УДК 631.879

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EFFECTS OF THE BIOMASS ASH ON GROWTH OF CEREAL PLANTS

We are currently, in Poland, observing increasing construction of huge combusting units for biomass. This might, in the next 2-3 years, lead to the accumulation of about 200,000 tons, or more of biomass ashes as a by-product resulting from this process. Biomass ashes have some positive properties i.e., high pH, high levels of K, and Ca, medium levels of Mg, P and some microelement. It could be treated as a source of useful material for improving soil reaction and plant fertilization as well as a component for mineral or organic-mineral fertilizers. In an earlier experiment, where the effect of ashes on plant germination and primary growth was estimated, no negative effect was observed, but it must be continuously monitored since its chemical content and reaction could vary extensively depending on the type of combusting unit and material burnt. The paper is a presentation of results from sprouting beds, pots and field experiments with different plants. Actual data obtained indicate that ashes have no negative influence on plant germination, initial growth of seedlings and physiological processes in the leaves.

Key words: *biomass, fly ashes, mineral-organic fertilizer*

Introduction. The growing need for energy production from renewable sources means that biomass is currently more often used instead of coal or lignite to fire power plants. Both, the fly ash composition and its properties will vary depending on such factors as: plant genetic features, agronomic treatments used in the plant cultivation, climatic factors, methods applied in processing biomass, and the type of installation and the temperature at which the combustion process takes place. Properties of biomass generated ash can vary quite significantly depending on the type of raw material, type of boiler or combustion process. Ashes are characterized by a high content of calcium (Ca) and potassium (K), the presence of phosphorus (P), magnesium (Mg) and micronutrients as well as high pH (9-13). The composition of different type of biomass is provided in Table 1. There is, however, lack of nitrogen (N) and organic substances. Apart from the preferred components such as potassium (K), phosphorus (P), magnesium (Mg), ash may also contain heavy metals (Stankowski and Maciorowski, 2011). Sometimes the presence of certain heavy metals can be in excessive concentration. Potentially, ash as a fertilizing substance can be used for plants (Vance 2000, Bielińska et al., 2010).

Table 1

Nutrients contained ash from the biomass combustion (based on data from Wrocław University of Environmental and Life Sciences)

Biomass	%P_2O5	%K_2O	%CaO	%MgO
hay pellets	4,3	10,4	18,8	2,7
grain oats	11,8	14,8	3,5	4,5
willow	4,0	8,9	34,4	0,3
oakwood	2,2	9,4	40,3	3,5
triticale straw	4,8	28,8	16,4	1,5
rye straw	3,6	6,5	7,4	3,4
sorghum	3,4	13,6	8,1	2,9
wood chips	1,3	3,6	15,4	6,3

Table 2

The presence of heavy metals in ash from pure biomass combustion (based on data from Wroclaw University of Environmental and Life Sciences)

Biomass	Pb	Cd	Hg	As
grain oat	1,53	0,42	-	-
willow	0,017	-	-	-
wood chips	85	8,26	0,172	3,72
oakwood	33,1-39	7,8-29	0,0041	21,9-23
approved metal content in mineral fertilizers*	140	50	2	50

**Regulation of the Minister of Rural Development of 18 June 2008. on the implementation of certain provisions of the Act on fertilizers and fertilization, No. 119, Journal of Laws-2008 poz.765 of 2008-07-7*

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Ash is useful both as a soil improver and a plant fertilizer. It is, however, worth remembering that the acquired biomass should be from controlled sources. There is need to monitor its chemical composition, and to sort or classify ashes into those suitable for use as a valuable fertilizer in accordance with the standards defined by the Law on fertilizers and fertilization. The quality of biomass ash exhibits considerable variation. In investigating the processing possibilities, attention will have to be paid to characteristic properties of ash.

Ash has an unfavorable physical form. Dustiness makes it difficult for both transportation and use in the field. Changing the form of powdery granules as well as retaining their chemical composition in the alignment through the skillful blending of ash from the pure biomass combustion with ash from coal, offers greater prospects of their use in agriculture. Despite the lack of nitrogen (N), ashes in their composition contain a lot of macro and micro elements sought after by farmers.

The use of ash as a fertilizer requires the granting of permission from the Minister of Agriculture and Rural Development. The law on fertilizers and fertilization of 10th July 2007, which has been in force since 15th November 2007, regulates the conditions and procedures for marketing fertilizers and plant conditioners. Chemical fertilizers from beyond the European Community are marketed under the authorization of the Minister responsible for agriculture. The Act, besides regulating types of mineral-, organic-, and organic-mineral fertilizers, also sets out categories of funds to improve the quality of soil and plants. The procedures for obtaining the necessary permits are not as demanding as in the case of other fertilizers. The authorization must include:

– the results of research and opinion showing compliance with quality requirements and the requirements in terms of pollutants;

– a review of suitability for use.

An obstacle to the attainment of relevant permits for ash, is the need for constant and repeatable chemical composition of the product, which is difficult in the case of fly ash from co-incineration.

Effects of biomass ash on *Festulolium braunii* Growth. The pot experiment was conducted in the laboratory of the Department of Agronomy at The West Pomeranian University of Technology in Szczecin in 2008. The effect of ash fertilization was confirmed by measuring the growth of shoots and roots, chemical composition and photosynthetic activity.

Table 3

Content of trace elements in the ash [g / kg S.M]

Biomass ash		P	K	Ca	Mg	Na
wheat grain (Austria)	***ZP***	3,39	49,0	134,8	43,8	0,43
straw (Suchań)	***S***	2,59	32,7	58,2	8,0	1,29
wood briquettes (Recz)	***BD***	0,69	13,4	177,1	20,3	6,99

Source:http://cbepolska.pl/images/ZUPS_111123/prezentacje/08ZUPS_Robert_Maciorowski.pdf (25.08.2013)

Table 4

Variants of ash fertilization

Biomass ash	dose of ash [g/pot]		dose of ash [g of component/pot]			
			P		K	
	I	II	I	II	I	II
ZP+N	10,17	20,34	0,0346	0,0692	0,498	0,996
S+N	15,23	30,46	0,0396	0,0792		
BD+N	37,27	74,53	0,0149	0,298		

Source:http://cbepolska.pl/images/ZUPS_111123/prezentacje/08ZUPS_Robert_Maciorowski.pdf (25.08.2013)

Table 5

Variants of mineral fertilization

Mineral fertilizer	N		P		K	
	[g/pot]	[kg/ha]	[g/pot]	[kg/ha]	[g/pot]	[kg/ha]
Control	0	0	0	0	0	0
Control N	0,3					
NPK I		100	0,0297	9,9	0,249	83
NPK II		0,0594	19,8	0,498	166	

Source:http://cbepolska.pl/images/ZUPS_111123/prezentacje/08ZUPS_Robert_Maciorowski.pdf (25.08.2013)

Table 6

Yield [g / pot]

Crop	Dose (D)	Variant of fertilization (W)				Average
		ZP+N	S+N	BD+N	NPK	
First	I	77,8	68,8	68,9	66,5	70,5
	II	75,5	74,5	73,3	76,5	75,0
	Average	76,7	71,6	71,3	71,4	72,8
	NIR 0,05	W-5,05; D-3,06; WxD-ns				
	Control N-69,5; Control – 48,2					
Second	I	42,8	45,6	42,5	38,6	42,4
	II	46,2	48,0	42,8	42,9	45,0
	Average	44,5	46,8	42,6	40,08	43,7
	NIR 0,05	W-4,02; D-2,11; WxD-ns				
	Control N-37,9; Control – 14,3					

Source: http://cbepolska.pl/images/ZUPS_111123/prezentacje/08ZUPS_Robert_Maciorowski.pdf (25.08.2013)

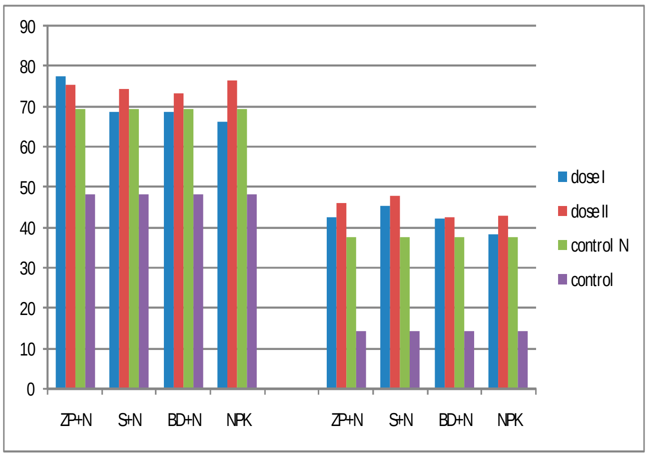

Fig. 1. Plant yield [g/vase] depending on fertilizer variants from first and second swaths

The positive effect of ash (version ZP + N) on the chlorophyll content and photosynthetic activity of plant processes was assessed by laser-induced chlorophyll fluorescence.

Effects of biomass ash on primary plant growth on some spring cereal species. Materials and methods. The experiment was conducted in the laboratory of the Department of agronomy at The West Pomeranian University of Technology in Szczecin during the 2012 spring period. Three species of spring cereals (Tybalt – a variety of wheat, Natasha - a variety barley, Slavko- a variety of oats), and four variants of the aqueous slurry of biomass ash (0 - control, 2%, 4%, 6%) were compared. The ash came from burning wood chips with 25 percent of sorghum in the fluidized bed boiler. Germination of seeds was carried out in the plates-germinator of the "Szmal" type. The germination process took place in trays with a slurry of ash for the period of experiment. There were 4 replications. After the emergence of the spring cereal species, the chlorophyll content in the 2-leaf stage was measured with chlorophyll meter Minolta SPAD 502 using a photo-optical method (SPAD). The height and weight of the seedlings was determined by measuring 25 pieces. The dry weight of seedling was determined by drying the product at a temperature of 130 ° C until the achievement of a constant weight. Statistical analysis was performed by analysis of variance of two factors in a completely randomized system. Confidence intervals were calculated using the Tukey's test at a significance level of 0.05.

Results and discussion. Cereal seedlings growing in a suspension of biomass ash, were characterized by a higher rate of SPAD value when compared with the control test. Increasing the share of ash from 0 to 2% and 4% contributed to increases in value of 1.3 and 1.8 respectively. Further increase in the share of ash in suspension remained without effects on the trait. The reaction of the tested species was varied. The most responsive of the plants was barley but only to the level of 2%.Wheat and oats reactions were weaker but the optimal option was at 4% of ash.

Table 7

Effect of biomass ash (P) on chlorophyll content (SPAD) in the leaves of three species of spring cereals (G)

Ash content (%)	Species			Average
	Barley	Wheat	Oat	
0	23,2	25,3	29,9	26,2
2	27,1	25,8	29,7	27,5
4	27,0	26,4	30,7	28,0
6	27,7	26,2	30,4	28,1
Average	26,3	25,9	30,2	27,5
NIR 0,05 for:	G-0,770; P-0,980; P(G) -1,697			

By increasing the amount of biomass ash a more rapid growth of tested cereal seedlings was observed (table 8, fig 1). Increasing the share of ash in the slurry from 0 to 2% and 4% resulted in increase in height by 23% and 31% respectively. The optimal variant was with the addition of 4% ash but the strongest response of 44% was found in the case of wheat.

Table 8

Effect of biomass ash (P) on seedling's height (cm) of the three species of spring cereals (G)

Ash content (%)	Species			Average
	Barley	Wheat	Oat	
0	16,0	16,3	11,9	14,7
2	17,8	22,4	14,0	18,1
4	19,6	23,5	14,5	19,2
6	19,4	23,4	15,6	19,5
Average	18,2	21,4	14,1	17,9
NIR 0,05 for:	G-0,88; P-1,12; P(G) -1,94			

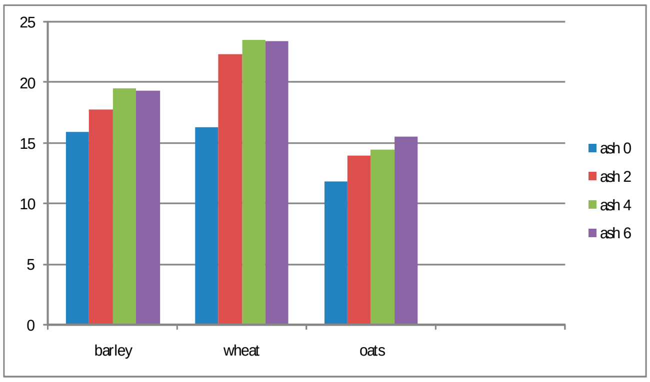

Fig. 2. Effects of biomass ash fertilization variants on seedlings height [cm] of three spring cereal species

The fresh weight of seedlings (25 pieces) from the 2% variant was characterized by a higher value than the control (Table 5). Further increases in the share of ash in the water suspension did not result in a significant increase in the plant weight, but also without any negative effects by lowering the plants' weights.

Table 9

Effect of biomass ash (P) on seedling's fresh weight (g) of the three species of spring cereals (G)

Ash content (%)	Species			Average
	Barley	Wheat	Oat	
0	2,64	1,54	1,16	1,78
2	3,31	2,29	1,41	2,34
4	3,44	2,54	1,44	2,47
6	3,58	2,32	1,72	2,54
Average	3,24	2,17	1,43	2,28
NIR 0,05 for:	G-0,237; P-0,301, P(G) – r.n.			

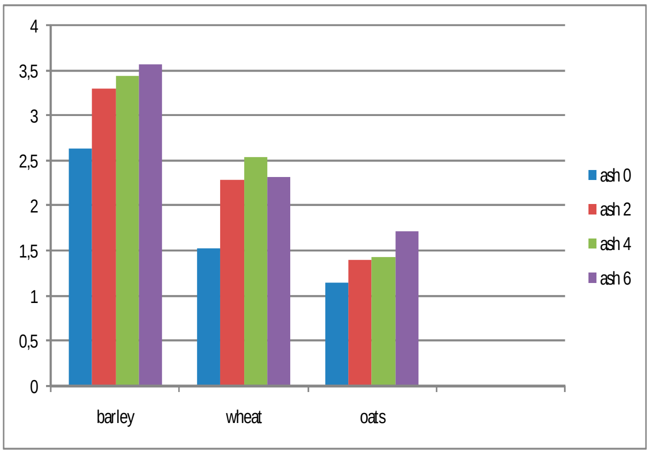

Fig. 3. Effects of biomass Ash fertilization variant on seedlings fresh weight [g] of three spring cereal species

Changes in the dry weight of the seedlings (table 10) under the influence of a different variants of ash in the slurry was similar to values of seedlings fresh weight. The dry matter content of seedlings did not differ significantly, thus indicating the lack of impact of the different variants of the ash products on plants' hydration. The highest dry matter content was characteristic of wheat seedlings while the lowest was of barley seedlings.

Table 10

Effects of biomass ash (P) on seedling's dry weight (g) of the three species of spring cereals (G)

Ash content (%)	Species			Average
	Barley	Wheat	Oat	
0	0,244	0,186	0,099	0,176
2	0,308	0,290	0,124	0,240
4	0,334	0,274	0,124	0,244
6	0,319	0,258	0,144	0,240
Average	0,010	0,252	0,123	0,225
NIR 0,05 for:	G-0,026; P-0,033, P(G) – r.n.			

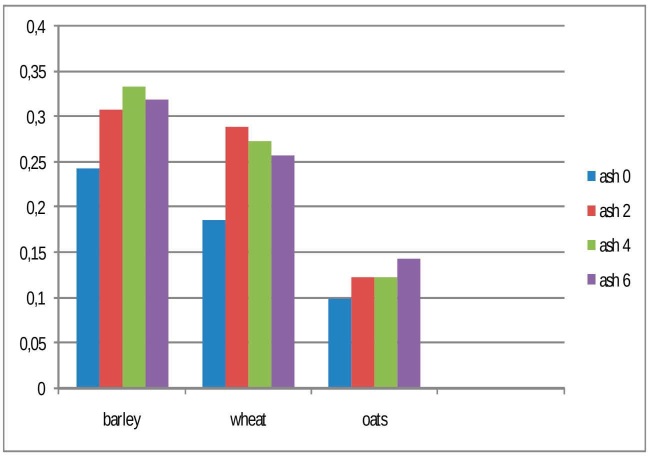

Fig. 4. Effects of biomass ash fertilization variants on seedlings' dry weight [g] of three spring cereal species

Research findings (Stankowski et al. 2008) confirm the positive impact of biomass ash on the yield of Festulolium grass, when compared with the control. They were similar to observations from mineral fertilization. Stankowski and Meller (1995) and Murkowski and Stankowski (2002) also showed that mineral coal had a beneficial effect on plant growth and photosynthetic parameters of triticale, rye and barley.

Conclusions:

The use of ash from biomass as a fertilizer component resulted in more rapid growth of wheat, barley and oats seedlings

The optimum dose was 2%-4% of the ash in water suspension.

There were no adverse effects of the additive ash used in the tests.

The fertilizer can be used for the cultivation of industrial and technical agricultural lands for the purpose of biogas, bio-ethanol, biodiesel, biomass burning, and fertilization of ornamental plants, forests, green spaces, including reclaimed areas.

Assessment of agricultural use of ash from the combustion of various types of biomass in pot and field experiments. The two-year experiment was conducted in the laboratory of the Institute of Environmental Protection and Development, Wroclaw University of Environmental and Life Sciences between 2010 and 2011. The experiment involved two research factors: type of ash and different levels of fertilization. Ash sourced from burning oats, willow, straw of winter cereals, sorghum, oak, hay pellets and wood chips was used in the experiment. Different levels of ash fertilizer, i.e., 5 g / 10 kg soil – 10 g / 10 kg soil – 20 g / 10 kg soil were applied. A control version without ash fertilization was also included.

Materials and methods. The study involved the use of Wagner's pot, each with soil of low potassium and phosphorus content. There were 5 replications with a control object, using the independent series method. Parabola, a variety of spring wheat, was sown with 30 seeds per pot (primed seeds).After the emergence of plants stabilized, the density was adjusted to 18 plants/ pot. Moisture content was maintained at 60% maximum capillary capacity throughout the growing season.

Number of pots: 8 types of ash x 3 doses of ash x 5 replication + 8 control objects = 128 pots.

Results and discussion.

Table 11

Plant parameters (the first year of study), grain weight [g]

Dose of Ash/pot [g]	Ash from combustion of biomass							
	Oats grains	Willow	Triticale straw	Spring wheat straw	Sorghum	Oak	Hay pellets	Wood chips
5	28,8	26,1	28,0	26,5	27,9	28,0	27,8	27,1
10	27,6	26,5	27,7	25,7	28,0	29,3	27,5	27,8
20	29,0	27,3	28,3	26,1	28,8	29,6	28,6	28,3
Average	28,4	26,6	28,0	26,1	28,2	28,9	28,0	27,8
Control	24,8							
NIR 0,05	1,6							

Source:http://cbepolska.pl/images/ZUPS_111123/prezentacje/09ZUPS_ROMAN_WACLAWOWICZ.pdf (25.08.2013)

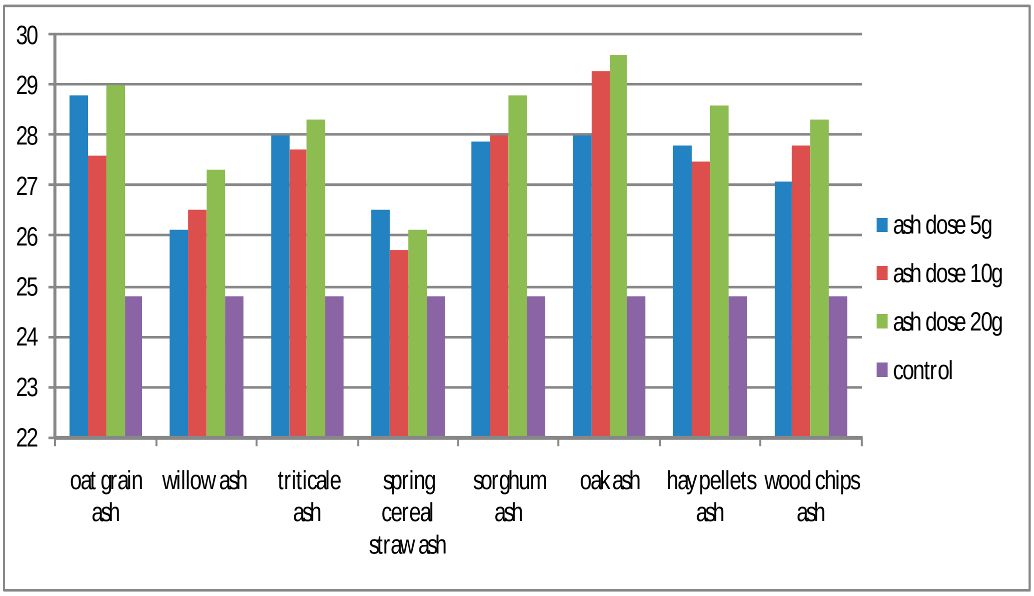

Fig. 5. Grain weight [g] from varied levels of fertilization with fly ash from the combustion of biomass in the first year of experiment

Table 12

Plant parameters (the second year of study), grain weight [g]

Dose of Ash/ pot [g]	Ash from combustion of biomass							
	Oat grains	Willow	Triticale straw	Spring cereal starw	Sorghum	Oak	Hay pellets	Wood chips
5	27,2	29,6	28,9	29,4	25,8	27,9	26,6	24,4
10	29,2	32,2	30,6	29,2	26,3	32,8	29,5	26,1
20	31,8	35,0	34,8	31,9	30,4	36,2	30,5	30,3
Average	29,4	32,3	31,4	30,2	27,5	32,3	28,9	26,9
Control	24,0							
NIR 0,05	1,7							

Source:http://cbepolska.pl/images/ZUPS_111123/prezentacje/09ZUPS_ROMAN_WACLAWOWICZ.pdf (25.08.2013)

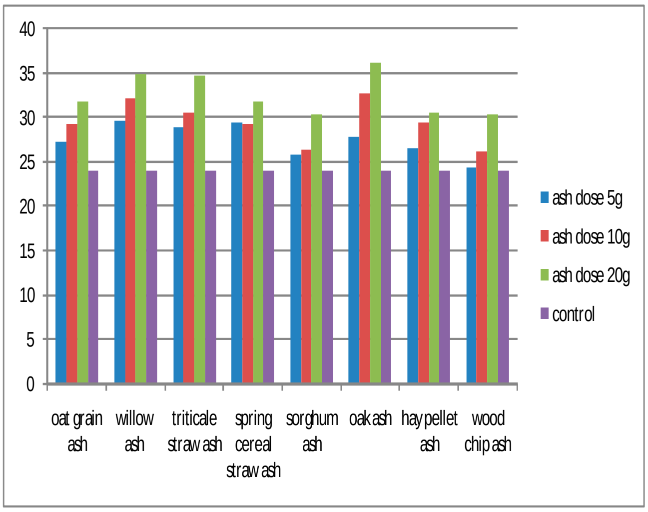

Fig. 6. Grain weight [g] from varied levels of fertilization with fly ash from combustion of biomass in second year of experiment

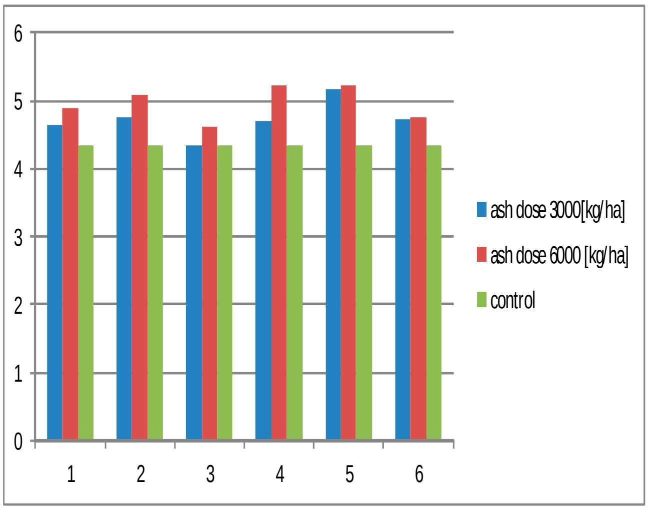

Fig. 7. Grain yield [t/ha] from varied levels of fertilization with ash from combustion of biomass

Effects of industrial ash from the "Czechnica" power plant and local ash on the yield of triticale and on soil properties. The next experiment was conducted on a field cultivated with triticale at the research centre of the Wroclaw University of Environmental and Life Sciences in 2011. The study focused on the effects of ash fertilization applied on triticale fields. The experiment involved two research factors: type of ash and different levels of fertilization. Two types of ash i.e., industrial (industrial - from Czechnica power plant: wood chips, wood chips + corn+ straw and wood chips + willow) and local (grain oat, straw from winter cereals, and oak wood) were used in the experiment. Three variants of fertilization: 3000 kg/ ha, 6000 kg/ ha and control without ash were applied.

Results and discussion.

Table 13

Estimation of yields [t/ha]

Ash dose [g/ha]	Ash from combustion of biomass					
	industrial			local		
	Wood chips (1)	Wood chip + maize + straw (2)	Wood chip + willow (3)	Oat grain (4)	Winter cereal straw (5)	Oak
3000	4,65	4,76	4,35	4,70	5,16	4,73
6000	4,88	5,08	4,10	5,22	5,21	4,76
Average	4,77	4,67	4,48	4,96	5,19	4,75
Control	4,35					

Source:http://cbepolska.pl/images/ZUPS_111123/prezentacje/09ZUPS_ROMAN_WACLAWOWICZ.pdf (25.08.2013)

The study showed that ash application in agriculture improves growth and yield of triticale.

Conclusions:

Recycling ash for soil use is totally environmentally friendly and compatible with sustainable development as it can benefit crop productivity and improve soil physical properties. Much of the macro and micro elements taken up by plants is returned to the soil, thus completing the mineral/ nutrient cycle in a habitat.

Byproducts of the combustion of biomass sourced from agricultural lands, generally do not contain toxic substances (especially heavy metals) in excess of the Polish standards and do not pose a threat to the environment.

By mixing the soil with ash from biomass combustion the yields of spring wheat and triticale are improved.

Increasing the dose of tested ashes led to overall improvements in crop yields.

Fly ash application in agriculture holds good promises, however, the impact of its application on soils' conditions needs to be studied further.

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ВПЛИВ ПОПЕЛУ З БІОМАСИ НА РІСТ ЗЕРНОВИХ КУЛЬТУР

На даний час у Польщі спостерігається інтенсивне будівництво комплексів для спалювання біомаси. У найближчі два-три роки це може спричинити нагромадження більше 200 000 тонн попелу з біомаси як побічного продукту процесу спалювання. Попіл з біомаси має окремі позитивні властивості, зокрема, високий pH, високий вміст *K* та *Ca*, середній вміст *Mg, P* та деяких мікроелементів. Це може розглядатися як джерело корисного матеріалу для покращення режиму кислотності грунту і складові компоненти органічно-мінеральних добрив для живлення рослин. У попередньому експерименті, де оцінено вплив золи на схожість насіння рослин та їх первинний ріст, негативного ефекту не спостерігалося, але необхідним є безперервний моніторинг хімічного складу золи та її хімічної реакції, які можуть змінюватись в широких межах залежно від типу горіння і спалюваного матеріалу. Дослідження представляє результати експерименту із встановлення особливостей росту й розвитку різних рослин у горщиках, на грядках та в полі. Отримані фактичні дані показують, що попіл не здійснює негативного впливу на проростання насіння рослин, початковий ріст сходів та фізіологічні процеси у листках.

Ключові слова: біомаса, летка зола, мінерально-органічне добриво

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ВЛИЯНИЕ ПЕПЛА ИЗ БИОМАССЫ НА РОСТ ЗЕРНОВЫХ КУЛЬТУР

В настоящее время в Польше наблюдается интенсивное строительство комплексов для сжигания биомассы. В ближайшие два-три года это может вызвать накопление более 200 000 тонн пепла из биомассы в качестве побочного продукта процесса сжигания. Пепел из биомассы имеет отдельные положительные свойства, в частности высокий pH, высокое содержание *K* и *Ca*, среднее содержание *Mg, P* и некоторых микроэлементов. Это может рассматриваться как источник полезного материала для улучшения режима кислотности почвы и компоненты органо-минеральных удобрений для питания растений. В предыдущем эксперименте, где оценено влияние золы на прорастание семян растений и их первичный рост, негативного эффекта не наблюдалось, но необходим непрерывный мониторинг химического состава золы и ее химической реакции, которые могут варьировать в широких пределах в зависимости от типа горения и сжигаемого материала. Исследование представляет результаты эксперимента по установлению особенностей роста и развития различных растений в горшках, на грядках и в поле. Полученные фактические данные показывают, что пепел не осуществляет негативного влияния на прорастание семян растений, начальный рост всходов и физиологические процессы в листьях.

Ключевые слова: биомасса, летучая зола, минерально-органическое удобрение.