

UNIVERSITY OF WEST-HUNGARY

THESIS OF PHD DISSERTATION

**DEVELOPMENT OF CULTIVATION TECHNOLOGY AND  
UTILIZATION OF MINI ROTATION WOODY CROPS  
FOR ENERGY PURPOSE**

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## TABLE OF CONTENTS

<b>1. Preliminaries of the research</b>	<b>2</b>
<b>2. Aims of the research</b>	<b>3</b>
<b>3. Methods of the research</b>	<b>3</b>
<b>4. Summary of the new scientific results, research fields for the future</b>	<b>5</b>
<b>4.1. Summary of the new scientific results</b>	<b>5</b>
<b>4.2. The utilization of the new scientific results</b>	<b>8</b>
<b>4.3. Possible new research fields</b>	<b>8</b>
<b>5. Publication in the theme of the dissertation</b>	<b>9</b>

## 1. Preliminaries of the research

In the last decades, it became clear for the developed countries that their stability of economy and policy is depended significantly on import of the non-renewable, fossil fuels. Therefore the IEA (International Energy Agency) was established in the first half of the 1970's, after the first oil crisis, which organization engaged in sustainable energy management.

In the 1980's and the 1990's, as well as in the beginning of the XXI. century, FAO and IEA established several international research programs of biomass production for energy purposes, (FAO CNRE Biomass for energy purposes program; IEA Bioenergy, different short rotation coppice researches: IEA Task 30 Short Rotation Crops for Bioenergy Systems), involving many world-famous, biomass researchers in. Large-scale researches are in progress in cultivation and utilization of biomass and dendromass for energy purposes.

The advantages of utilization of the short rotation woody plants for energy purposes, summarized by the researchers, are in the followings:

- Biomass, inside the short rotation woody plants, is the most simple solution of utilization of solar energy, which can be inserted in completely natural processes.
- The energy short rotation coppice as an energy-carrier is renewable and can be totally renewed. In its production the value of living place change for the better.
- Fossil fuels can be replaced with the utilization of RES, with which the import dependency of countries can be decreased.
- In the course of utilization of dendromass for energy purposes – because of the elements of lignocelluloses – the pollution compared to fossil fuels can be reduced significantly.
- Their utilization provide possibilities for the implementation of decentralized energy production, which is a keyelement in the foregoing programs.

The researchers agreed that the increasing of community, economy, industry require more and more wood material. Affects of developments of energy sector, the natural forests cannot satisfy the increasing basic wood material, that's why the production of short rotation crops almost the single solution for the discharge of the natural forests. The requirements are strongly growing, which cannot be supplied by the natural forests. Industry and energetics need unified quality, large quantity wood material. The conditions of satisfaction of the energetical and other requirements are that the price of wood decreasing as well as possible, which can be solved by utilization of short rotation woody crops.

The majority of the researchers consider the results in direct and indirect economy affects of the utilization of dendromass as an energy-carrier. Reduction of costs of energy unit is a direct economy effect. On the other hand reduction of global, health and environmental problems of production short rotation woody crops may be consider as indirect effects.

The utilization and the dissemination of mini rotation woody crops for energy purposes, as a biological energy-carrier, is not only a technological and biological question. The technical and the biological results can be only utilized in adequate economical, political system.

## **2. Aims of the research**

The PhD-dissertation contains my own research results from the last 5 years in the topic of mini rotation woody crops.

In the area of Parképitő Rt., Pannonpower Holding Rt. and some other grounds, with the consultant of University of West-Hungary, Department of Energetics, in the course of researching of mini rotation woody crops for energy purposes, the following exercises were scientific research aims:

- Analysis of the Hungarian and the EU energy policy from the point of view of the utilization of dendromass for energy purposes.
- In case of mini rotation woody crops, the implementation and the measure of the optimal rotation, during single cultivation technologies.
- Develop the growing features and relations of mini rotation dendromass crops for energy purposes.
- The determination and comparison of yields (t/ha/year) of mini rotation woody (MRWC) crops.
- Involving of other wood species and cultivars into the mini rotation cultivation.
- Integration of MRWC cultivation technology depends on wood species. Measure of different type of foreign and national cultivation technologies.
- Development of the harvesting systems of mini, midi and short rotation woody crops.
- Energetic and firing-technical measures of wood materials production in mini rotation woody crops.
- Research and analysis of new potential utilization technologies of dendromass plantation for energy purposes.

In the previous themes, exercises, the main aim was that in the field of the connected special themes develop researches to make conditions of new scientific results.

The main goal of the dissertation is to develop the area of cultivation and utilization of the mini rotation woody crops for energy purposes with the solution of the previous exercises.

## **3. Methods of the research**

Adjusting to the dendromass research aims, the research method was partly theoretical, laboratory, scientific cooperation and exchange of information.

The research was in theoretical-style in the following general themes:

- (a) Growing features of the mini rotation woody crops.
- (b) Analysis, estimating of features of developed foreign machine systems (harvesting, planting, briquetting, pelleting)
- (c) Analysis of harvesting of mini and short rotation dendromass plantations.
- (d) Research of energetic and firing quality of lignocelluloses and short rotation dendromass.
- (e) Estimating of lignocellulose briquettes quality.

The research was in laboratory-style:

- measurement of wood quality of mini rotation woody crops,
- in the measurement of moisture content, ash content, element content, higher and lower heating value, and other energetic qualities,

- in case of biobriquettes and biopellets quality analysis.

The research was in trial-style in

- analysis of national and foreign machine, in abroad and inland.

The research was in scientific cooperation and exchange of information:

- in the course of measure of mini rotation woody crop yields,
- in the methods of measure energetic plantation wood material,
- in the course of utilization of dendromass for energy purposes.

The following institutes provide possibilities for the researches, for the laboratory works and for the trials:

- University of West-Hungary (UWH), Faculty of Forsetry, Department Energetics Laboratory, Sopron and trial woody crops, in Tata
- Centre Library of UWH,
- Optigép Ltd.,
- SEFAG joint-stock company,
- Pannonpower joint-stock company laboratory and trial woody crops,
- Ministry of Agriculture, Hungarian Institute of Agricultural Engineering, Agroenergetic Laboratory,
- University of Veszprém, Chemistry Institute,
- Fantoni Ltd., Oposso, Italy,
- Italian National Research Cooperation, Trees and Timber Institute, Fiorentino (Florence), Italy.

The abroad institutes of scientific cooperation and exchange of information:

- Italian National Research Cooperation, Trees and Timber Institute, Fiorentino (Florence) Italy,
- University of Technology, Zólyom, Slovakia,
- Universität für Bodenkultur, Wien, Austria,
- International Commission of Agricultural Engineering (CIGR).

In the course of the mini rotation woody crops for energy purposes, the researches, the laboratory works and the other trials were made like the followings:

The yield and the growing measures in differential inland woody stocks from 2001, in some from 2005, were made.

During analysis of the growing qualities (rooting factor, chest-high and stock diameter, height, mass) of mini rotation woody crops, 38 stand-forms were measured, in which trial areas, in species or in some other cases 10\*10 meter quadrats or accidentally marked 10-meter-long rows, depend on dimension of the area, were designated as a sample area. In these previous growing and other analysis, in the different mini rotation woody crop stand-forms, 200 black locust, 550 poplar, 150 willow and 50 tree of heaven stems were measured.

In the sample area of the different mini rotation woody crops, mass measures were done with lower elements – compared to the previous data, in the course of black locust 30 %, poplar 20 %, willow 30 %, tree of heaven 40 % – since in these measures the analysed wood species were cut. (The repetition number were 3-5 in the different analysis.)

The harvesting analysis have been researching since 2002, in each years from december to february, sometimes in summer. Faction-analysis were done on the chipped wood material during the harvestings, in which the measuring number was 5.

Furthermore the repetition number was five in the higher heating value measures and elemental analysis of the harvested and chipped mini rotation woody material.

Research of briquetting lignocelluloses and mini rotation poplar material have been researching continuously since 2000.

During the analysis, measures and trials, the following statistical factors and methods was utilized:

- average,
- minimum,
- maximum,
- dispersion,
- average error,
- average bias error,
- correlation coefficients,
- correlation analysis,
- regression analysis (trendanalysis),
- variation analysis.

#### **4. Summary of the new scientific results, research fields for the future**

##### **4.1. Summary of the new scientific results**

1. On the basis of analysis of international and national special literature, I consider, that estimation methods for woodvolume of the traditional forestry cannot be applied, or can partly be applied to the woodmass and yield of wood determination of the mini rotation (1-5 years rotation) woody crops for energy purposes.

1.1. With the transformation of woodmass straight line and woodmass curve woodvolume estimation methods, developed at first by KOPECZKY (1891), it was stated, that these methods are able to estimate the woodyield of mini rotation woody crops for energy purposes. (The woodmass straight line method:  $M=a*G_{1,3}-b$ , M-mass of the whole stem (kg),  $G_{1,3}$ -chest-high area ( $cm^2$ ), a,b-constants. The woodmass curve method:  $M=a*D_{1,3}^2-b*D_{1,3}-c$ , M-mass of the whole stem (kg),  $D_{1,3}$ -chest-high diameter (cm), a,b,c-constants.)

1.2. On the basis of several years analysis, measure and statistical methods, it was stated, that the woodmass estimation, power functions, applied in the international short rotation forestry:

$$M \text{ (kg)} = a * D_{1,3}^b,$$

$$M \text{ (kg)} = a * G_{1,3}^b$$

are put into practise – which correlation coefficients is well over higher than the methods, developed by Kopecky – and which correlation is suitable for the whole stem mass estimation of the hungarian 2-5 years old poplar and black locust mini rotation

woody crops for energy purposes. (M-mass of the whole stem,  $D_{1,3}$ -chest-high diameter (cm),  $G_{1,3}$ -chest-high area (cm<sup>2</sup>), a,b-constants.)

2. On the basis of my experiments, it could be stated, that the following methods are able to have such correlation coefficients which are adequate for the utilization in the practice for the estimation of the Hungarian mini rotation woody crop woodmass and woodyield:

2.1.  $Y=MT*S*\dot{R}$ ,

( $\dot{Y}$ -species/cultivar/clone yearly yield in a hectar (ÉNT/ha/év – living moisture tonns/hectar/year), MT-rooting factor<1, S-stand-form density, stem number/hectar,  $\dot{R}$ -average whole stem mass in sample area (kg/stem).)

2.2.  $\dot{Y}=Y-wcf*MT*S*\dot{R}$ ,

( $\dot{Y}$ -species/cultivar/clone yearly yield in a hectar (odt/ha/év – oven dried tonns/hectar/year), Y-species/cultivar/clone yearly yield in a hectar (ÉNT/ha/év – living moisture tonns/hectar/year), wcf-moisture content factor (moisture content (%)\*0,01), MT-rooting factor<1, S-stand-form density, stem number/hectar,  $\dot{R}$ -average whole stem mass in sample area (kg/stem).)

(The last two research results were developed on the trial wood plantation for energy purposes in Tata (18 ha) – on medium deep, possible shallow arable land, moistured till surface, possibly permanent watereffect, alluvial meadow roll, simple or twinrow poplar and black locust mini rotation woody crops.

3. On the basis of the research and development of cultivation technology of Hungarian mini rotation (1-5 years rotation) woody crops for energy purposes and of the stand-form-, yield- and rooting-measurements, the following statements are important:

3.1. In the course of the simple row poplar mini rotation woody crops on medium deep, possible shallow arable land, moistured till surface, possibly permanent watereffect, alluvial meadow roll, it was stated, that the woodyield majorly increase till the 3-4th years. The yield is good even in the fourth year, but in the fifth year it decreases drastically. The mini rotation poplar woody crops optimal rotation 3 or 4 years. In the case of 'Koltay' and 'Beaupre' clones, it was stated, that the yield increase till the 4th year, but after that it reduce in great quantity. In addition to in 'Pannónia' clone, this growth lasts till the third year, after the yield decrease, but less than the previous two clones. Therefore, in case of 'Pannónia' clone for mini rotation woody crops the optimal rotation should be 3 years.

3.2. In the course of the simple row black locust mini rotation dendromass plantation on medium deep, possible shallow arable land, moistured till surface, possibly permanent watereffect, alluvial meadow roll, the yield of the plantation increase till the third year, and after that it decrease. On the basis of the experiments the optimal rotation is 3 (possibly 4) years.

4. On the basis of the research and development of cultivation technology of Hungarian mini rotation (1 year rotation) woody crops for energy purposes and of the stand-form-, yield- and rooting-measurements, the following thesis were stated:

4.1. On the basis of the measurements of so deep arable land, alluvial meadow roll, in twinrow network, the new italian clones ('Monviso', 'AF2', 'AF1', 'AF6') have significantly higher yields, than the old hungarian clones ('Koltay', 'Beaupre',

- 'Raspalje', 'BL-Constanzo'). The 'AF2' and the 'Monviso' clones produced 2-3 times higher yield than the other clones.
- 4.2. Among the new Italian poplar clones, so deep arable land, alluvial meadow roll, 'Villafranca' and 'Pegaso' cannot be utilized clones, because their low rooting factor.
- 4.3. On so deep arable land, alluvial meadow roll, in twinrow network, it was stated that in the case of the 'AF2' poplar clone, its height growth was significantly higher in 70 cm stem distance, than in 50 cm stem distance during the first period of the vegetation. In summary, on the basis of the measurements, it was stated, that in the 50 cm stem distance stand-form had higher growth. 'AF2' clone is more suitable in 50 cm stem distance, than in 70 cm.
5. On the basis of harvesting researches, made in inland, mini and midi rotation woody crops for energy purposes, the followings were stated, that the present analysed walking-chipper machine, which machine development were started by MAROSVÖLGYI, and developed by the Optigép Ltd.:
- 5.1. The researches stated, that the hungarian OGFA walking-chipper suitable for the harvesting of 2-3-year-old poplar and 1-2-year-old black locust mini rotation woody crops in walking-chipper wood plantation worksystem.
- 5.2. The Hungarian developed, OGFA walking-chipper harvester made mini rotation woodchip, which chip quality is only in medium group (the 15 cm sized chip has 30 % rate), so it is not suitable for fluidized-bed boiler, it has to be afterchipped.
6. During the energetic analysis of mini rotation woody crop material, the followings can be stated:
- 6.1 On the basis of higher heating value measurements and researches – with correlation analysis – it could be stated, that the utilized method in Hungary, which based on Dulong's (1880) higher heating value method, developed by element addition, can be suitable with 50 % lower correlation coefficients for the determination of higher heating value of woodmaterial, without bark, of the mini rotation woody crops for energy purposes (4 poplar and 1 willow clones), than the other methods, which were established in the last decads and at present years (GRABOSKY ET BAIN, 1981., CHANNIWALA ET PARIKH, 2002., SHENG ET AZEVEDO, 2005.). The higher heating value and other measurements were made in qualified biomass-research laboratory with 5 repetition.
- 6.2. On the basis of the researches, in mini rotation cultivation the higher heating value of tree of heaven – agreed with MAROSVÖLGYI, disagreed with UDVARDY – seems to reach the higher heating value of black locust. On medium deep, possible shallow arable land, moistured till surface, possibly permanent watereffect, alluvial meadow roll, the higher heating value of mini rotation *Ailanthus altissima* is changing in the intervallum of 19,33-19,78 MJ/kg.
7. In the course of the researches of the lignocelluloses and the mini rotation woody crops for energy purposes, it was stated, that in the interests of the arrangement of the bioenergetic decisions, and the comparison of the solid biofuels, required to develop a FuelBiomass Value Index (FBVI). On the basis of international bibliography, a biofuel

indicator were researched to value the different solid biomass, which can be suitable in Hungary. The FBVI depends on the higher heating value, moisture content, ash content and/or density:

7.1. FuelBiomass Value Index – FBVI:

$$\text{FBVI}=(\text{HV}*\text{G})/(\text{AC}*\text{WC}),$$

HV-Heating Value of solid biomass (KJ/g), G-gravity of solid biomass (g/m<sup>3</sup>), AC Ash Content of solid biomass (g/g), WC Water Content of solid biomass (g/g).

8. On the basis of the pressing measurements of the mini rotation woody crops for energy purposes and other lignocelluloses, it could be stated, that the different features of biobriquetts, made from chip of young poplar roots, are significantly more favourable, than the features of the other lignocellulose biobriquetts, made from wooddust, energygrass, chinese reed, energyhemp.

#### **4. 2. The utilization of the new scientific results**

The scientific results were utilized partly in establish of mini rotation woody crops, in considerable importance national development conceptions, partly in technological developments, and international scientific cooperation.

The international and national analysis research statements were used in:

- NKFP-Forest-Game program, Woodenergetics conception,
- Ministry of Education, KMFP program „The basic material and technology development of biobriquet production” conception.

#### **4. 3. Possible new research fields**

In the effect of the legal system of the European Union and the global, international enviromental prescriptions, the renewables, and the dendromass-based energysources and energy production was significantly increased, and results of present researches, it can be expexted presumably that it will increase in Hungary, too.

On the basis of present research, the following new scientific exercises could be interesting for the future:

- Yield estimation, cultivation technology and harvesting trials and analysis should be continued.
- Measurement protocoll of the mini rotation woody crops for energy purposes must be established.
- On the basis of the present research results, the standard of biobriquet and biopellet in Hungary is to be developed.
- Higher heating value measurements of the wood material of mini rotation woody crops and other new dendromass must be continued.

## 5. Publication in the theme of the dissertation

### Book, chapter of book, university notes

**IVELICS R.:** The harvesting of woody crops.

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