Tibor Alpár[1], Tibor Fáczán[2], István Rácz[1], Gabor Kátoli[2]

MDF/HDF Production from Plantation Wood Species

Proizvodnja MDF/HDF ploča od plantažnih vrsta drva

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ABSTRACT • *The purpose of this research was to establish the raw material base for the newly built MDF/HDF production line in Mohács, Hungary. The desired raw material for the factory is 80 % poplar and 20 % other species (conifers and broad leaved species). These raw materials should be obtained from wood plantations.*
*Laboratory experiments were done in production of MDF and HDF boards with the following raw materials: 5 and 10 year old Pannonia poplar (*Populus x euramericana Pannónia*), I214 poplar (*Populus x euramericana 'I214'*), black locust (*Robinia pseudoacacia*) and Austrian pine (*Pinus nigra*). The selected trees were evaluated based on the following parameters: diameter, bark volume, ability for barking, ability for chipping, fiber yield, fiber quality, energy consumption of defibrating, chemical analysis of waste water after defibrating. MDF and HDF boards were made in laboratory from clear poplar species, and from a mixture of poplar and Austrian pine and poplar and black locust. In both cases of mixing, the ratio of poplar and other wood species was 80:20. Urea-formaldehyde adhesive and ammonium-sulphate hardener were used during board production. Also some paraffin was added to increase the moisture resistance. The following board characteristics were tested: bending strength, internal bond, modulus of elasticity, thickness swelling, density, moisture content, formaldehyde content. Except the values of internal bond, the results were very satisfactory, highly above the standard requirements. The reason for the low internal bond values is as follows:*
- in the laboratory we could not apply a proper blending of fibers and additives,
- mat forming by hand.
In spite of this, we are sure that an actual technological test production will give good results.

Key words: *MDF, HDF, wood plantation, Pannonia poplar, I214 poplar, black locust, Austrian pine, fiberboard production, physical aspects of MDF/HDF boards*

SAŽETAK • *Cilj je rada bio ustanoviti sirovinsku bazu za novu proizvodnu liniju ploča srednje i velike gustoće (MDF/HDF ploče). Predviđeni materijal za proizvodnju ploča činilo je 80 % topolovine i 20 % ostalih vrsta drva (četinjača i listača). Za proizvodnju ploča upotrijebljeno je drvo dobiveno plantažnim uzgojem.*
*Laboratorijski eksperiment započeo je proizvodnjom MDF i HDF ploča od ovih materijala: 5 i 10 godina starih stabala panonske topole (*Populus x euramericana Pannónia*), klona topole I214 (*Populus x euramericana 'I214'*), crnog bagrema (*Robinia pseudoacacia*) i austrijskog bora (*Pinus nigra*). Izabrana stabla procijenjena su uzimanjem u obzir ovih parametara: promjera, obujma kore, mogućnosti otkoravanja, mogućnosti usitnjavanja, količine proizvedenih vlakanaca, kvalitete vlakanaca, potrošnje energije za razvlaknjivanje i kemijske analize otpadne vode nakon razvlaknjivanja.*

[1] Authors are associate professor and assistant at Institute of Wood and Paper Technology, Faculty of Wood Sciences, University of West Hungary, Sopron, Hungary. [2]Authors are employees of Kronospan-MOFA Hungary Ltd., Mohács, Hungary.
[1] Autori su izvanredni profesor i asistent Odjela za drvne kompozite u Zavodu za tehnologiju drva i papira Sveučilišta zapadne Mađarske, Sopron, Mađarska. [2]Autori su zaposlenici tvrtke Kronospan-MOFA Ltd., Mohács, Mađarska.

U laboratoriju su napravljene MDF i HDF ploče samo od topolovine, od mješavine topolovine i drva austrijskog bora te od topolovine i drva crnog bagrema. U oba slučaja miješanja topolovine s drugom vrstom drva omjer miješanja bio je 80:20. Za proizvodnju ploča upotrijebljeni su urea-formaldehidno ljepilo i amonij-sulfatni učvršćivač. Također je dodano nešto parafina radi povećanja vodootpornosti ploča. Ispitana su ova svojstva ploča: savojna čvrstoća, čvrstoća raslojavanja ploča, modul elastičnosti, debljinsko bubrenje, gustoća, sadržaj vode, sadržaj formaldehida. Osim čvrstoće raslojavanja ploča, druga su svojstva ploča bila vrlo zadovoljavajuća, daleko veća od zahtjeva odgovarajućih normi. Loša vrijednost čvrstoće raslojavanja ploča bila je posljedica toga što u laboratorijskim uvjetima nije bilo moguće ostvariti dobro miješanje vlakana i ljepila, a tepih ploče oblikovan je rukama. Može se pretpostaviti da bi ploče proizvedene u uvjetima stvarne proizvodne tehnologije imale bolja svojstva.

Ključne riječi: *MDF i HDF ploče, plantažno drvo, panonska topolovina, klon topole I214, crni bagrem, austrijski bor, proizvodnja ploča vlaknatica, svojstva MDF/HDF ploča*

1. UVOD
1 INTRODUCTION

Only a small part of Hungary area is forest: ~ 20 000 km^2 (20 %) (Molnár, 2000). The industrial utilization of wood is getting harder because of the recent energy price supporting system of the government. A good solution for both the wood processing industry and the energy sector could be the wood plantations, where improved and selected clones could ensure a higher yield of biomass with improved properties at a more reasonable price. These might relieve traditional forests regarding energy use in power stations (Mőcsényi, 2003).

In Hungary the total forest area is handled by forestry plans, but in the European Union only 60 % of the total area is handled in this way. The governmental forest property in Hungary is 59 %, and in the EU it is only around 21 % on average. In practice, harvesting of forests are only the 80 % of the possible total, which means that the renewable resources are partly unused (National Development Plan).

Recently, there have been only ~ 15 km^2 of plantation forests in Hungary, while 30 km^2 are allowed. The intent of the energy sector is to utilize this surplus. The distribution of plantation species are: 9 % black locust, 22 % willow, 69 % poplar (Szajkó, 2009). It could be a solution to increase suitable plantation forests to balance the demand of both energy sector and wood based panel industry.

This research was done within the scope of NKFP4-0011/2005 FAFORRÁS project's sub-project: „1.5. Scientific establishing of new wood working technologies by laboratory experiments“. The task was to investigate whether the raw material base of MDF/HDF production can be widened to species of plantation forests in domestic relations (Alpár *et al*, 2006).

Common species for MDF production in Europe are spruce (*Picea abies*) and beech (*Fagus sylvatica*) but it largely depends on local market supply as Deppe *et al*. (1996) outlines in his book. Traditionally, in Hungary different species are used at the same time with specific mixing ratios. It is because Hungary's forests are very mixed, so for panel board production several species must be harvested. A typical set up of species is: Scots pine (*Pinus sylvestris*), fir (*Abies alba*), spruce (*Picea abies*), beech (*Fagus sylvatica*), oak (*Quercus robur*) and different poplar clones (*Populus spp.* - eg. *alba* and *nigra* and *cv. euramericana*). There is another reason for different recipes: the required density and quality of the desired board. Higher density boards (eg. HDF) contain more high density broad leaved species like beech or oak (Winkler, 1999). Traditionally, these species come from natural forests but in this research we used only timber from plantation forests.

The main questions of this research were connected to the dry process technology of fiberboard production:

- find suitable plantations – procurement of suitable row material,
- examination of row material,
- chipping – examination of wood chips,
- defibrating – examination of defibrating parameters and the fibers themselves,
- experimental laboratory board production,
- examination of board properties,
- evaluation of examinations.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Procurement and examination of wood from plantations
2.1. Nabava i analiza plantažnog drva

In this research the following species, which might be grown in plantations, were examined:

- poplar clones (*Populus spp*): Pannonia and I214,
- black locust (*Robinia pseudoacacia*),
- black pine (*Pinus nigra*).

First, forest plantations were sought, which were considered suitable for the aims of the research.

The woodlands of two forestry units were visited, the plantations of VIRÁGH Producer, Commercial and Service Deposit Company (*VIRÁGH Termelő, Kereskedelmi és Szolgáltató Bt.*) at Csemő, where the plantations of 4 years old Pannonia poplar, 6 years old black locust, 3 years old black locust, 5 years old I214 poplar, and 5 years old black locust were evaluated, and the plantations of Forestry of North Kiskunság (*Észak Kiskunsági Erdészet*) at Kerekegyháza, where the plantations of 9 year old black locust, 10 year old black pine, 9 year old black locust and 4-5 year old black pine were evaluated.

The evaluation of these plantations showed that the 5 year old timber is not suitable for fiberboard (MDF/HDF) production, because the diameter of this timber is below the required 4 cm in the largest part of

Table 1 Mixing ratio and marking of the produced boards
Tablica 1. Omjer miješanja različitih vrsta drva i oznake proizvedenih ploča

Mark *Oznaka*	**I-214** *klon topole I-214* %	**Pannonia** *panonska topola* %	**Black pine** *crni bor* %	**Black locust** *crni bagrem* %	**Age** *years*
I10_10	100	0	0	0	10
P10_10	0	100	0	0	10
PI55_10	50	50	0	0	10
IF82_10	80	0	20	0	10
PF82_10	0	80	20	0	10
IA82_10	80	0	0	20	10
PA82_10	0	80	0	20	10

the logs (in case of smaller diameter the size of chips is unsuitable). In spite of this the main characteristics of this timber were also examined.

2.2 Preparation and examination of raw materials
2.2. Priprema i analiza sirovine za izradu ploča

The preparation of raw material was made at MOFA Zrt. in industrial conditions: chipping was done by a Ferrari drum chipper and the chips were defibrated by an industrial Defibrator.

The moisture content and the size distribution of the chips were examined in the laboratory of the Institute of Wood and Paper Technology at the University of West Hungary. In case of the latter a Retsch Plan vibrating classifier was used. The sieves and the requirements of different size ranges are as follows (opening of the sieves in mm): 31.5 – max. 20 %; 20.0 – min. 50 %; 10.0 mm – max. 20 %; bottom tray – max. 10 %. To determine the bark content, the fractions were completely sorted out. Maximum bark content is 20 %.

All the four species were defibrated with the same parameters. In the pre-heater, the steam pressure was 7.8 bar, the temperature was 173 °C, and the filling level was set to 45 %. The fibers (moisture content of about 50 %) were dried in laboratory drier with daily air mixing for 8 hours during 20 days at 70 °C.

Regarding the fiber production the following examinations were done:

1. size distribution analysis:
   This was made by a vertical Defibrator fiber separator in wet condition; the mounted sieve hole sizes were 1.0, 0.3, 0.15, 0.08 mm.
2. amount of produced fiber:
   This gives the fiber capacity per hour.
   amount of produced fiber = (*volume of fiberboard* x *density*) / *production hours*
3. energy need for fiber production:
   The electric energy consumption, production time and steam consumption were measured.

2.3 Laboratory board production
2.3. Proizvodnja ploča u laboratoriju

Table 1 shows the mixing ratio and the marking of the produced boards.

General parameters of board production are shown in table 2. In every case urea-formaldehyde adhesive (UF) was used with ammonium-sulphate as a hardener. Also, 1.5 % of paraffin dispersion was added.

The thickness of 4 mm was chosen, because the successor of MOFA Zrt., the Kronospan-MOFA Kft. plans to produce mainly 3-4 mm fiberboards.

The boards were pressed in a laboratory size Siempelkamp hot press at 180 °C. The prevailing initial pressure was decreased in two steps during the 68 sec press time. The average initial specific pressure was 7 MPa. The required 4 mm thickness was ensured by steel bard.

2.4 Board tests
2.4. Ispitivanje ploča

The following tests were made on the laboratory fiberboards:

– Density (EN 323) - ρ
– Bending strength (EN 310) - f_m
– Modulus of elasticity (EN 310) - E_m
– Internal bond (EN 319) - f_{ti}
– Thickness swelling (EN 317) - G_t
– Formaldehyde content (EN 120) - P_e

During the evaluation of test results EN 622-5 was considered, (Table 3), which specifies the requirements of fiberboards produced by dry process (MDF).

Table 2 General parameters of MDF/HDF boards
Tablica 2. Parametri MDF/HDF ploča

Length / *duljina*, m	0.40
Width / *širina*, m	0.40
Thickness / *debljina*, mm	4.0
Planned density oven dry /*gustoća u suhom stanju*, kg/m^3	800
Solid resin content, % (oven dry wood) / *sadržaj smole, % (suho drvo)*	12
$(NH_4)_2SO_4$, %	1.0
MC_{board}	8 %
Solid content of resin / *sadržaj smole*, %	66.0
Solution of $(NH_4)_2SO_4$ / *otopina $(NH_4)_2SO_4$*, %	35.0

Table 3 Standard requirements for MDF of 4 mm thickness
Tablica 3. Zahtjevi normi za MDF ploče debljine 4 mm

Properties / *Svojstvo*	**Test method** *Ispitna metoda*	**Unit** *Jedinica*	**Nominal thickness** *Nominalna debljina*, >2,5-4,0
Thickness swelling – 24 h / *debljinsko bubrenje – 24 h*	EN 317	%	35
Internal bond / *čvrstoća raslojavanja*	EN 319	MPa	0,65
Bending strength / *savojna čvrstoća*	EN 310	MPa	23
Modulus of elasticity / *modul elastičnosti*	EN 310	MPa	-

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

3.1 Examination of plantation woods
3.1. Analiza plantažnog drva

Diameters on both ends of logs of purchased species were measured with and without bark by a caliper. From these data the portion of bark was determined (Table 4 and Figure 1).

In case of the investigated poplars and pine, the bark volume is in inverse relation to the age of the tree. The reason for this is that these species create an initially thick bark, which grows significantly slower than wood.

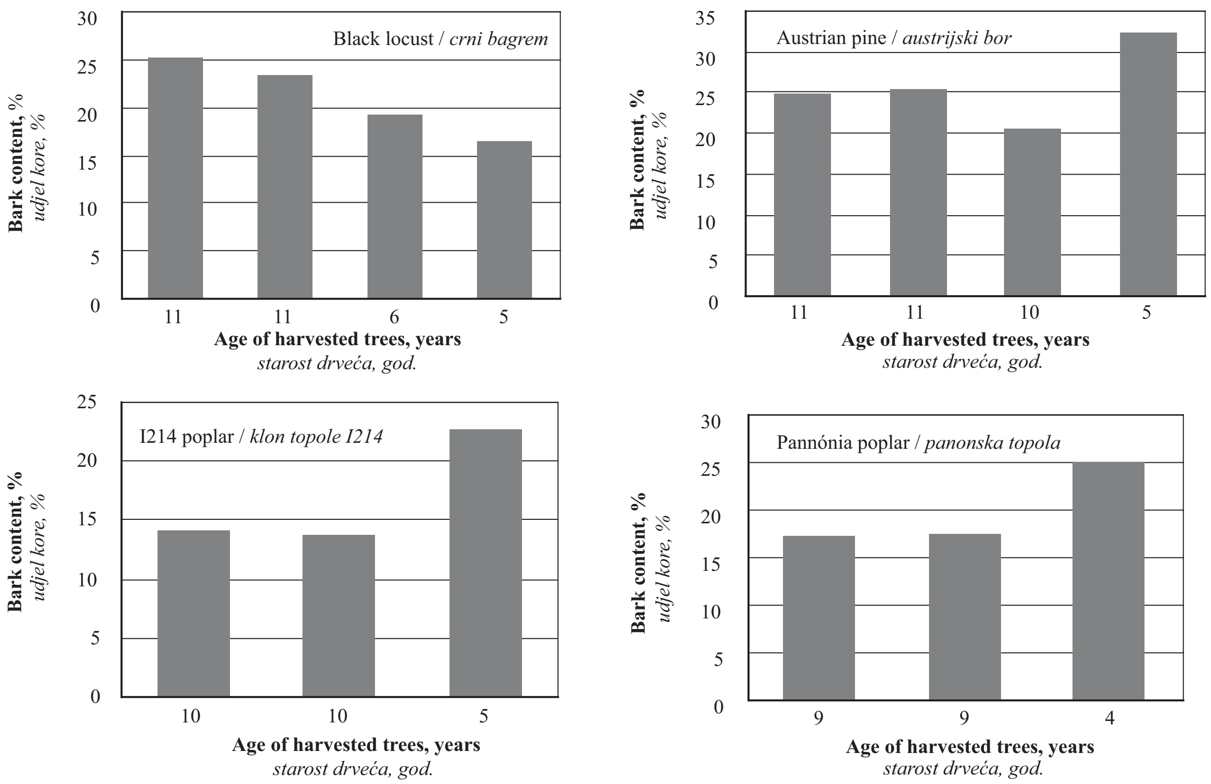

Figure 1 Bark content of different species
Slika 1. Sadržaj kore različitih vrsta drva

Table 4 Portion of bark of species of different age
Tablica 4. Udjel kore u drvu različitih vrsta i starosti

Species / *Vrsta*	**Age,** years / *Starost*, god.	**Share of bark** / *Udjel kore*, %
Black locust / *crni bagrem*	11	25.2
Black locust / *crni bagrem*	11	23.3
Black locust / *crni bagrem*	6	19.3
Black locust / *crni bagrem*	5	16.5
Black pine / *crni bor*	11	24.8
Black pine / *crni bor*	11	25.3
Black pine / *crni bor*	10	20.5
Black pine / *crni bor*	5	32.2
I214 poplar / *klon topole I214*	10	14.1
I214 poplar / *klon topole I214*	10	13.7
I214 poplar / *klon topole I214*	5	22.7
Pannonia poplar / *panonska topola*	9	17.2
Pannonia poplar / *panonska topola*	9	17.6
Pannonia poplar / *panonska topola*	4	25.1

In case of poplar and pine species the bark volume decreases with time. In case of the examined poplars the decrease of bark volume was 7-8% during 5 years. In case of pine the decrease was 12% during the same period.

Regarding black locust, the slow growth of the wooden part also results in a small diameter of 4 cm even at age of 11. Also the bark grows faster (gets thicker) than the wooden part in the investigated period of their life. Therefore, the wood of young black locust is not adequate to produce fiberboards; it would be unprofitable.

On the other hand, the volume of the wooden part is a more important factor in fiberboard production. A smaller amount of fiber can be obtained from pine than from poplar at the same age.

None of the examined species were found suitable for fiberboard production at the age of 5. The bark volume of such timber is too large and timber is too thin, so it is hard to debark them, and the fiber yield is too low.

3.2 Examination of wood chips
3.2. Analiza drvnog iverja

The following diagrams (Figures 2 to 5) show the examination results of chip size distribution and bark content of chipped material.

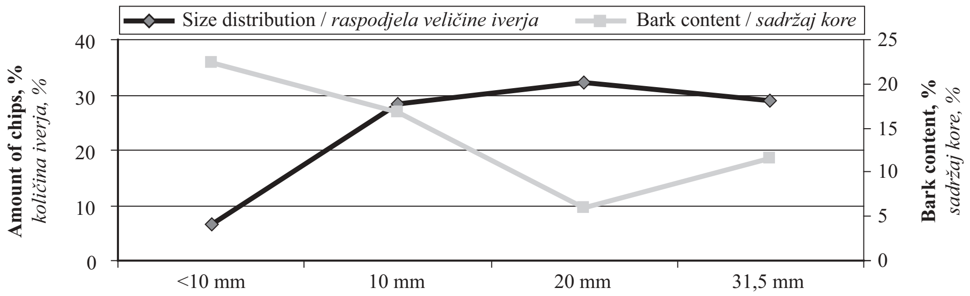

Figure 2 Size distribution and bark content of I214 poplar
Slika 2. Raspodjela veličine iverja i udjel kore za drvo klona topole I214

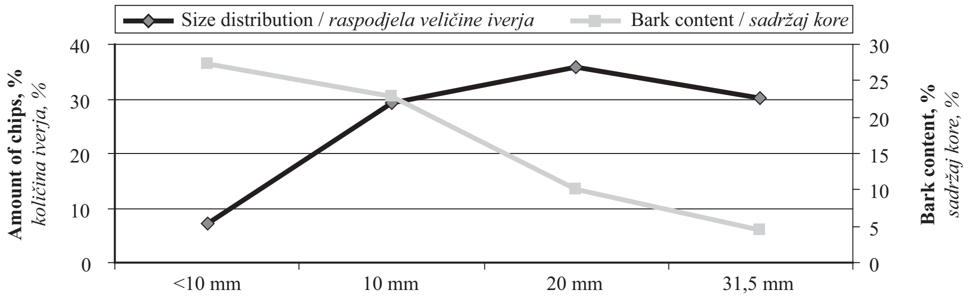

Figure 3 Size distribution and bark content of Pannonia poplar
Slika 3. Raspodjela veličina iverja i udjel kore za drvo panonske topole

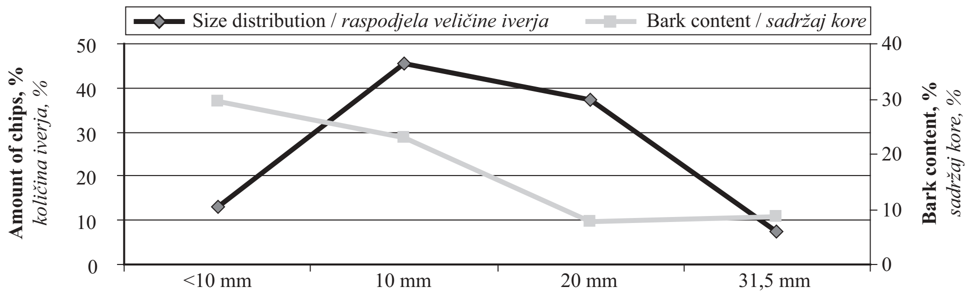

Figure 4 Size distribution and bark content of black locust
Slika 4. Raspodjela veličine iverja i udjel kore za drvo crnog bagrema

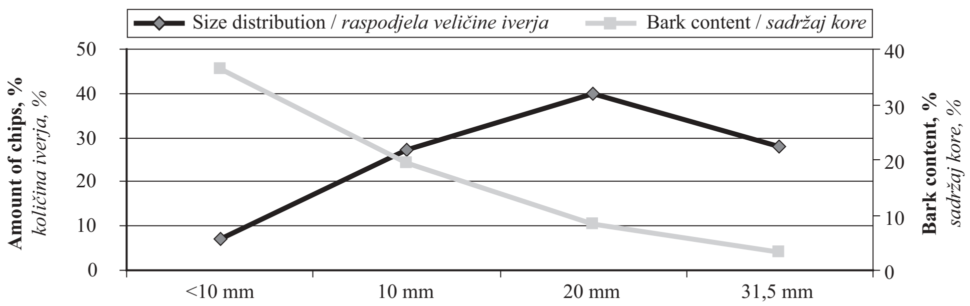

Figure 5 Size distribution and bark content of black pine
Slika 5. Raspodjela veličine iverja i udjel kore za drvo crnog bora

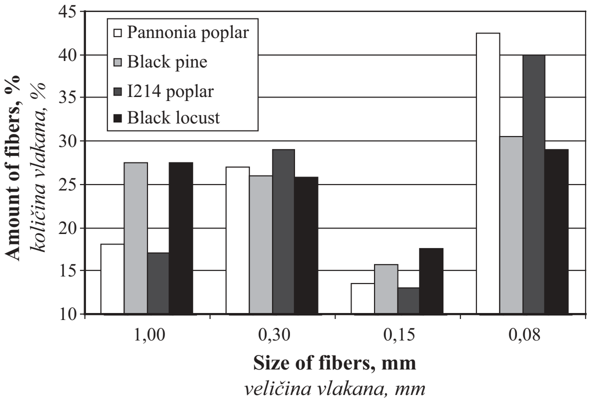

Figure 6 Fiber size distribution
Slika 6. Raspodjela veličine vlakanaca

In case of all four species only the size range below 10 mm met the length requirements of chips, as described in the "Technical Documentation" of the company MOFA Zrt.. At the same time the size distribution curves were adequate, except in case of black locust.

The reason for the differences regarding black locust as compared to poplar and pine is a more dense structure and higher stiffness of fibers. Therefore black locust has to be rechipped in some cases.

Regarding bark content, the amount was found below the limit of 20 % in every case.

3.3 Examination of fibers
3.3. Analiza vlakanaca

3.3.1 Fiber size distribution
3.3.1. Raspodjela veličine vlakanaca

Figure 6 shows the size distribution of produced fibers.

The best fibers for dry process fiberboard production are the ones that remain on the 0.15 mm hole size sieve. At this size almost the same amount of fibers were measured in case of both poplar species.

However, in case of black pine and black locust more fibers were found at 1 mm level. In the case of the poplars a small amount of fibers at 0.08 mm level is favorable.

Comparing the results of black locust and black pine to poplars, it was established that the amounts at the levels of 0.08 mm and 1.0 mm are almost the same. This means that it is more difficult to defibrate pine and black locust than the poplars, and hence smaller amount of fine fibers can be produced from them. This also means that these two species can be defibrated better together than together with other species. Species should be defibrated separately with specifically defined defibratig parameters to achieve the same fiber quality in case of different species.

Based on fiber size distribution diagrams all the four examined species (these are 10 year old trees!) are suitable for dry process fiberboard production, but if the finest and the roughest fraction could be decreased more technical fibers could be obtained.

3.3.2 Obtained fibers and power consumption
3.3.2. Količina proizvedenog iverja i potrošnja energije

Table 5 shows economical parameters of fiber production.

Based on our previous experiences the harder wood species can be defibrated at a lower energy consumption. In this experiment while defibrating the black locust the feeding snail of the Defibrator was jammed several times so this species resulted in the highest energy consumption. This result should be discarded.

The highest steam consumption was found in the case of black pine, but its electric power consumption was not so high.

In case of Pannonia poplar the electric power consumption was lower and the steam consumption higher, but in case of I214 poplar it was quite the opposite.

3.4 Examination of board properties
3.4. Analiza svojstava ploča

In the following chapter, the results of tested parameters are introduced. Only tests based on EN standards were made as described above.

3.4.1 Density (EN 323)
3.4.1. Gustoća (EN 323)

In the research plan, the production of two types of fiberboard was planned: 800 kg/m^3 (MDF) and 950 kg/m^3 (HDF).

The measured density of the produced experimental MDF boards was 801±15kg/m^3.

The measured density of the produced experimental HDF boards was 915±15kg/m^3.

3.4.2 Bending strength (EN 310)
3.4.2. Savojna čvrstoća (EN 310)

As shown in Figure 7 the bending strength exceeded the standard requirement (23 MPa). In case of fiber boards with lower density (800 kg/m^3) the requirements

Table 5 Obtained fibers and power consumption
Tablica 5. Količina proizvedenih vlakanaca i potrošnja energije

Wood species *Vrsta drva*	**Obtained fibers** *Proizvodnja vlakanaca* t/h	**Specific electric power consumption** *Specifična potrošnja električne energije* kWh/m^3	**Specific steam consumption** *Specifična potročnja pare* t/m^3
Pannonia poplar *panonska topola*	1.90	99.51	0.806
I214 poplar *klon topole I214*	1.76	107.27	0.746
Black locust *crni bagrem*	0.94	144.80	0.883
Black pine *crni bor*	1.98	96.80	0.892

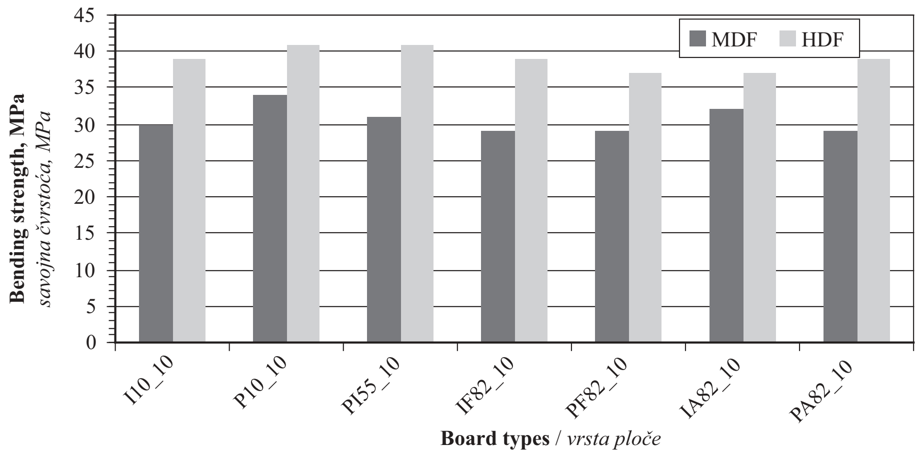

Figure 7 Bending strength of MDF and HDF
Slika 7. Savojna čvrstoća MDF i HDF ploča

(27 MPa) for MDF.H type board (use in wet condition for general purposes) were fulfilled, and in case of higher density boards the requirements (30 MPa) of MDF.HLS type (use in wet condition for load bearing purposes) were fulfilled.

Regarding the poplars, Pannonia clone showed slightly better values than I214. When other species (black pine or black locust) were mixed with poplar in a 20% ratio, a small decrease of bending strength was measured.

In case of MDF boards, testing was carried out of a control board made of special fibers from a dry process line. Its bending strength was the highest, because these fibers were shorter and smoother than the fibers from MOFA's wet process line.

3.4.3 Modulus of elasticity (EN 310)
3.4.3. Modul elastičnosti (EN 310)

The EN 622-5 standard has no requirements for MOE in case of board thickness below 4 mm for MDF of general use type. At the same time it should be mentioned that all of the HDF experimental boards have fulfilled the minimum requirements even of MDF.HLS type panels (3000 MPa)!

Regarding MDF boards of lower density, only in case of boards made 100 % of poplar was the MOE higher than the requirement (2700 MPa) for MDF.H type panels (Fig. 8).

3.4.4 Internal bond (EN 319)
3.4.4. Unutrašnje raslojavanje (EN 319)

The internal bond values of both MDF and HDF boards were above the standard requirements. There is no significant effect of the species on the internal bond values (Fig. 9).

3.4.5 Thickness swelling (EN 317)
3.4.5. Debljinsko bubrenje (EN 317)

The values of thickness swelling were much better than the standard requirements in every case (Fig. 10).

Regarding water adsorption, higher values were measured in case of lower density MDF boards (average 75 %) than in case of denser HDF boards (average 56 %).

3.4.6 Formaldehyde content (EN 120)
3.4.6. Sadržaj formaldehida (EN 120)

Hence the content of adhesive was the same (12 %) in case of each board type and the free formaldehyde content was measured only on one board: No. P10 10M MDF.

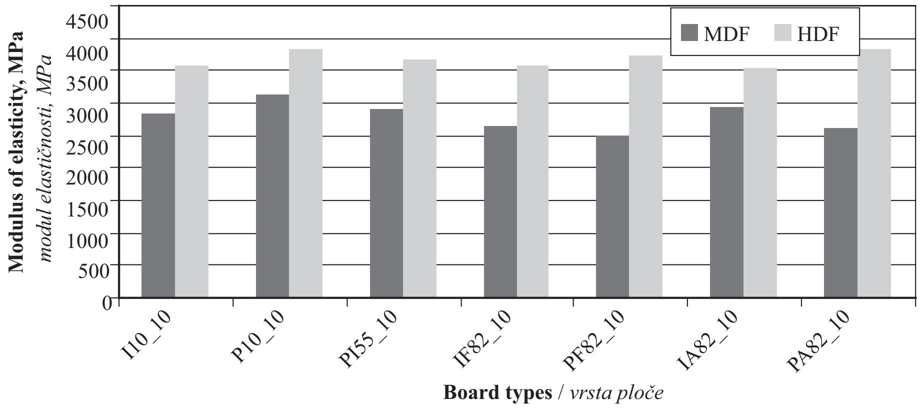

Figure 8 MOE of MDF and HDF boards
Slika 8. Modul elastičnosti MDF i HDF ploča

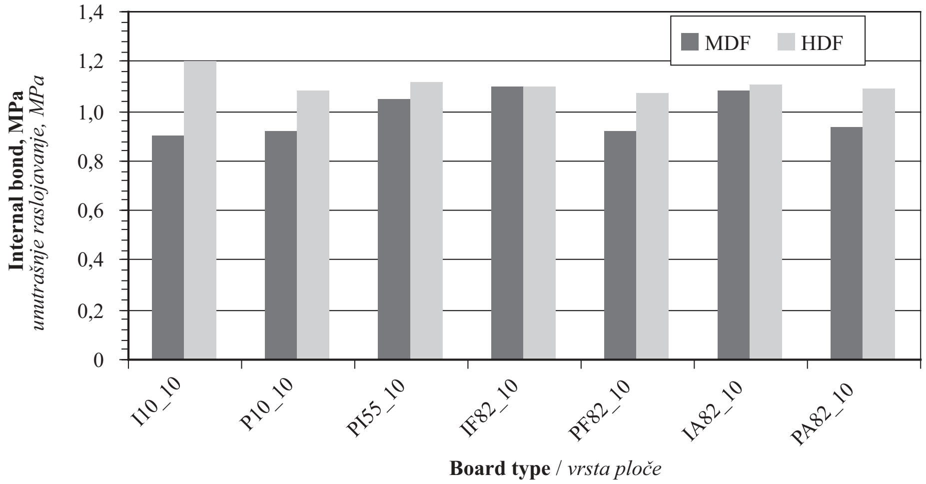

Figure 9 Internal bond of MDF and HDF boards
Slika 9. Čvrstoća raslojavanja MDF i HDF ploča

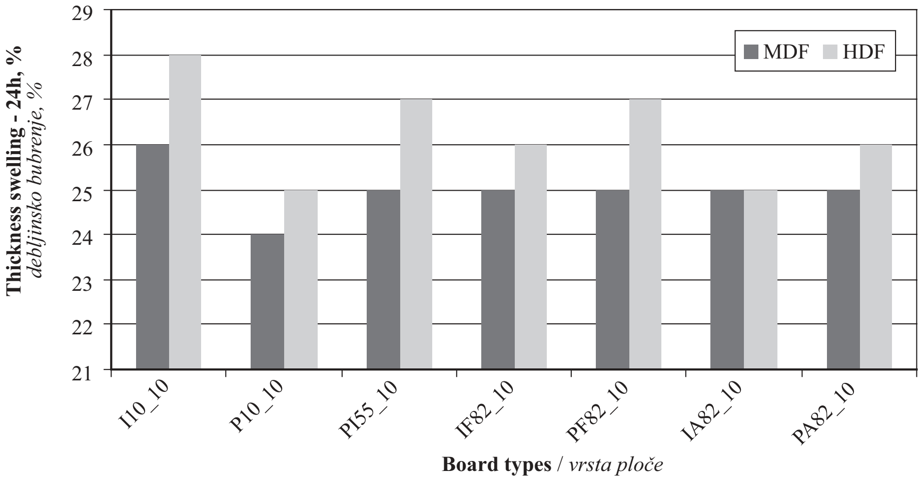

Figure 10 Thickness swelling (24h) of MDF and HDF boards
Slika 10. Debljinsko bubrenje (24 h) MDF i HDF ploča

The result was 6.5 mg/100g, which is below the standard requirement of a maximum 8 mg/100g. So these boards are considered as E1.

4 CONCLUSIONS
4. ZAKLJUČCI

The aim of this project was to examine whether the raw material basis of dry process MDF/HDF production can be widened by species from domestic wood plantations. In this project in 2006 the following 5 and 10 year old species were examined: Pannonia poplar, I214 poplar, black pine and black locust.

Based on previous examinations, the 5 year old timber was discarded for laboratory board production. It could be established during visiting the plantations that the 5 year old trees are not suitable to produce MDF/HDF boards, because the diameter of their log is below the required 4 cm. Also these young trees have larger bark volume, and debarking is difficult.

In case of plantation wood, regarding the diameter, a drum debarker is recommended. Regarding the amount of obtained technical fibers in case of black pine and the poplars no significant differences could be observed. The measured values of defibrating of black locust are not usable because of the jam of the feeding snail.

Regarding energy consumption, Pannonia poplar needed lower use of electric energy but higher use of steam. In case of I214 poplar it was quite the opposite.

Boards were made 100% from both poplar species, from mixtures of poplars at a 50%-50% ratio and from mixtures with both other species at an 80%-20% ratio. All standard physical and mechanical properties were tested.

All the standard requirements were fulfilled.

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Corresponding address:

Associate Prof. TIBOR ALPÁR, Ph.D.

Institute of Wood and Paper Technology
Faculty of Wood Sciences
University Of West Hungary
Bajcsy-Zs. u. 4
9400 Sopron, HUNGARY
e-mail: atibor@fmk.nyme.hu