University of West Hungary
Faculty of Forestry

Theses of doctoral (PhD) dissertation

POSSIBILITIES OF AGRICULTURAL UTILIZATION OF WOOD ASH

István Füzesi

Sopron
2014

University of West Hungary
Faculty of Forestry
Sopron

Doctoral School:	Pál Kitaibel Doctoral School of Environmental Sciences
Leader:	Prof. Dr. Márton Veress
Program:	K2 Geo-enviromental Sciences
Leader:	Prof. Dr. László Szarka
Supervisors:	Dr. habil Gábor Kovács Dr. habil Bálint Heil

1. OBJECTIVE

The present-day increasing energy demand and the uncertainties that may occur in energy supply have focused the attention to CO-neutral and sustainable energy sources. Application of biomass for energy purposes has become more and more common and has increased the significance of wood heating. In Hungary, along with regular households, in many of the coal-fired power plants such as in towns of Pécs and Ajka, a partial or full switch towards biomass heating solutions has happened recently. So in these power plants forest biomass and wood wastes, sawdust and firewood have been used as a source of heating.

Naturally, the greater utilization of biomass energy is accompanied with the increase in the amount of combustion by-products, that is with the increase in the amount of ashes. The estimated annual amount of ash produced during wood heating in Hungary is about 30-40 thousand tonnes. The produced ash is mainly used as waste and being managed by disposal. However, the increasing costs as well as the opposition to new waste disposal sites have drawn the attention to new, alternative methods of waste-disposal both in Hungary and at the international level.

One of these disposal methods which has been used for thousands of years in garden plots, is the utilization of wood ash for agricultural, forestry and horticultural purposes, through its application as a soil conditioner and fertilizer.

The main objective of this thesis is

- to give an overview of both the Hungarian and the international literature related to the issue, thus defining accurately the scope of research and facilitating to find the proper methods and equipment for further investigation;
- to investigate the utilization possibilities of wood ash in West Hungary, where it may play an important role in amelioration of acidic soils;

- to investigate its influence on the chemical properties of soil and its nutrient supplying capacity, related to different doses of ash;
- using test plants, to investigate the possible negative effects on the plant growth of heavy metals occurring in wood ash in high concentration.

2. MATERIALS AND METHOD USED

2.1. Pot experiments

In spring 2009, the applicant has launched a pot experiment in the greenhouse of the Directorate of Plant Protection and Soil Conservation of the Vas County Government Office, in municipality of Tanakajd. Perennial ryegrass and white mustard were used as test plants in the experiment, during 10 treatments (5 ash-loads - 2 plants), with four repetitions, using 40 pcs. of Mitscherlich-pots with volume of 6 cubic decimetres. The treatments provided a soil loading of 0, 1, 5, 10, 20 tonnes of wood ash per hectare.

The untreated ash used for the pot experiment came from the biomass heated furnace of the Szombathely District Heating Plants Ltd., with thermal input of 7 MW. The ash was collected in February 2009. The soil chosen for the experiment was collected in March 2009, from the arable soil of the agricultural land near municipality of Pecöl in Vas-county. The mechanical composition of the soil incorporated during the experiment had the physical consistency of gritty adobe, with acidic pH, with no soda lime content and with nearly 20 per cent of clay and over 50 per cent of mud sediments.

During the pot experiment the author recorded the number of emergences of test plants, their height, their green mass, the number of bases, as well as all phytotoxic symptoms possibly occurring in the test plants. On completion of the experiment the author also took samples of the test plants and from the soil of test pots, for further laboratory investigations.

2.2. Examination of anti-sprouting and phytotoxic effects

In order to examine the anti-sprouting and phytotoxic properties of wood ash, in 2009 the author launched an experiment with four repetitions under greenhouse conditions. The soil and the untreated wood ash incorporated in the experiment were identical with those used during the pot experiment.

During the 16-day experiment the author tested the effect of raising doses of wood ash (0 t/ha - control treatment, 5 t/ha, 10 t/ha, 20 t/ha, 40 t/ha, 80 t/ha) on soil and white mustard test plants. The author examined the changes occurring in the soil pH, in the number of emergences, in the number of bases and in the height of test plants, and also observed the phytotoxic effects.

2.3. On-farm small plot experiments

The author launched the on-farm small plot trials in May 2010. The untreated ash used for the experiment was provided by ADA Hungária Furniture Factory Ltd., Körmend, where the wood waste produced during the manufacturing procedure is being re-used by incineration. The wood ash was collected in March 2010. For the premises of the experiment was chosen the agricultural land of Tanakajd, with consideration of the alkalizing effect of ash on the soil. During the on-farm experiment the effects of ash were examined on a soil only slightly different from that in the greenhouse. The mechanical composition of the soil incorporated for the experiment was of clay adobe consistency, with 27 per cent clay content and over 60 per cent mud sediments.

The treatments corresponded to application of 0, 1, 2.5, 5, 10 tonne doses of ashes per hectare. In the experiment perennial ryegrass and white mustard were used as test plants, during 10 treatments (5 different loads of ash per 2 plants), with four repetitions, on 40 pcs. of small plots. (1 m^2

each). The ashes were applied after the spring soil preparation and incorporated evenly into the upper layers of the soil. The treatments were performed with randomized block arrangement.

Throughout the experiment the author continuously measured the air temperature and the amount of precipitation. He recorded the number of emergences of white mustard test plants per each plot, the number of bases, their height and mass, as well as the average height and mass of perennial ryegrass test plants per plot. On completion of the trial the author took samples from 0 to 10 cm soil layers of the plots as well as of the test plants, for further laboratory examinations.

2.4. Laboratory examinations

The laboratory analyses of samples from the wood ash, soils and plant were performed in the Laboratory of the Institute of Geography and Environmental Sciences of University of West Hungary, as well as in the accredited laboratory of the Directorate of Plant Protection and Soil Conservation of the Vas County Government Office. Determination of the total element content was performed following cc. HNO_3 + cc. H_2O_2 destruction using Inductively Coupled Plasma / Optical Emission Spectroscopy. The soluble nutrient content of the soil was determined according to the method of Hungarian Standard MSZ 20135:1999.

2.5. Statistical evaluation of results

The applicant evaluated the results received during the treatments and the correlation between them using version 11 of the data analysis software system STATISTICA, of StatSoft, Inc. (2012), (www.statsoft.com), as well as using analysis of variance and regression analysis. The examination of significant differences between the treatments detected by analysis of variance was performed by Dunnett test.

3. EVALUATION OF RESEARCH RESULTS

The density of the ash incorporated for the greenhouse experiments is 0.605 g/cm^3. The ash is highly acidic, the pH measured in suspension in the water is 12.8. Among the nutrients the content of phosphorus is 1.09 per cent by weight, of Calcium – 27.73 per cent, of Magnesium – 1.89 per cent and of Potassium – 3.99 per cent by weight.

During the examination of the anti-sprouting and phytotoxic effect of wood ashes, as a result of the amount of ash-dose corresponding to 80 t/ha, the pH-value of the soil significantly raised: the original value of 5.48 reached 7.89. By increasing the dose of ash, the sprouting time extended and the anti-sprouting effect improved. Both related to the number of bases and height, the dose corresponding to 5-10 t/ha turned out to be the most favourable dose. In case of doses exceeding this dosage, the number of individuals and the height of plants reduced. When treated with doses corresponding to 40 and 80 t/ha, certain phytotoxic symptoms could be detected; slight thinning was be observed on the test plants.

In the pot experiment, influenced by the highest dose, the pH-value measured in suspension in the water raised by two pH units compared to the original value (5.7). From among the examined nutrients, influenced by a dose of 20 t/ha, the P_2O_5-content raised from 61 to 173 mg/kg, while the K_2O-content raised from 123 to 247 mg/kg. The total amount of magnesium and sulphur raised too, while no significant change could be detected in the N-content. No significant change could be observed in the heavy metal-content of the soil either, subsequent to the treatment. Adding doses of 1 to 5 t/ha of wood ash increased the number of emergences, the number of bases, their height and the green mass of test plants. Following the application of the maximum dose, a reduction in heights of both test plants could be measured and statistically verified. The increased variety of nutrients resulted by the treatments could not be proved by the nutrient content of the plants, which can be explained by the original optimum nutrient supply at the time of the control.

The ash incorporated during the on-farm experiment was highly alkaline, with a pH of 13.00. Its phosphorus content was 0.37 per cent by weight, content of Calcium was 23.29 per cent, of Magnesium – 2.68 per cent and of Potassium – 5.42 per cent by weight. The iron content of the ash was significant too: 13.46 g/kg.

In the small plot experiment, on the influence of the highest dose the pH-value measured in suspension in the water raised by nearly 1 pH unit in each test plant, compared to the original control value (6.41). Influenced by the ash-treatment, the soda lime content of the soil with calcium deficiency changed to 0.8 per cent by weight, subsequent to a 10 t/ha treatment. Among the examined macroelements in case of the dose of 10 t/ha, the P_2O_5-content raised from 760 to 1144 mg/kg, while the K_2O-content raised from 301 to 792 mg/kg in the 0 to 10 cm soil layer. Based on the data, the phosphorus and potassium content were well supplied originally, and a further increase in their content could be detected after the wood ash treatment. The magnesium-, zinc- and sulphur content also raised in the soil, while the nitrogen content of the treated soil showed no significant modification.

Effected by the wood-ash treatment, the total cadmium content of the soil increased, its value changing from 0.28 to 0.50 mg/kg on the influence of the maximum dose, which did not exceed the value characteristics of the uncontaminated soils throughout Hungary. In case of other heavy metals no change of such degree could be observed. The increased variety of nutrients resulted by the treatments caused no statistically verifiable change in the yield of plants and their nutrient content. Also, no increased heavy metal content could be detected in the test plants, as a result of the treatment. Similarly to the pot experiments, no toxic symptoms could be observed on the plants either.

4. THESES OF THE DISSERTATION

1. Based on the soil tests it can be stated that the applied wood ash increases the pH value of the soil measured in the suspension in the water. The correlation between the used dose of ashes and the soil pH can be described by a saturation curve. The pH value measured in suspension of KCl with concentration of 1 mol/dm^3, closely follows the pH modification detected in aqueous solution.

2. It has been proved that with application of wood ash, the P_2O_5- and K_2O-content of the soil both significantly raise. Wood ash also increases the magnesium- and sulphur content of the soil, as well as the amount of Zn of all the microelements. No far-reaching conclusions can be drawn based on the percentage of humus, the soil cohesion and the changes in Na, Cu, Mn values. As wood ash is practically nitrogen free, its application will not significantly modify the mineral nitrogen content of the soil.

3. If the toxic heavy metal content of the wood ash applied is average or below the average, the heavy metal content of the soil won't show a statistically verifiable change even in case of application of 20 tonnes of wood ash in the tested soil. If the heavy metal content of the wood ash applied exceeds the average, the concentration of some of the toxic heavy metals will slightly increase in the soil when a 20 tonnes wood ash per hectare treatment is performed; which at the same time did not cause any verifiable damage in the test plants.

4. The test results prove that application of 1 to 5 t/ha wood ash will cause an increase in the number of emergences, in the number of bases, in their heights and the green mass of white mustard test plants. Significant variations in these parameters compared to the untreated control values could be detected in the greenhouse pot experiments only. It can also be stated that wood ash treatment won't increase the content of toxic elements in the white mustard test plants. No toxic symptoms can be detected on the test plants of white mustard and

perennial ryegrass as far as a dose of 20 t wood ash per hectare is used for treatment. If higher doses are used, a slight thinning can be observed on the white mustard test plants.

5. It can be stated that wood ash can effectively be utilized for agricultural purposes in West Hungary instead of liming, in order to moderate the acidification of soils, as well as for amelioration purposes in acidic soils. Due to its calcium and lime content, the soda lime content of the on-field soil with lime deficiency has grown to 0.8 per cent by weight after the 10 t/ha treatment.

6. It can be concluded based on the experiments that wood ash can successfully be used in agriculture for fertilization purposes. It needs to be applied before sowing, and evenly incorporated into the upper layers of the soil. Its recommended application dosage is 1 to 5 t/ha, as doses higher than that may have harmful effects on the emergence and growing of plants. In case of higher doses the P_2O_5 and K_2O values measured in the soil tend to be significantly higher than the optimum, which can lead to leaching out of the applied fertilizing substances from the topsoil in default of a sufficient colloid content.

7. Agricultural utilization of wood ashes is of great importance from economical point of view too, as the cost of waste disposal may also be reduced by its application on arable lands. By agricultural utilization of wood ash available in large amounts, the costly soil conditioners and chemical fertilizers may be partially replaced. The nutrient supplying capacity of 1 tonne of wood ash equals approximately 25 kg of chemical fertilizers with the active substance of P_2O_5 and 48 kg of chemical fertilizers with the active substance of K_2O, which means that a treatment of 1 t wood ash per hectare saves approximately 22 thousands of HUF.

5. PRACTICAL APPLICABILITY OF THE RESULTS

The by-product produced during wood combustion is ash, which increases the soil pH-value when applied to the land. Thanks to the ash-treatment, the soda lime content of the soil increases, so ash can effectively be used for amelioration of acidic soils in West Hungary.

Ash is also an important source of nutrients, thus promoting the plant growth and development. It contains a great number of macro- and microelements, which on the other hand cannot be found in NPK fertilizers. Availability of phosphorus and potassium in ash is smaller than in fertilizers, so ash can ensure nutrients for the plants for a longer period. According to the measurements, ash has a low N-content, so in soils with nitrogen deficiency, the best application of ash is when combined with nitrogen fertilization.

Based on the experiment results it can be concluded that the recommended ash application dose is 1 to 5 t/ha, however, a preliminary soil test is recommended in order to accurately determine the application dosage. The agricultural utilization of ash is an activity subject to authorization, which is normally granted by the Directorate of Plant Protection and Soil Conservation of the competent county Government Office.

6. PUBLICATIONS

Publications in reviews and conference proceedings:

FÜZESI I. – HEIL B. – KOVÁCS G. (2014): Examination of the effects of wood-ash in small plot experiments. Acta Silvatica & Lingaria Hungarica. (proofreading is in progress).

FÜZESI I. – HEIL B. – KOVÁCS G. (2013): Biomassza tüzelésből származó hamu felhasználásának mezőgazdasági lehetőségei. In: Kémia, Környezettudomány, Fenntarthatóság: Kémia Intézet Tudományos Ülése (2013.08.29.). Konferencia-kötet. Sopron: Nyugat-magyarországi Egyetem Kiadó. pp. 93-98.

FÜZESI I. – HEIL B. – KOVÁCS G. (2013): Hamulúg készítése és kémiai vizsgálata. In: MESTERHÁZY BEÁTA (szerk.): XII. Természet-, Műszaki és Gazdaságtudományok Alkalmazása Nemzetközi Konferencia (2013.05.11.). Konferencia-kötet. Szombathely: Nyugat-Magyarországi Egyetem. pp. 174-178.

FÜZESI I. – KOVÁCS G. (2012): A talaj nehézfémtartalmának változása fahamukezelés hatására. In: MESTERHÁZY B. (szerk.): XI. Természet-, Műszaki és Gazdaságtudományok Alkalmazása Nemzetközi Konferencia (2012.05.19.). Konferencia-kötet. Szombathely: Nyugat-magyarországi Egyetem. pp. 224-230.

FÜZESI I. – KOVÁCS G. (2011): Fahamukezelés hatása a növény-talaj rendszerre. In: LAKATOS F. – POLGÁR A. – KERÉNYI-NAGY V. (szerk.): Tudományos Doktorandusz Konferencia (2011.04.13.)., Konferencia-kötet. Sopron: Nyugat-magyarországi Egyetem. pp. 87-91.

FÜZESI I. – KOVÁCS G. (2011): A fahamu talajra gyakorolt hatásának vizsgálata tenyészedény-kísérletben. In: FARSANG A. – LADÁNYI ZS. (szerk.): Talajaink a változó természeti és társadalmi hatások között: Talajvédelem különszám. Talajtani vándorgyűlés (2010.09.03-2010.09.04.). Konferencia-kötet. Budapest; Gödöllő: Talajvédelmi Alapítvány; Magyar Talajtani Társaság. pp. 203-210.

FÜZESI I. (2010): Vas megye talajainak nehézfémterheltsége. In: MESTERHÁZY B. (szerk.): IX. Természet-, Műszaki és Gazdaságtudományok Alkalmazása Nemzetközi Konferencia (2010.05.15.). Konferencia-kötet. Szombathely: Nyugat-magyarországi Egyetem.

Presentations:

FÜZESI I. – HEIL B. – KOVÁCS G. (2013): Biomassza tüzelésből származó hamu felhasználásának mezőgazdasági lehetőségei. Kémia, Környezettudomány, Fenntarthatóság: NymE EMK Kémia Intézet Tudományos Ülése, Sopron, 2013. augusztus 29.

FÜZESI I. – KOVÁCS G. (2012): A tápanyag-gazdálkodás elvei és gyakorlata a rendszerváltást megelőző és az azt követő időszakban. In: PUSKÁS J. (szerk.): VII. Regionális Természettudományi Konferencia, Szombathely, 2012. január 26., pp. 15-16.

FÜZESI I. – KOVÁCS G. (2011): Fahamukezelés hatása a talajra és a termesztett növényekre. In: FÜZESI I. – PUSKÁS J. (szerk.): X. Természet-, Műszaki- és Gazdaságtudományok Alkalmazása Nemzetközi Konferencia, Szombathely, 2011. május 21., p. 31.

FÜZESI I. – KOVÁCS G. (2011): Fahamukezelés hatása a növény-talaj rendszerre. Tudományos Doktorandusz Konferencia, Sopron, 2011. április 13. p.

FÜZESI I. – KOVÁCS G. – MOLNÁR ZS. (2011) Termésnövelő és talajjavító anyagok alkalmazása Vas megyében. In: PÉNTEK K. (szerk.): VI. Euroregionális Természettudományi Konferencia, Szombathely, 2011. január 25-27., pp. 35-36.

FÜZESI I. – KOVÁCS G. (2010): A fahamu talajra gyakorolt hatásának vizsgálata tenyészedény-kísérletben. Talajaink a változó természeti és társadalmi hatások között: Talajtani vándorgyűlés, Szeged, 2010. szeptember 3-4.,

FÜZESI I. – KOVÁCS G. (2010):Fahamukezelés hatása fehér mustár és angol perje tesztnövényekre. In: FÜZESI I. – PUSKÁS J. (szerk.): IX. Természet-, műszaki és gazdaságtudományok alkalmazása nemzetközi konferencia. Szombathely, 2010. május 15., p. 20.

FÜZESI I. – KOVÁCS G. (2010): Study on the effect of wood ash application in a pot experiment. Fahamu-terhelés hatásának vizsgálata tenyészedény-kísérletben. Meddig lesz még Föld Napja? – Doktoranduszok I. Környezettudományi konferenciája, Budapest, 2010. április 17., pp. 14-15.

FÜZESI I. – KOVÁCS G. (2009): A fahamu talajra gyakorolt hatásának vizsgálata tenyészedény-kísérletben. Megújuló energiák, környezeti változások – NymE TTK Tudomány Napi Konferencia, Szombathely, 2009. november 17.

Posters:

FÜZESI I. – KOVÁCS G. (2013): Hamulúg készítése és kémiai vizsgálata In: FÜZESI I. – PUSKÁS J. (szerk.): XII. Természet-, Műszaki és Gazdaságtudományok Alkalmazása Nemzetközi Konferencia, Szombathely, 2013. május 11., p. 34.

FÜZESI I. (2010): Vas megye talajainak nehézfémterheltsége. In: FÜZESI I. – PUSKÁS J. (szerk.): IX. Természet-, Műszaki és Gazdaságtudományok Alkalmazása Nemzetközi Konferencia, Szombathely, 2010. május 15., p. 42.

FÜZESI I. (2009). A fahamu talajra gyakorolt hatásainak vizsgálati módszerei. In: FÜZESI I. – PUSKÁS J. (szerk.): VIII. Természet-, Műszaki és Gazdaságtudományok Alkalmazása Nemzetközi Konferencia, Szombathely, 2009. május 23., p. 35.