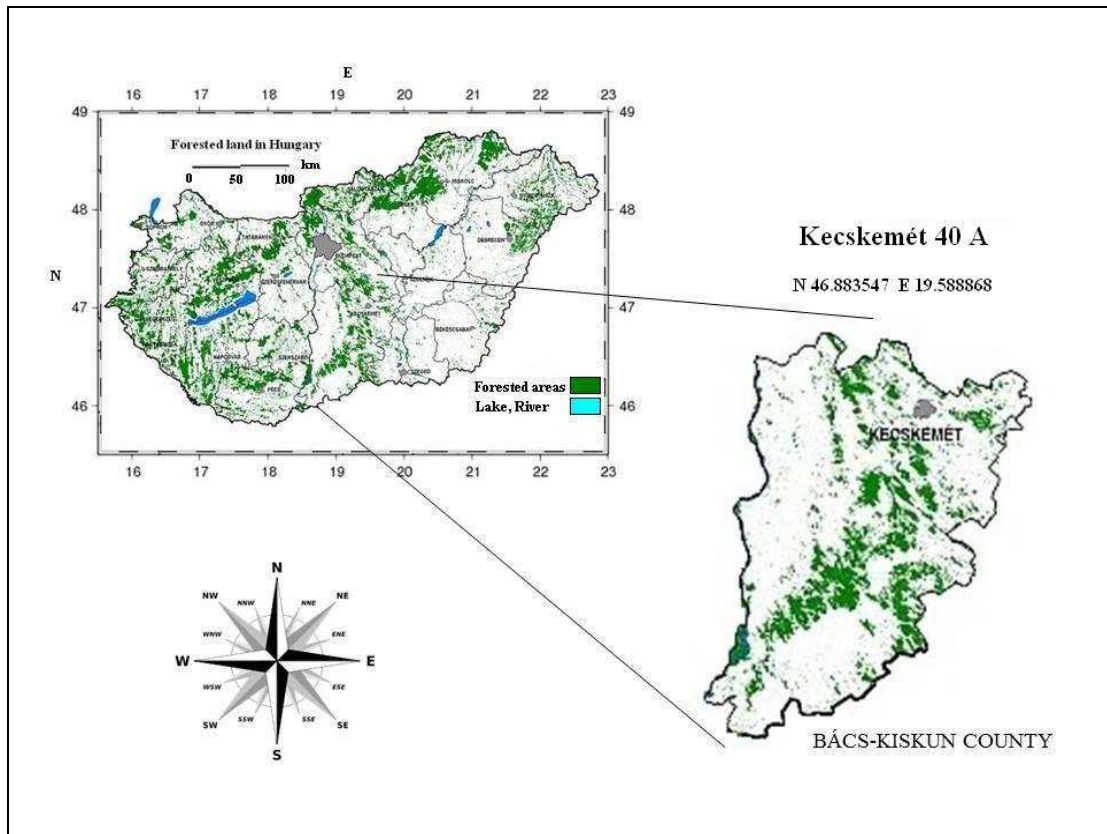


Figure 1. Location of the experimental areas

In the course of the stand-survey we used the so-called whole-tree survey method. The advantage of this method, that it provides an exact value regarding the yield of the given experimental area against with the different estimation methods. The used instruments were the follows: digital tree calliper and ‘Vertex Forestor’ altimeter.

After measurements for calculations the yield of single trees the Király numerical volume function was applied by me. The formula of the Király numerical volume function is the following:

$$V = \frac{d^2 \cdot h^{k+1}}{(h-1,3)^k \cdot 10^8} \cdot (p_1 \cdot d \cdot h + p_2 \cdot d + p_3 \cdot h + p_4)$$

where V is the yield of the measured tree (m³),

d is diameter at breast height (cm),

h is tree height (m),

k, p₁, p₂, p₃, p₄: different parameters requiring to the estimate.

k=4, p₁=-0.42364, p₂=12.43, p₃=4.6, p₄=3298

In the course of my statistic analysis I used the analysis of variance and the discriminant analysis. The collected data were analyzed by IBM SPSS STATISTICS 20 programme. Analysis of variance was done on the basis of data of height and diameter (diameter at breast height), since these parameters are highly correlated with the mean tree volume. The annual ring analyses were done by Digitalpositionimeter Type 2 annual ring analyser that can be found in Püspökladány Experimental Station of Forest Research Institute (*Figure 2*).

In the case of sample trees to make analysis I used discs cutted at the diameter in breast height because it is the most specific segment of a given sample tree for the measuring of the diameter growth (*Figure 3*). The annual ring analyses were done after drying and burnishing of the discs.



Figure 2. DIGITALPOSITIONIMETER Type 2
annual ring analyser

The investigations were made seven times (2004, 2005, 2006, 2007, 2009, 2011, 2012) by us. I have investigated the following stand parameters: stem number (surviving stems), dbh. (diameter at breast height), tree height, mean tree volume, health condition and stem quality.

To determine tree quality, the *stem quality index* was defined, by using the following stem quality classes:

1. *Class 1* - The stem is straight, cylindrical, healthy and reaching the top of the crown. Crooks are tolerated in one dimension only, up to a bend of less than

twice the stem diameter. The lower two-third of the bole is free of live branches.

2. *Class 2* - The stem is straight and healthy, forks are tolerated, but only if they are in the uppermost third of the tree. Crooks are tolerated in one dimension only, up to less than four times the stem diameter.
3. *Class 3* - The stem is crooked, leaning and more or less damaged. Crooks may reach six times the stem diameter in one dimension and minor crookedness in a second dimension is tolerated.
4. *Class 4* - The stem is very crooked in more than one dimension and heavy damaged. Low branching, forked trees sometimes with broken crown.

The stem quality index was calculated as the average of the stem classes weighted by stem number.



Figure 3. Discs prepared for the annual ring analysis

4. MAIN STATEMENTS OF THE DISSERTATION

The evaluations have proved that mostly the clones H-337 and H-384 seem to be suitable for poplar growing under unfavourable ecological factors, while the clone H 425-4 could be considered as an alternative one for wood production.

Table 1 shows the most important stand structure parameters of the Leuce-poplar clones at the age of 8 (Kecskemét 40A, Block I.). On the basis of the data, considering the growth in height, the clones *H-337* and *H-384* provided the best results. They surpassed the control by 51 and 22 %, respectively. As regards the growth in DBH (diameter at breast height) the above-mentioned clones surpassed the control by 30 and 25 %; the tendency was also the same with regard to the mean tree volume values. The effect of differences in DBH on the mean tree volumes seems to be very considerable (an additional 102 and 49 % for the above-mentioned clones). As the stem quality index is concerned, the succession from best to worst is: *H-337*, *H-384*, *H 425-4*, *H-325* and the *control*. According to the significance test at $P = 5\%$ level, significant differences were found in height ($SD_{5\%} = 2.07$ m), in DBH ($SD_{5\%} = 2.11$ cm) and in the mean tree volume values ($SD_{5\%} = 21.2$ dm³).

Table 1. Some yield data and stem qualification of Leuce poplar clones at age of 8 years. (Kecskemét 40A, 2011) Block I.

| Name of clone | Mean height (m) | % | Mean diameter at breast height (cm) | % | Mean tree volume (dm ³) | % | Stem quality index (1-4) |
|------------------------|-----------------|------------|-------------------------------------|------------|-------------------------------------|------------|--------------------------|
| H-325 | 8,05 | 111 | 7,40 | 102 | 25,8 | 102 | 2,14 |
| H-337 | 10,95 | 151 | 9,44 | 130 | 51,3 | 202 | 1,33 |
| H-384 | 8,84 | 122 | 9,08 | 125 | 37,9 | 149 | 1,61 |
| H 425-4 | 7,66 | 106 | 7,82 | 108 | 26,6 | 105 | 1,91 |
| <i>Control</i> | <i>7,24</i> | <i>100</i> | <i>7,26</i> | <i>100</i> | <i>25,3</i> | <i>100</i> | <i>2,28</i> |
| SD_{5%} | 2,07 | | 2,11 | | 21,2 | | 0,52 |

Table 2 demonstrates the stand characteristics of Leuce poplar clones at age of 6 years (Kecskemét 40A, Block II.). According to the values of this clone trial the tendency was very similar to results of the above mentioned clone trial in block I. On the basis of

the data, considering the growth in height, the clones *H 337* provided the best result. It surpassed the second best clone *H 425-4* by 56 % and far exceeded the control (by 70 %). As regards the growth in DBH the above-mentioned clones surpassed the control by 57 and 23 %; and the difference was even bigger with regard to the mean tree volume values. The effect of differences in DBH on the mean tree volumes seems to be very considerable (an additional 166 and 52 % for the above-mentioned clones). As the stem quality index is concerned, the succession from best to worst was the following: *H 337*, *K-1*, *K-2*, *H 425-4* and the *control*. According to the significance test at $P = 5\%$ level, significant differences were found in height ($SD_{5\%} = 1.2$ m), in DBH ($SD_{5\%} = 1.69$ cm) and in the mean tree volume values ($SD_{5\%} = 6.0$ dm³).

Table 2. Some yield data and stem qualification of Leuce poplar clones at age of 6 years. (Kecskemét 40A, 2012) Block II.

| Name of clone | Mean height (m) | % | Mean diameter at breast height (cm) | % | Mean tree volume (dm ³) | % | Stem quality index (1-4) |
|------------------------|-----------------|------------|-------------------------------------|------------|-------------------------------------|------------|--------------------------|
| H-337 | 8,1 | 170 | 6,45 | 157 | 19,4 | 266 | 1,78 |
| H 425-4 | 5,5 | 114 | 5,05 | 123 | 11,1 | 152 | 2,63 |
| K-2 | 4,0 | 83 | 3,77 | 92 | 6,3 | 86 | 2,22 |
| K-1 | 3,8 | 79 | 3,73 | 91 | 5,4 | 74 | 1,99 |
| <i>Control</i> | 4,8 | 100 | 4,10 | 100 | 7,3 | 100 | 3,02 |
| SD_{5%} | 1,2 | | 1,69 | | 6,0 | | 0,48 |

On the basis of evaluation of the annual ring analyses we can say that selection surplus can also be detected exactly under marginal site conditions. As regards the average annual ring width (growth in diameter at breast height) the clone *H-384* surpassed the control by 52.7 % while the clone *H-337* surpassed it by 46.2 % (*Figure 4*).

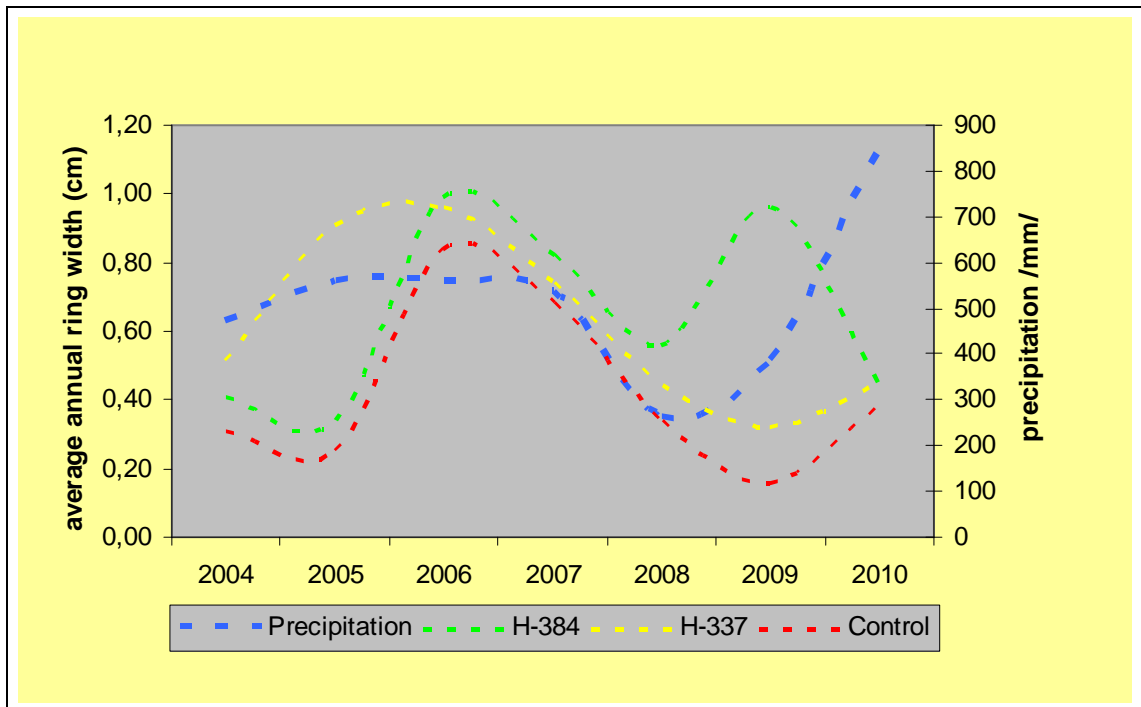


Figure 4. Annual ring analysis of the two most promising Leuce-poplar clones at the age of 7. (Kecskemét 40A, 2010)

I have done discriminant analysis considering the d.b.h. (diameter at breast height), height, rate of growth, stem quality, health condition – as quantitative variables – according to the different clones – as observation groups. *Figure 5* shows the ordination diagram based on canonical discriminant functions of the variety comparison clone trial. In the course of the discriminant analysis if the number of groups more than two – as in this case – the discrimination of cases (variables) belonging to the single groups (clones) can be done by the help of so-called canonical variables.

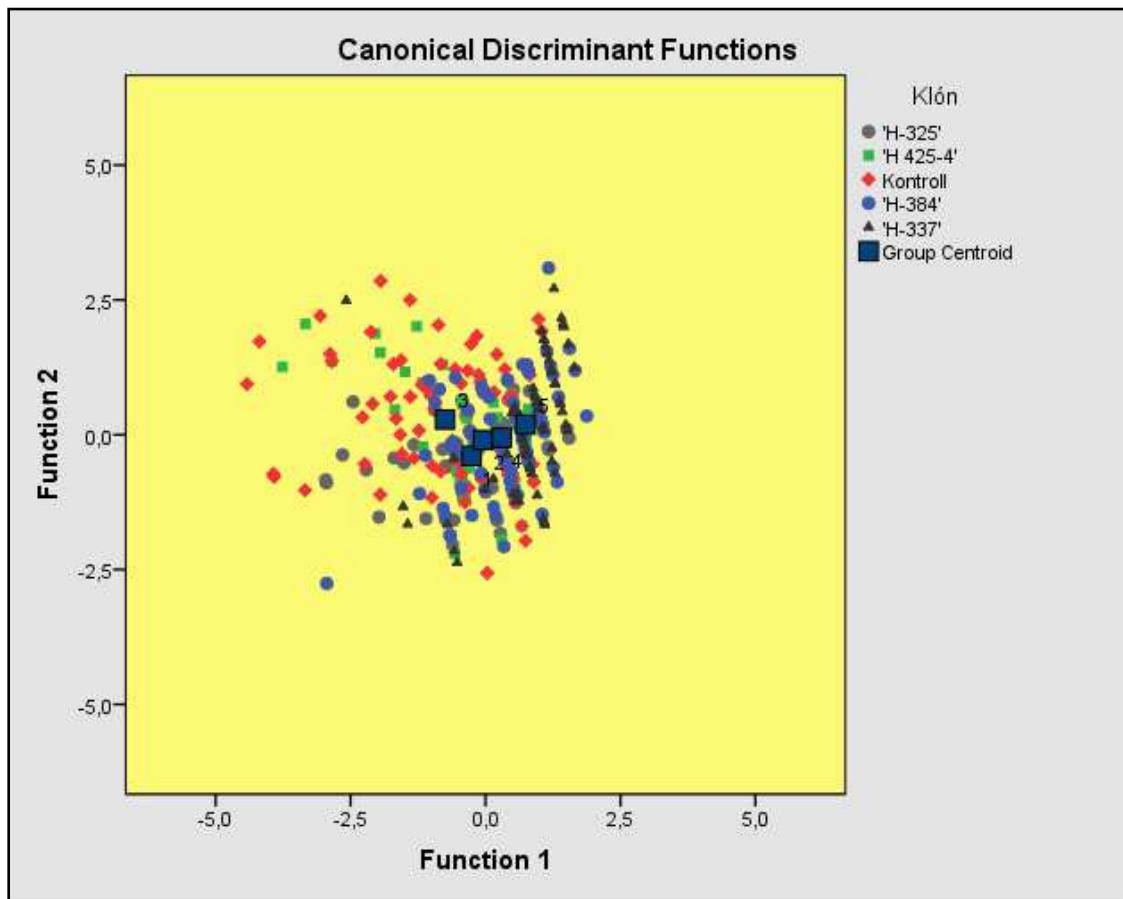


Figure 5. The common ordination diagram of the 5 groups (clones) on the basis of the investigated characteristics.

According to the *figure 5* we can say that the groups – though not clearly – separate from each other considering the first function (horizontal axis). The figure also shows that the control (commercial) white poplar specimens show the highest deviation according to the investigated characteristics compared to the other clones.

The H-384 and H-337 clones presented the most homogeneous distribution. *These results also prove the excellent stem form and yield properties, health condition and outstanding rate of growth of these two promising Leuce-poplar clones.*

5. CONCLUSION, NEW SCIENTIFIC RESULTS

1. On the basis of the literature and previous R+D (Research + Development) results I described the importance of Leuce-poplar stands growing under sandy soil conditions between in the rivers of Danube and Tisza.
2. On the basis of detailed investigation and evaluation carried out over several years of variety comparison trials established in Kecskemét 40A subcompartment in spring of 2004 and in autumn of 2005 two promising Leuce-poplar clones – namely *Populus alba* x *Populus grandidentata* H-384 and *Populus alba* x *Populus grandidentata* H-337 clones – seem to be suitable for utilization of wood production under marginal site conditions. The cultivar certification procedure for the purpose of official recognition of the above mentioned two promising Leuce-poplar clones can be started in the course of proper results of other experiments.
3. Test results related to the cultivar candidate *Populus alba* x *Populus alba* H 425-4 ('Homoki') proved that the mentioned clone can also be used successfully in the course of forestation under sandy marginal site conditions.
4. The tissue culture method (micropropagation) presented in the dissertation can be considered as a successfully method in the course of selection breeding of Leuce-poplar clones. In this regard the reviewed R+D results may be considered a pioneer on the research field of the Hungarian poplar breeding.
5. The excellent stem form and yield properties of the two promising Leuce-poplar clones proved that the selection surplus can also be detected exactly under marginal site conditions.

6. PRACTICAL USE OF THE RESULTS

More than 80 per cent of Leuce-poplar stands and plantations can be found on calcareous sandy sites on the Danube-Tisza region as well as on the floodplain of the rivers Danube and Tisza. In these areas which prove marginal site conditions for poplar growing in many cases the importance of Leuce-poplars will be increasing in all likelihood. This statement is confirmed by several problems to be solved in today's forest management.

1. In our Scotch pine stands growing on the remarkable part of sandy sites between the rivers of Danube and Tisza there is a significant problem caused by increasing damage of fomes root rot (*Heterobasidion annosum* (Fr.) Bref.).
2. We have to carry out the species conversion of lower quality hybrid poplar stands growing under such a sandy sites that prove marginal site for poplar growing in many cases. The promising Leuce-poplar clones investigated by us seem to be suitable for utilization of marginal sites and for regeneration with species conversion of these areas.
3. With the official recognition and the solution of vegetative propagation method done in plant level of the two promising Leuce-poplar clones, they may play a very important role in the course of the regeneration of lower quality hybrid poplar stands and scotch pine stands infected by fomes root rot growing under sandy soil and marginal site conditions. In addition, the range of cultivar assortment of the officially recognized poplar cultivars can be expanded with two new Leuce-poplar clones which may help to avoid a potentially white poplar monoculture growing system.

7. PUBLICATIONS

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