

**University doctoral (PhD) dissertation theses**

**The possibility of changing land use by involving “energy willow”  
(*Salix viminalis* L.) into production in the county of  
Szabolcs-Szatmár-Bereg**

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## 1. Background and objectives of the doctoral thesis

Upon examining the soil and climate features of Szabolcs-Szatmár-Bereg county, as well as the ecological requirement of “energy willow” it can be stated that this county has a significant potential regarding “energy willow” production. In spite of this, according to the national tendency, from 2008 on, the size of areas utilized with “energy willow” has been continuously decreasing.

In order to improve this situation, we were examining which are the areas that could be appropriate for “energy willow” production. Our investigations have been concentrated on two areas. One of them are the areas not utilized in food or feed plant production and permanently set aside, and the other one is the Inter-Szamos-Kraszna flood emergency storage.

During our work, we have examined the legislative environment of the production of this plant, as well as compared the registrations kept about “energy willow” plantations.

In our country, the production practice of “energy willow” (*Salix viminalis* L.) has a history of nearly a decade but the process of production work still has elements that are not entirely clarified. Detailed studies have appeared by renowned experts about the production technology of this plant; however, so far these works have dealt little with the morphological features of “energy willow”, the optimal propagation length, plant protection as well as drying the canes in sheaves. Therefore, during our research, we placed special emphasis on these areas. Marginalization of plant protection of “energy willow” is also supported by the fact that, as of day, the plant still has no plant protection product authorized on arable land in Hungary.

### Objectives:

- One of the objectives of the thesis is to compare the different registrations of arboreal energy plantations in order to find the possible differences.
- A further objective of the thesis is to specify in the county of Szabolcs-Szatmár-Bereg the size of cultivated areas where there has been no arable land plant production for at least three years, as well as to define the area out of this that could be utilized in “energy willow” production in order to rationalize land use.
- On the basis of setting up a sample model, we wish to make a proposal in order to change the usage of arable land at the Inter-Szamos-Kraszna flood emergency storage by involving “energy willow” into production.

- We have set the aim to carry out investigations at two areas with different features (edaphic feature) (Mátészalka and Nyíregyháza), which could provide data for the formulation of a later, complex production technology adapted for local circumstances. We have set out the following aims related to production technology:
  - specification of the ratio of arteries of woody cuttings of different lengths on sand soil,
  - to specify the weed flora established in the plantations; furthermore, configuration of the weed regulation experiment with chemicals applying not yet authorized herbicide combinations,
  - to investigate the insect species settled into the “energy willow” plantations and describe the damage caused by them,
  - the specification of fungal species appearing in the course of etiologic investigations,
  - investigation of the drying dynamics of canes tied in sheaves and ordered in cones,
  - carrying out production-biological measurements,
  - on the basis of the measurement results, specifying the connections between each morphological feature.

By building on each other, the researches related to the formulated objectives could create the conditions for new scientific results and practical solutions. They can contribute to the establishment of rational land use in Szabolcs-Szatmár-Bereg county.

Following the analysis of the special literature related to the subject, we have set the initial hypothesis of our investigations:

H<sub>1</sub>: It can be supposed that there are significant differences between the land use data of the different registrations on arboreal energy plantations.

H<sub>2</sub>: Szabolcs-Szatmár-Bereg county has an area of 3,500 to 4,000 hectares that could be well utilized for the production of “energy willow”. These are primarily agricultural areas permanently set aside, as well as a significant part of the Inter-Szamos-Kraszna flood emergency storage.

H<sub>3</sub>: in the case of weed control implemented pre-emergently, appropriate weed cutting effect can be reached without damages in “energy willow” (*Salix viminalis* L.) when using so far not authorized herbicide combinations.

H<sub>4</sub>: Willow-specific and polyphagous animal pests settle into the “energy willow” plantations, the specification of the amount of settling of which could be important for later successful protection.

H<sub>5</sub>: The sensitivity to rust pustule (*Melampsora larici-viminalis* Klebahn) various “energy willow” (*Salix viminalis* L.) species is different.

H<sub>6</sub>: In the case of harvesting smaller tables manually, an appropriate way of storing and drying “energy willow” can be if we store the cut canes gathered in sheaves, ordering them in cones, at the side of the table.

H<sub>7</sub>: Even though “energy willow” (*Salix viminalis* L.) bears being covered by water permanently, this leads to significant reduction in biomass yield.

H<sub>8</sub>: The individual morphological features of „energy willow” (*Salix viminalis* L.) are related to the expected yield to a different extent. The diameter of the canes measured in the stem has the closest relationship with the yield.

During our research, besides proving our initial hypotheses, we have been searching for an answer to the questions below:

Q<sub>1</sub>: How does the size of areas utilized in “energy willow” change on the basis of land use data in Hungary, as well as in the county of Szabolcs-Szatmár-Bereg?

Q<sub>2</sub>: To what extent does the arteries % change by increasing the length of the woody cuttings?

Q<sub>3</sub>: How do the various nutrient-supply operations influence the extent of weed coverage and the composition of the dominant weed species?

Q<sub>4</sub>: What fungal species appear in the “energy willow” plantations?

## **2. Research methods**

### **2.1. The methods of land use data collection**

In order to assess the current situation of the land use of the Inter-Szamos-Kraszna flood emergency storage, as a first step, we have specified the physical blocks of Vásárhelyi Plan on the Inter-Szamos-Kraszna flood emergency storage area, as well as their individual block identifier with the help of the MePAR internet browser. Afterwards, in MePAR, by using the detailed data sheets stored from the blocks, we have specified the characteristic classifications of the area of the involved blocks characteristic important from the aspects of nature protection. Then, by using the map database of the Plant- and Soil Protection

Directorate of the Governmental Department, we have assessed the topography of the flood emergency storage.

In the next step, with the help of the experts of the Upper-Tisza Environment Protection and Water Directorate, due to enforcing water management criteria, we have identified the areas where the roughness caused by the plant coverage should be reduced to the lowest level possible in order for the water to flow without obstacles.

Except for the areas sensitive from the aspect of nature protection, as well as a important due to water management, by assigning a sample area, we have specified the current land use of the flood emergency storage on the basis of the utilizations reported in the year 2012.

During the investigation related to “energy willow”, we have compared the registration published by the National Food Chain Safety Office (with its Hungarian abbreviation: National Food Chain Safety Office) on their official website and the area data received from the Central Statistical Office as accumulated on the basis of the utilization directions submitted when requiring the integrated area-based subsidies for the year 2012.

## **2.2. Experiments related to the individual elements of the production technology**

We carry out our experiments at two sites. In Mátészalka, in the “energy willow” plantation established by “Szalka-Pig” Kft in 2005, which is situated on alluvial soil, as well as in Nyíregyháza, in the Nyíregyházi Research Institute and Experimental Farm of the Central of Agro-science of the University of Debrecen (hereinafter as DE ATK) where there is waterlogged sand soil. When choosing the site for the investigations, it was important that the ecological features of the sites represent the agricultural sites of Szabolcs-Szatmár-Bereg county that could be taken into account from the aspect of “energy willow” production.

### **2.2.1. Method of the experiment related to the length of the “energy willow” cuttings intended for planting**

On the 25<sup>th</sup> February 2006 (in the rest period), in Mátészalka we cut straight-thread canes with intact bark and carried them to the site of planting (Nyíregyháza). Few days before the planting, we have chopped the canes with the help of scateurs. Afterwards, we have soaked it in water for 2 days. On the day of the planting, we placed the upper end of the cuttings into melted paraffin. In the experimental plantation, we have applied single-row planting system with a row distance of 1 m and a cane distance of 0.5 m. For the experiment, we have assigned 3 plots of 2 m x 25 m, where we planted 100 cuttings of 20, 30 and 40 cm

into each. The planting has been carried out manually. The rows have been measured by a measuring tape and sticked, then the sticks have been tied together by a rope. Placing the cuttings into the soil has been done according to these. The cane distance has been measured by a 50-cm bar. On the 4<sup>th</sup> week following the planting, we have counted the extended stems, and on the basis of this, we have specified the arteries %.

### **2.2.2. Methods of the plant protection experiments of „energy willow” (*Salix viminalis* L.)**

In the Mátészalka "energy willow" plantation of „Szalka-Pig” Kft, weed regulation experiment has been set in May 2005. The size of the individual plots was 22.5 m x 22.5 m (506 m<sup>2</sup>). 3 product combinations have been used in 2 dosages each. The dosages of the applied herbicides have been selected in accordance with the data of the license document. The number of repetitions per treatment was 4. At the control area, between the rows hoeing has been carried out twice by machines and, in the rows, twice manually.

The assigned quadrants have been evaluated twice every 14 days, with the Balázs-Újvárosi weed recording method, then compared our data with each other and with the data of the mechanically treated plots.

On the basis of the Mátészalka investigation results, we have also carried out the weed regulation experiment in the “energy willow” plantation of the Nyíregyháza Research Institute of University of Debrecen (DE ATK). Due to the size of the plantation, the size of the assigned plots was 4 x 10 m. The earlier used herbicides have been completed with two new combinations. The number of repetitions in Nyíregyháza was also 4. As a control, this time we also used an area hoed twice. The recording method was identical with the one used in Mátészalka.

The applied herbicide combinations are summarized in table 1.

**Table 1: Herbicides applied for the Mátészalka and Nyíregyháza “energy willow” pre-emergent weed regulation experiment**

<b>Serial number</b>	<b>Name of the products</b>	<b>Location of the experiment</b>
1.	Click FL + Dual Gold 960 EC	Mátészalka + Nyíregyháza
2.	Callisto 4 SC + Dual Gold 960 EC	Mátészalka + Nyíregyháza
3.	Stomp 330 + Dual Gold 960 EC	Mátészalka + Nyíregyháza
4.	Goal Duplo + Dual Gold 960 EC	Nyíregyháza
5.	Successor T + Dual Gold 960 EC	Nyíregyháza
	Control = 2x hoed area	Mátészalka + Nyíregyháza

After the weed regulation experiments, we continued the weed recording at the control areas in order to localize the weed flora of the investigated areas.

At Nyíregyháza, we noticed how different the weed coverage and weed composition was at the areas of the different experiments carried out in the research institute’s “energy willow” plantation. In order to specify the factual difference, we have assigned 4 recording quadrants each in the tables treated with fertilizer and sewage sludge compost. In this case, a twice hoed area served as control.

During the weed regulation experiments, we observed the settling of aphids in the plantation. In our research work, special emphasis has been placed the studying of the aphid species appearing in the plantation species, as well as the measurement of their populations. At the recording carried out in the spring, at uncut areas, we observed the settling of significant amounts of bark aphids. Due to their appearance in high numbers, we carried out the investigation of the settling of bark aphids, as well.

The rest of the pests have been investigated by randomly observing the plantation twice every season (without assigning recording sites). These observations have been carried out in both plantations. We have not identified the extent of the settling of the rest of the pests just registered their presence. We have made photos and descriptions on the damages caused by them on the host plant.

In the course of the “energy willow” plant protection observations we could not help noticing a fungal species causing rather serious plant diseases, rusts (*Melampsora*). We have carried out etiologic recordings regarding the rusts in the case of 6 species. 4 recording quadrants (1 x 1 m), including 5 stems have been assigned at random. On each stem, we have carried out the counting of infected mushrooms. From the top of the sprout towards its stem, we have investigated 10 leaves on each. For the valuation, we have used the value numbers included in table 2.

**Table 2: Value numbers used in the case of etiologic recordings**

<b>Value number</b>	<b>Symptoms</b>
0	The leaf is completely healthy, no traces of pathogens can be found
0.5	A small but well recognizable amount of uredo and teleuto sites can be found on the leaf, not more than on 30% of the leaf surface
1	The disease is striking, really strong propagation formulae of fungi can be found on the infected leaf, between 30 to 50 %
2	The leaf is over 50 % infected

### **2.2.3. The specification method of the drying dynamics of canes cut in the stem, in sheaves, stored outdoors**

Following the manual harvest, we tied the cut canes into sheaves, and then placed the sheaves into cones at the side of the table. Every week between the 13<sup>th</sup> December and the 5<sup>th</sup> of July, we took a random sample from the cones. A sample contains an average of 8 to 10 canes. The canes have been cut into 30-cm pieces, they have been marked prepared for laboratory investigation where, with the help of the drying oven, we have specified their moisture content.

### **2.5. Methods of the production-biological investigation of willow plantations**

A productivity investigation has been carried out in both experimental plantations by the measurement of one-year cane yield of two-year-old stems. As a first step, recording plots have been assigned. When assigning, we took into consideration that, in Mátészalka double twin row planting took place, therefore, the recording plot consisted of 4 rows. Its breadth has been specified by the plantation's row distance, and its length, by the stem distance applied when planting, as well as the number of samples, which was 16 stems per plot. On the basis of these, the size of the recording plots in Mátészalka was 5.2 m x 7.2 m (37.4 m<sup>2</sup>), in Nyíregyháza, 4 m x 8 m (32 m<sup>2</sup>).

The number of recording plots has been specified according to the size of the plantation; thus, in the 12.3 ha plantation in Mátészalka, 8, whereas in Nyíregyházán, 4 have been assigned. The sites of the plots have been selected in a way that their distribution would be even on the entire area; this way, well representing the features of the plantation.

There is a part in the Nyíregyháza plantation which, due to its deep location, is temporarily waterlogged (Figure 1).

In each plot, 4 stems have been selected. The stems have been cut one by one, by branch cutting scissors and measured at the side of the plantation. We wrote down the number of canes to be found on the stems, then with the help of a measuring tape, we measured their length. Afterwards, with the help of a calliper, we have measured the diameter of the canes at the stem and at the height of one and a half meters.



Figure 1. **Waterlogged area of deep location in the Nyíregyháza “energy willow” plantation**  
(Photo: own photo)

### **3. The new scientific results of the thesis**

The results and the conclusions, as well as the proposals have been compiled in the order of the hypotheses listed in chapter 1. In relation with the given hypothesis, the answers provided to the questions asked at the beginning of the investigation are listed as in relation with each other.

#### **3.1. Results of the land use investigations**

*H<sub>1</sub>: It can be supposed that there are significant differences among the land use data of the different registrations kept about the arboreal energy plantations.*

In 2012, the National Food Chain Safety Office has registered 2,338 ha arboreal energy plantation in connection with its authorization procedure. According to the data collection of the Central Statistical Office, in 2012 there were 2,745 ha of energetic tree plantations in Hungary. As opposed to this, when requiring the integrated area-based subsidy, the farmers have reported arboreal energy plantations on 6.208 ha.

This drives us to the conclusion that several thousands of ha of energy plantations have been established in Hungary without official authorizations. One of its reasons could be that since the decree 71/2007 (14<sup>th</sup> April) of the government on the authorization procedure of

the arboreal energetic plantations, it has been modified almost every year, altogether 7 times, which makes traceability difficult and decreases legal security. Another reason could be that the authorization procedure poses significant administrative burdens on the farmers. Due to the above, the simplification of the procedure of registration and the on the long term fixing of its framework rules is recommended.

In order for the authorization to take place in as high numbers as possible among the so far unreported plantations, we are making the following proposal. In our opinion, it would be useful to determine as the condition for the payment of the integrated area-based subsidy, sending a copy of the official authorization, which the farmer should fulfil simultaneously with submitting the request. This would motivate towards the acquisition of the licenses; furthermore, it could be avoided that a plantation without the appropriate authorization receive subsidy.

In order to restrict the establishment of new plantations without license and improve the efficiency of the controls, we suggest to join the data of the National Food Chain Safety Office and the Agricultural and Rural Development Agency on the arboreal energy plantations in a single registration system, which would have an integrated structure and both parties would have access to it. To this, the Agricultural and Environmental Information System to be introduced in the near future could be perfectly appropriate. We would find it worth to consider that a table-level registration on the arboreal energy plantations would be established within the Agricultural and Environmental Information System.

Furthermore, we suggest that following the creation of the integrated data set in the Agricultural and Environmental Information System, the studies and plans created on the basis of information earlier only available to the Central Statistical Office and the National Food Chain Safety Office, should be updated and supervised on the basis of the new database.

*Q1: How does the size of the areas utilized in “energy willow” on the basis of land use data in Hungary, as well as in the county of Szabolcs-Szatmár-Bereg?*

On the basis of the “energy willow” national and county time-scale land use data, we have specified that the after the initial quick growth, within an extremely short period of time, the size of the production areas involved by the plant has continuously decreased. While, in 2008, the size of “energy willow” plantations in our country was 1,476.4 ha, in 2012 only 1,201.5 ha, and 2014 merely 859.5 ha. This means that within a few years (between 2008 and 2012), 200 to 250 ha newly settled plantations not older than 3 years have been closed, despite the fact that the planting costs are rather high. Regarding the fact that payback time

according to the professional literature is approximately 5 years and maintenance time is 15 to 20 years, this reduction is especially surprising. For the future it would be important to reveal the reasons for the closing of the plantations. A method appropriate for that could be a questionnaire survey. The closing of young plantations draws the attention to the importance of the period before the establishment of the plantations, the thorough planning taking into consideration every possible circumstance.

When investigating the ecological requirement of “energy willow” and the features of Szabolcs-Szatmár-Bereg county, it can be stated that a significant part of the county is appropriate for the production of this plant. This is well reflected in the fact that 81 % of the county’s arboreal energy plantations are “energy willows”. In 2012, in the county of Szabolcs-Szatmár-Bereg, “energy willow” production was taking place on 160.2 ha. With this area size, after Tolna and Bács-Kiskun county, our county is at the third position among the counties. The national tendency of the reduction of the number of areas under production can be seen in this county, as well. When investigating the geographical situation of the settlements involved in “energy willow” productions, it can be stated that the most significant “energy willow” plantations have been established at the Szatmári-plain, as well as in the southern and western parts of Nyírség (Figure 2).

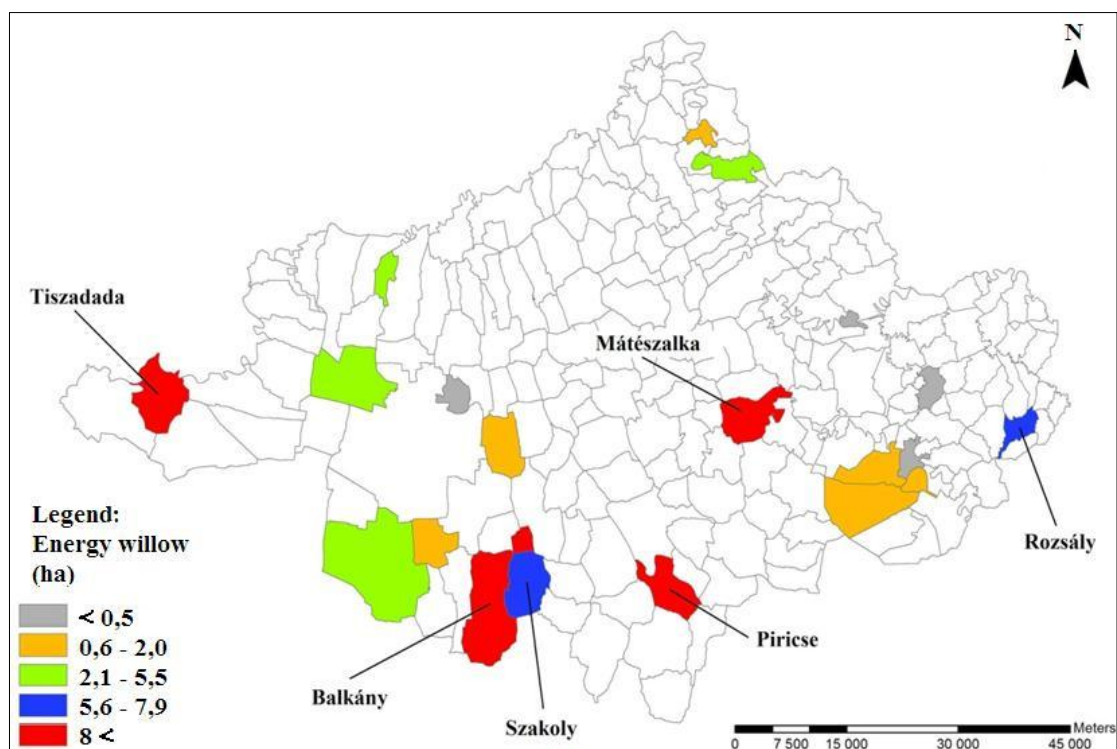


Figure 2. Settlements involved in “energy willow” production in the county of Szabolcs-Szatmár-Bereg in 2012  
(Source: own edition)

$\frac{1}{3}$  of all the “energy willow” plantations have unfavourable features, and they have been established on flood-stricken areas, as well. This proves that, in the county, this plant species plays a great role in the utilization of croplands involved with different environmental disadvantages. Knowing this, we have examined where and what sizes of such areas can be found in the county. Primarily, we were focusing on areas permanently set aside and Inter-Szamos-Kraszna flood emergency storage established in the framework of the programme Vásárhelyi Plan’s Further Development.

*H<sub>2</sub>: Szabolcs-Szatmár-Bereg county has an area of 3.500 to 4.000 ha which could be well utilized with “energy willow” production. These are primarily agricultural areas permanently set aside, as well as a significant part of the Inter-Szamos-Kraszna flood emergency storage.*

We have found that, in the county of Szabolcs-Szatmár-Bereg the size of areas set aside was between 4,200 and 5,500 ha in the period between 2010 and 2012. This is smaller than the data published by the scientific literature.

The size of those arable areas permanently set aside which could be appropriate for the production of “energy willow” is 3,171.17 ha. This is over twenty times more than the current production area. We have specified the proportion of the permanently set aside areas compared to the total area at the level of settlements (Figure 3).

Regarding the location of these areas, as well as their average table size, we have come to the conclusion that, in the county of Szabolcs-Szatmár-Bereg, the totality of permanently set aside areas do not mean a significant potential from the aspect of “energy willow” or any other energy plant production.

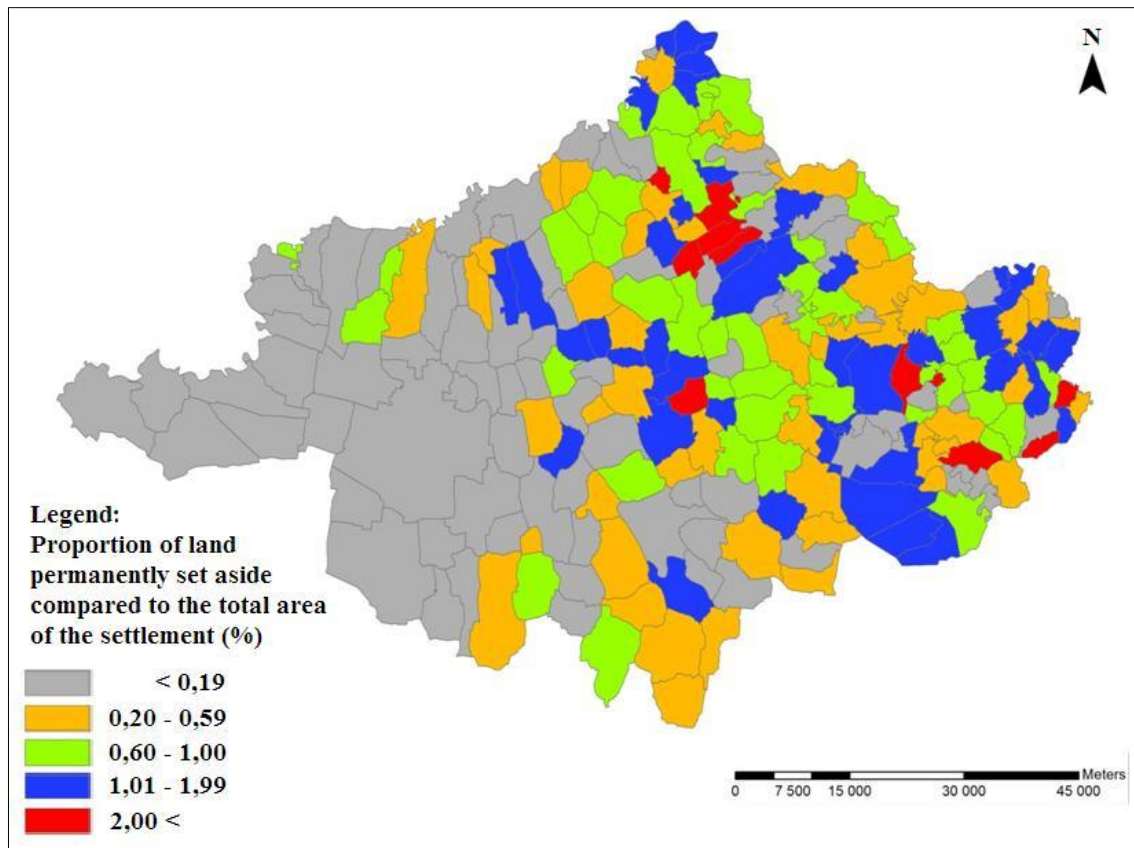


Figure 3. **The proportion of the permanently set aside areas compared to the total area of the settlement in the county of Szabolcs-Szatmár-Bereg**  
(Own edition)

At the area of the Inter-Szamos-Kraszna flood emergency storage, on the basis of model set by us, land use adjusted to the exceptional circumstances of the storage, a increasing the security of production at a significant extent by involving “energy willow” production could be implemented at an area of 1,300 to 1,350 ha. The storage itself nearly offers a possibility for “energy willow” production as  $\frac{1}{3}$  of the county’s arable area not utilized for 3 years. On the basis of the model, at the area of the storage, the total energy value to be produced out of “energy willow” is 210,000 to 270,000 GJ per year.

We suggest that the received results be taken into consideration when supervising the plan of Inter-Szamos-Kraszna flood emergency storage land use.

During the investigation, we have found that the average land size of the area permanently set aside, as well as the Inter-Szamos-Kraszna emergency storage area under temporary flooding is rather small (2,1 ha). Taking into account size efficiency, as well as the fact that unemployment in the region significantly supersedes the national average, we have

come to the conclusion that there implementing each element of the production technology manually would make sense.

### 3.2. The results of production technology experiments

*Q<sub>2</sub>: How does the arteries % change when the length of woody cuttings is increased?*

Scientific writers usually determine the installable normal cutting length between, depending on the type of willow and the circumstances of the growing land between 15 to 45 cm. On the basis of the results of our experiment implemented in connection with the propagation length (table 1), we have found that on the sand soil of the Nyíregyháza plantation, among given circumstances, the differences between the arteries % of the cuttings of different lengths (20, 30, 40 cm) were of such a small extent that their statistical verification has not been carried out.

Table 1: Arteries percentages of cuttings of different lengths in the case of species S-311

Cutting length (cm)	Arteries %
20	95.2
30	96.8
40	97.1

We find it probable that we would have experimented greater differences if we leave the paraffin treatment and the soaking of the cuttings for 2 days. We have found that when establishing the Nyíregyháza experimental plantation (except for the 2 experimental plots), the application of the 20-cm cuttings proposed by *Marosvölgyi B. (2005)*, *Lőrincz S. – Tóth Sz. (2006)* and *Gyuricza Cs. (2010d)* has been a good decision. This way, the specification of the optimal cutting length is particularly important because too much length has no advantages but the production of the propagation has a higher flat cost.

*H<sub>3</sub>: In the case of weed control implemented pre-emergently, with certain (so far unauthorized) herbicide combinations, appropriate weed control effect can be reached without the damaging of “energy willow” (Salix viminalis L.).*

We tried to find a solution for chemical weed regulation with so far unauthorized herbicide combinations, and we have found that the herbicides pre-emergently applied by us had rather good efficiency degrees when taking care of “energy willow” plants among the circumstances of Nyíregyháza and Mátészalka plantations. The best results were reached with

the agent combinations of mesotrione + S-metolachlor, as well as a pethoxamide + terbutylazine + S-metolachlor. We accept the opinion of Gyuricza Cs. (2009b) and Kraczmajer R. (2006) who earlier proposed the application of these agents.

We would like to note that in the course of mechanically implemented weed control, none of the herbicides treatment could provide a better and safer result. We find it necessary to support the results of the weed regulation experiments with long-term experiments.

*Q<sub>3</sub>: How do the different nutrient-supply operations influence the extent of weed coverage and the composition of the dominant weed species?*

In the course of the recordings, we have found that the weed coverage and weed flora composition of the experimental plots fertilized, treated sewage sludge and not nutrient-replaced showed significant differences. This should be taken into consideration when formulating plant protection technology.

*H<sub>4</sub>: In the “energy willow” plantations, willow-specific and polyphagous animal pests settle into, the specification of the extent to which those settle in could be important in terms of later successful protection.*

We have paid particular attention to the settlement of homogenous insect pests of these plantations of short-term cultivation, forming large surfaces. We have found that as early as in the second year such insect communities settled in the “energy willow” plantations that are partly characteristic of the willow species, such as small willow aphid (*Aphis farinosa* Gmelin /= *A. saliceti* Kaltenbach/) (Figure 4), the large willow bark aphid (*Tuberolachnus salignus* Gmelin), the dwarf willow leaf aphid (*Plagioderia versicolor* LaiCharting), the willow oily leaf beetle (*Galerucella lineola* Fabricius), the blueberry leaf roller (*Cheimophila salicella* Hübner) and the redtipped clear wing (*Synamthedon formiceaformis* Esper) as well as partly polyphagous insects, such as the American white fall webworm (*Hyphantria cunea* Drury), the May cockchafer (*Melolontha melolontha* L.), and the American buffalo treehopper (*Stictocephala bisonia* Kopp et Yonke) (Figure 5).



Figure 4 **An ant feeding on honey dew selected by green willow-leaf aphids (*Aphis farinosa* Gmelin /= *A. saliceti* Kaltenbach/) on an “energy willow”**  
(Source: own photo)



Figure 5 **The American buffalo treehopper’s (*Stictocephala bisonia* Kopp et Yonke) image and damage image**  
(Source: own photo)

We have experienced that the natural enemies of the settling insect species damaging the willows have also appeared in the plantations such as the larva of the seven-spotted ladybird (*Coccinella septempunctata* L.), the harlequin ladybird (*Hamonia axyridis*) and the common scorpionfly (*Panorpa communis*). Insect species unidentified by us also parasitized the great willow-bark aphid. We have implemented stock protection twice against the insect pests. Since we have executed our observations in relatively young plantations; therefore, the biodiversity of the pests is expected; therefore, continuing the observations is necessary.

*H<sub>5</sub>: The sensitivity of the rusts (Melampsora larici-viminalis Klebahn) of different „energy willow” (Salix viminalis L.) species is different.*

By the calculation of the infection index, we have specified the sensitivity of 6 “energy willow” species against willow rust. “Tordis”, “Tora” and “Sven” were the most resistant against rust, while “S-311” has proven to be the most sensitive. The rusts (*Melampsora larici-viminalis* Klebahn) (Figure 6) appearing in the 2-year-old “energy willow” plantation have not yet caused any serious plant healthy problems but, under our circumstances, their uredo and teleuto spores have developed, as well. The international scientific literature draws attention to the significant amount of damages caused by willow rust. We have not experienced this either in Nyíregyháza or in Mátészalka.

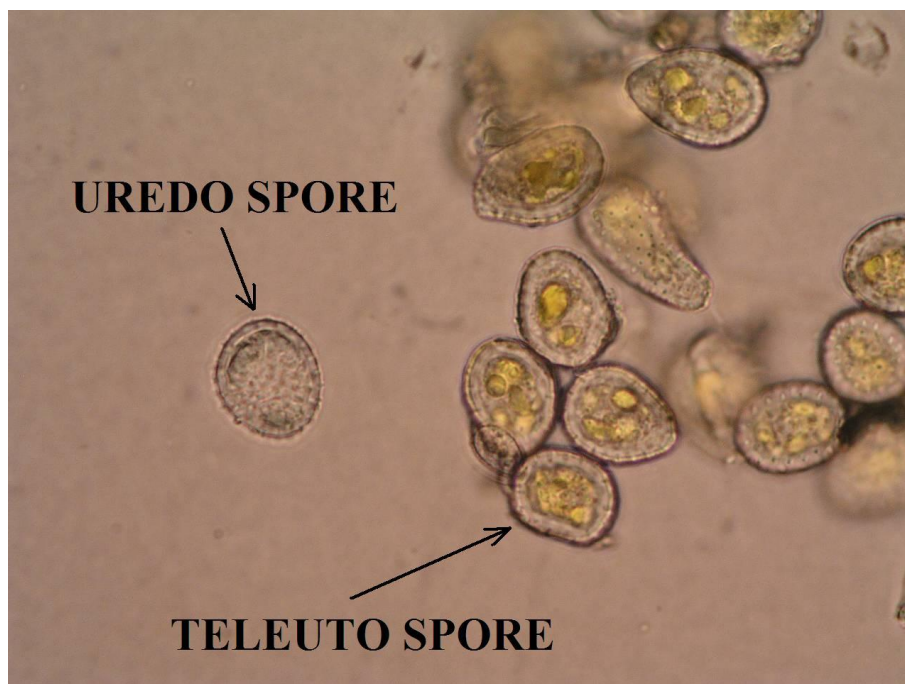


Figure 6. Rust uredo and teleuto spores of the *Salix viminalis* L. willow pests (*Melampsora larici-viminalis* Klebahn)  
(Source: own photo)

*Q4: What fungal species appear in the “energy willow” plantations?*

In the course of the etiologic investigation of the “energy willow”, we have found that, at the area of the plantations, along with 4 symbionts 25 saprophytes, 5 optional parasites and parasite fungi have appeared, as well (table 2). These fungal species grew on the growing soil, on the older tree parts, on the young canes, as well as the sprouts and mushrooms. 3 parasite fungal species having appeared on the tree part, mean potential danger in the case of stems injured during the harvest; therefore, from a plant etiologic aspect, we find it necessary to execute the harvest along with the smallest stem damage possible, and we also suggest wound treatment at the level of the stock in order to avoid possible infections of greater extent. During the recordings, we have registered 4 fungal species living in symbiosis with the willow, i.e. in mychorriza form. No protection has been implemented against the settling fungi.

**Table 2: Parasite fungal species recorded in the Mátészalka “energy willow” plantation**

<b>Place of recording</b>	<b>Name of fungal species</b>	<b>Lifestyle of fungal species</b>
On 1 to 3 year-old tree parts	<i>Nectria gallrathera</i>	Parasite
	<i>Stereum rugosum</i>	Parasite
	<i>Glomerella miyabeana</i> (anam.: <i>Colletotrichum gloeosporioides</i> )	Parasite
On mushroom sprouts	<i>Uncinula adunca</i>	Parasite
	<i>Melampsora salicina</i>	Parasite

*H<sub>6</sub>: In the case of manual harvest of smaller-size tables, an appropriate way of the storage and drying of the “energy willow” could be if the cut canes gathered into sheaves are stored in cones, at the side of the table.*

On the basis of the results of our drying experiments, we have found that the willow cane stored in sheaves and dried at the side of the table, by the end of May or the beginning of June, reaches the 18 to 20%- of moisture content required for the utilization for energetic purposes (Figure 7). The 48 to 50 % moisture content of the canes measured at harvest does not decrease under 40 % before the middle of March. This leads us to the conclusion that if the “energy willow” canes are cut at the time considered optimal by the professional literature (November to March) then the harvest time will have no effect on the drying time in case we are applying this method.

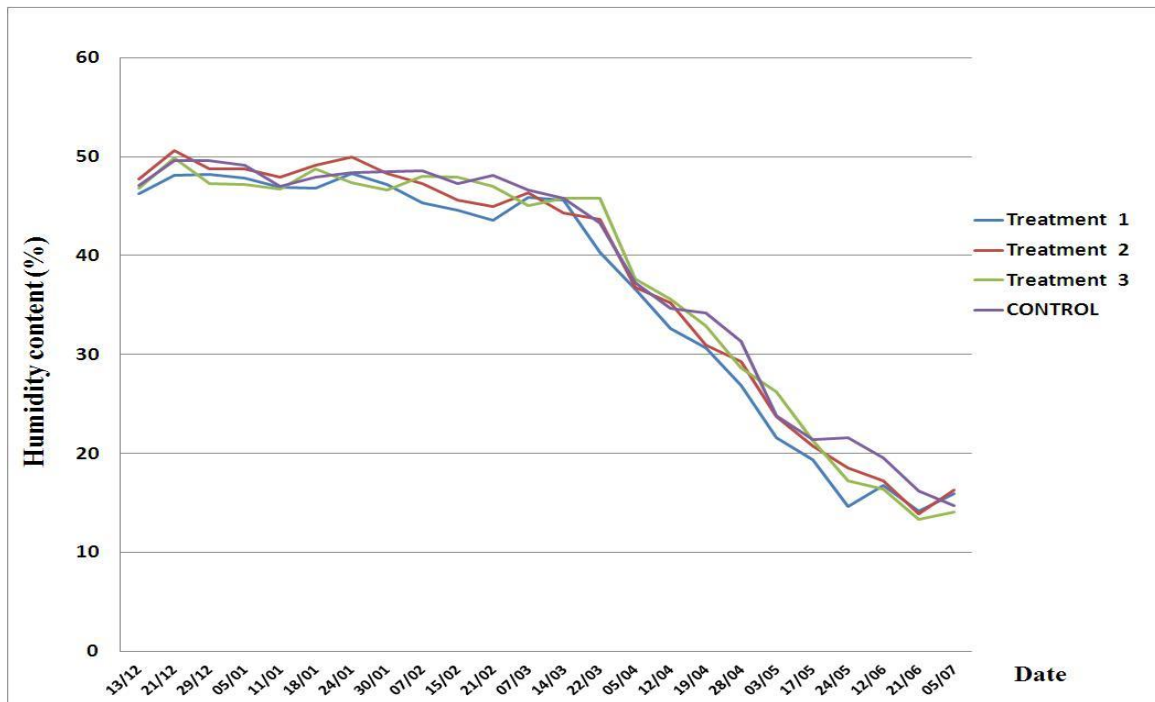


Figure 7. The drying dynamics of "energy willow" canes gathered into sheaves, ordered in cones

### 3.3. The results of production-biological investigations

*H<sub>7</sub>*: Even though it bears continuous water coverage, the "energy willow" (*Salix viminalis* L.) will suffer a significant amount of reduction in its biomass yield.

The results of the production biological investigations (table 3) have shown that the "energy willow" tolerates longer water coverage lasting for 2 to 3 month; however, it will produce significantly smaller yields, which can greatly influence its productivity.

Table 3: The results of production-biological investigations in comparison according to production areas

Name	Nyíregyháza higher area	Nyíregyháza deeper, waterlogged area
Wet mass (t/ha)	19.0	16.1
Moisture content (%)	47.45	51.58
Dry mass (atro t/ha)	9.98	7.80
Average height of canes (m)	238.50	188.70
canes at the stock (cm)	12.37	10.42
Average diameter of canes at a height of 1.5 m (cm)	8.67	6

On the basis of our experiences, we accept the statement of Tompa K. – Bründl L. (1964) according to which *Salix viminalis* L. is a very air demanding plant; therefore, it cannot be planted to an area of stagnant water or (for a longer period of time), to an area of high soil water. On the basis of the previous, we suggest that when selecting the production area of “energy willow” and calculating the expected yields, these should be taken into consideration by the experts.

*H<sub>8</sub>: Certain morphological features of the “energy willow” (Salix viminalis L.) are connected to the expected yield to different extents. The diameter of the canes measured in the stem has the closest relationship with the yield.*

We have also examined the connections between the parameters measured in the course of the production-biological investigations. By the method of correlation analysis, we have specified the type of relationship that exists between the different features (Table 4).

**Table 4: Connections between the different morphological features of “energy willow”**

		Wet mass of stems	The number of canes	Average height of cane	Diameter average at the stem	Diameter average 1.5 m
Wet mass of stems	Pearson Correlation	1	0.754**	0.833**	0.897**	0.878**
	Sig. (2-tailed)		0.001	0	0	0
	N	16	16	16	16	16
The number of canes	Pearson Correlation	0.754*	1	0.630**	0.632**	0.617*
	Sig. (2-tailed)	0.001		0.009	0.009	0.011
	N	16	16	16	16	16
Average height of cane	Pearson Correlation	0.833*	0.630**	1	0.955**	0.969**
	Sig. (2-tailed)	0	0.009		0	0
	N	16	16	16	16	16
Diameter average at stock	Pearson Correlation	0.897*	0.632**	0.955**	1	0.931**
	Sig. (2-tailed)	0	0.009	0		0
	N	16	16	16	16	16
Diameter average 1.5 m	Pearson Correlation	0.878*	0.617*	0.969**	0.931**	1
	Sig. (2-tailed)	0	.011	0	0	
	N	16	16	16	16	16

Remark: \*\* Correlation significant at level 0.01; \*Correlation significant at level 0.05  
(Source: own calculation – SPSS)

We have found that cane yield is in a strong stochastic relationship with the number of canes, the average height of the canes, their diameters and average height. According to our calculation, the yield is in the closest connection with the diameter measured in the stock (the extent of the correlation: 0.897); thus, our measurements do not support the results of *Nordh , N-E.* (2005), according to which the diameter at the height of 105 cm is in closest connection with the yield. In spite of this, the yield estimation formula set out by him could be a good starting point to create an equation adapted to the domestic circumstances.

We have found that the diameter of canes is in close connection with the height of canes, and that the diameter measured at the stock is in a closer correlation with height than that at the height of 1,5 meters. Even though *P Vlasák* and his colleagues (2008) have not measured the diameter of the stock at exactly the same height since they carried out their investigation at the height of 0.3 meters and 1 meter, they have received similar results.

When processing the professional literature, a number of advantages of „energy willow” production have been presented in detail, as well as the important role the plant plays in decentralized energy production, in country-side employment, in sustainable land use, in nature-friendly sewage cleaning and in the utilization of degraded areas. Despite all this, the size of the areas utilized with “energy willow” have continuously decreased in the past 6 years. In order to reverse this process, in order to use the potential in the country, a detailed situation analysis will be needed, which would cover the entire product line, reveal the problems , as well as a well-thought development conception to be used for practice, having a systematic approach.

By processing the part of the professional literature related to our investigations by publishing our research results, we would like to provide extra data to this.

From the point of view of the development of “energy willow” production, we find it important to unite our research results related to production technology, as well as to rethink the registration and authorization system, to make the legislative regulation environment more stable and more calculable and the decrease of administrative burdens related to production.

#### 4. New scientific results

1. We have revealed the differences in the different registrations of arboreal energy crops and “energy willow”. At a national level, the data published in the various registrations, regarding arboreal energy plantations, have a deviation of 55.8 to 62.3; whereas, in the case of „energy willow”, of 36.4 to 63.5 %. According to our research, the amount of deviations justifies the review of registration systems.
2. We specified the size of the lands suitable for the establishment of short rotation “energy willow” plantations permanently set aside, as well as their most important parameters in Szabolcs-Szatmár-Bereg county. Based on our results, the size of the lands suitable for the growing of “energy willow”, permanently set aside in Szabolcs-Szatmár-Bereg county is 3,171 ha.
3. We have formulated a model within the Inter-Szamos-Kraszna flood control storage for the realization of the short-term cultivation “energy willow” plantations. According to this model, the size of the lands suitable for usage with “energy willow” plantations is 1,300 to 1,350 ha (25% of the area of the reservoir). The model elaborated for the utilization of the flood-control reservoir of the Inter-Szamos-Kraszna can be well applied for the elaboration of the utilization of the rest of the water reservoirs to be established in the framework of the Programme of the Further Development of Vásárhelyi Plan.
4. We have provided data for the plant protection of “energy willow” (*Salix viminalis* L.). In the plantations examined by us, we have recorded 34 species of fungi (5 out of which are parasites), 5 obligates, as well as 6 polyphagous pests. All of these can become factors significantly decreasing production in case they should have an occurrence in great proportions.
5. We have specified the connections between the individual production-biological features of “energy willow” (*Salix viminalis* L.). According to our calculation, the cane yield in the closest correlation, significant at the value of 0.01 with the diameter measured at the stem ( $r = 0.897$ ).
6. We have specified the drying dynamics of “energy willow” canes (*Salix viminalis* L.) tied in bundles and stored at the edge of the farmland. In the first 3 months of the drying, the reduction of moisture content was at its minimum. In the 2 months following this, an intensive water release took place, and then in the last 2 months, the pace of water release slowed down again. Following the December harvest, by the end of the 7<sup>th</sup> month, the tested samples got into an air dry state. The moisture content

measured at the time of the harvest, at 48 to 50 %, decreased to 12 to 14 % by the middle of July.

## **5. The practical utility of the results**

1. We have revealed the deviations hidden in the databases made about the arboreal energy plantations, as well as “energy willow” plantations and their possible causes; also, we have made a proposal for the registration of the arboreal energy plantations in a single system. The results of our researches provided us a stronghold for the execution of the review of the registrations.
2. Our results related to the areas permanently set aside led to the rethinking of the change of land use in Szabolcs-Szatmár-Bereg county, as well as the establishment of the arboreal energy plantations, and the planning of the creation of the village heating works.
3. The result of the investigation directed at the utilization of the Inter-Szamos-Kraszna flood-control reservoir contributed to the preparation of the reservoir’s land-use plan. The method presented by us can be adapted to other flood emergency reservoirs, as well; thus, it can be used well for the planning of the complex utilization of the temporary water reservoirs established within the frameworks of the Vásárhelyi Plan taking into consideration the amount of the temporary water coverage.
4. The result of the research implemented at the area of the plant protection of “energy willow” (*Salix viminalis* L.) provide data for the development of a future plant protection technology, adapted to the local circumstances, which could form part of a complex production technology.
5. The results of the examination of the connections between the various production-biological features have provided guidance for the formulation of a yield estimation method and the selection of a species adapted for the growing area.
6. The investigation of the dynamics of water release has proven that, under natural circumstances, the “energy willow” (stored at the edge of the field) cane harvested in the winter, tied in bundles and arranged in cones releases its moisture content 1 or 2 months before the next heating period. By applying the tested method, the storage and shipping of the canes does not require any significant investment.

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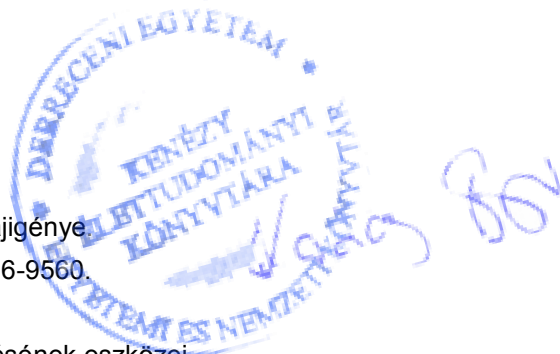
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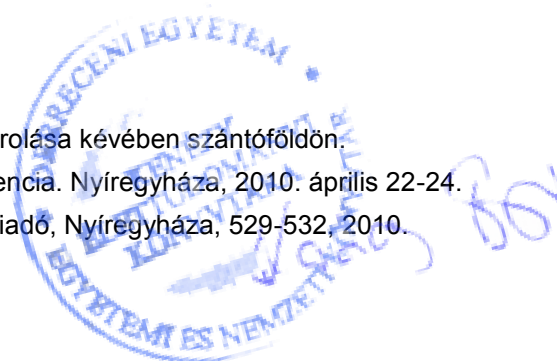
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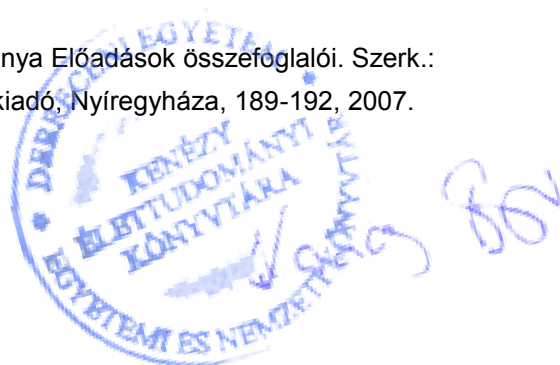
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The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of Web of Science, Scopus and Journal Citation Report (Impact Factor) databases.

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