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GRANULATED COFFE GROUNDS EFFECT ON SELECTED PHYSICO-CHEMICAL AND FUNCTIONAL PROPERTIES OF SOIL

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ABSTRACT

The study evaluates granulated coffee grounds use as an additive to soil. Specific physico-chemical and functional properties of soil that enable assessment of its fertility and that have a possible impact on plants growth and development were analysed. The research proved that granulated coffee grounds added to soil increase sorption properties and decrease pH of the soil solution. Moreover, the increase of the phenol compounds that decreased the germination ability and reduced the length of roots of a test plant, namely winter wheat, was reported.

Introduction

Organic matter is a basic component of the solid phase of soil. It is a non-uniform mixture composed of living and dead organisms, and products of their decomposition and humification called soil organic substance. Plant residue is the biggest source of organic substance in the soil environment. Organic fertilizers such as: manure, liquid manure, poultry litter, composts constitute supplementation of organic substance deficit (Kwiatkowska-Malina, 2014).

Organic matter decides on many physical, chemical and biological properties of the soil environment and on the properties of the entire soil complex which influence its fertlity and productivity. Moreover, it has a positive effect on hydrothermal properties of soil and formation of aggregates. Humus substances included therein form with micro-organisms combination with loamy minerals, multi-value cations and other compounds forming complexes that bind soil components and basic particles of soil aggregates. The aggregate structure facilitates water and air circulation in soil, increases porosity and improves mechanical soil properties, which is important for agricultural production. The highest content of organic matter in soil, the darkest its colour resulting from the presence of humus substances. The darkest is soil the highest is absorption of solar radiation which results in faster heating of the surface layer of soil which fastens the vegetation period (Gonet et al., 2015). Organic matter increases sorption and buffer volume of soil, is a source of energy and nutrients for

macro and micro-organisms living in soil (Natywa et al., 2014). Moreover, it positively influences availability of micro-components and is a chelating factor of multi-value cations (Gondek et al., 2014). Soils rich in humus have a higher biological activity because micro-organisms populations occur in a greater amount and are stabilized, and take active part in humification processes, mineralization of organic material, and nitrification of the ammonia nitrogen introduced to the soil environment (Lehmann and Kleber, 2015). Physiological effects of hummus substances on plants are known. They include the effect on: protein and nucleic acids synthesis, activity of enzymes and membrane processes which improve transport of ions. Similarity of humus substances to auxins was also proved, which was used in agricultural and horticultural practice for the increase of the amount and quality of yield (Gonet et al., 2015; Andreetta et al., 2013).

The laboratory research aimed at checking how natural coffee grounds change the physico-chemical and functional properties of soil.

Research methods

Dried natural coffee grounds and horticultural soil constituted a test material. Horticultural soil after previous drying was subjected to granulometric analysis with the screen method and classified as light loamy sand (PTG, 2008).

Coffee grounds after brewing were subjected to non-pressure granulation by means of surrounding. Description of construction and principles of operation of the stand was presented in the papers by Hejft and Leszczuk (2011) and Leszczuk (2011). Non-pressure granulation of coffee grounds after with a binder was carried out with the following technical and technological parameters: angle of inclination of the granulation plate to the level of: 50º; angle of setting of a blade in a granulation plate: 90º; rotational speed of the plate: 48 rot/min, mass of coffee grounds on the plate: 500 g, weight of a binder 150 g; granulation time – 16 minutes. Intensity of granulation liquid flow was $0.0251 \cdot min^{-1}$.

Then, granulated coffee grounds and horticultural soil were mixed in various proportions. Six assays in three iterations with 410 g weight were carried out and placed in pots. Proportions of the granulated coffee grounds added to soil in particular assays were as follows: pot no. 1 – soil without coffee grounds, pots no. 2-6 – soil mixed with granulated coffee grounds in the proportion 5, 10, 15, 20 and 30%. Assay no. 7 consisted only in granulated coffee grounds without the addition of soil. Specific weighted amounts were collected from the prepared assays to carry out such determinations as: pH - potentiometer method, sorption properties and content of polyphenolic methods of Folin-Ciocalteus (Singleton et al., 1999). Then, in pots with the prepared mixture, wheat caryopses of Kalman variety were sowed, watered and dynamics of their germination was observed. After 5 weeks from sowing, biotest was finalized because since 22nd day of observation no germinated caryopses were reported. The cultivated seedlings were taken out and the length of shaped root systems was measured.

Statistical analysis

Results were subjected to a one-way analysis of variance. Significance of differences between average values from four iterations were analysed with Tukey's test. Pearson's correlation coefficient (r) was calculated for determination of the degree of mutual combi-

nations between particular parameters. Testing was made at the level of significance of $p \leq 0.05$. All analyses were carried out in Statistica 13.1 program (StatSoft Inc.)

Results and discussion

Reduction of pH was the first reported change after the use of coffee grounds addition (Fig.1). Along with the increase of the amount of added granulated coffee grounds, pH decreased (pH in water r=-0.59; pH in KCl r=-0.60). Reaction is an important parameter because the course of many soil processes, assimilability of nutrients by plants and their growth depend thereon (Kwiatkowska – Malina, 2014; Andreetta et al., 2013).

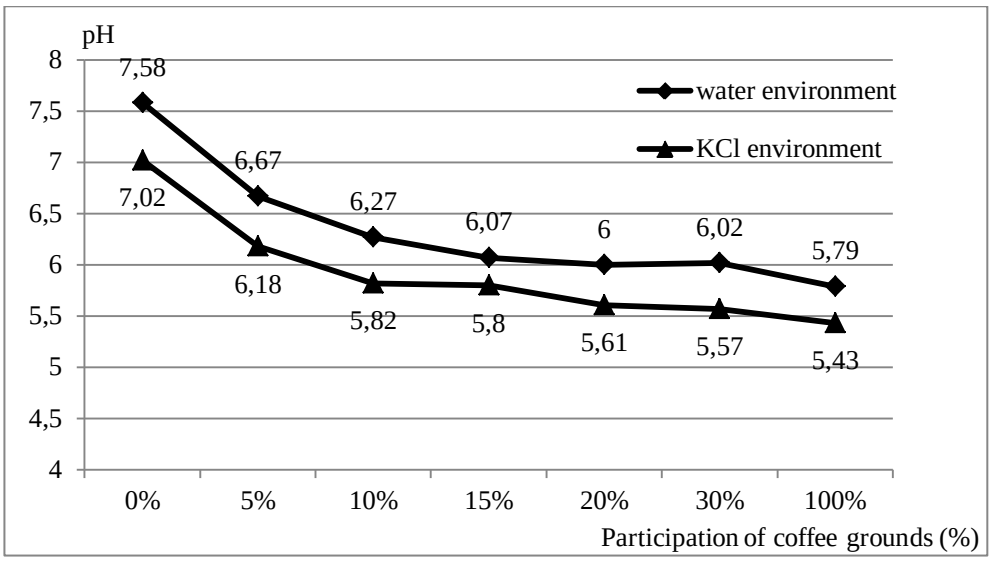

Figure1. Relation diagram of pH of investigated soil solutions to the content of coffee grounds granulate

Sorption capacity of soil is an ability to keep and absorb suspensions, gases, ions and particles which affect storing of nutrients, regulation of soil pH and neutralization of xenobiotics. (Kwiatkowska-Malina, 2014) Sorption capacity of soil means a maximum amount of acid and alkaline ions which can be absorbed by soil. The higher amount of hydrogen ions in the sorption complex, the more it is unsaturated and soil becomes acidic.

Research carried out by Jakubus (2015) with regard to the impact of urbanization transformations on soil properties proved that along with the pH increase the value of hydrolitic acidity (H) decreases and the sum of exchangeable bases and the total sorption volume raises. According to Jakubus (2015), the increase of pH is a favourable phenomenon for calciferal plants.

Figure 2 presents relations of sorption capacity of soil to the amount of granulated coffee grounds added thereto. The obtained research results, values of sorption capacity of soil

with addition of coffee grounds are high (scope: 40.93-47.26 mmol·100 g^{-1} of soil), at pH_{KCl} within the scope: 5.43-6.18, but the pH value is related to the change of the sorption capacity value of soil. Based on the obtained research results it was reported that along with the pH decrease, the value of the total amount of acidic cations (H) raises (r=0.97) while the value of the total amount of exchangeable basis (S) and the total sorption properties occur in case of soil with 20 and 30% participation of coffee grounds and the lowest – soil with 10% addition of coffee grounds. Bogacz and Przybylska obtained similar relations of pH to sorption properties (2010) when they investigated physico-chemical properties of peat soil of the so-called irrigation fields on which municipal waste were disposed (previously devoid of substances that are toxic and harmful for plant growth) with pH close to a neutral one. The obtained values of sorption capacity of soil were in relation to the depth on which assays were collected within: 28.45-39.84 mmol·100 g^{-1}_{soil}, at pH_{KCl} within 5.7-6.1.

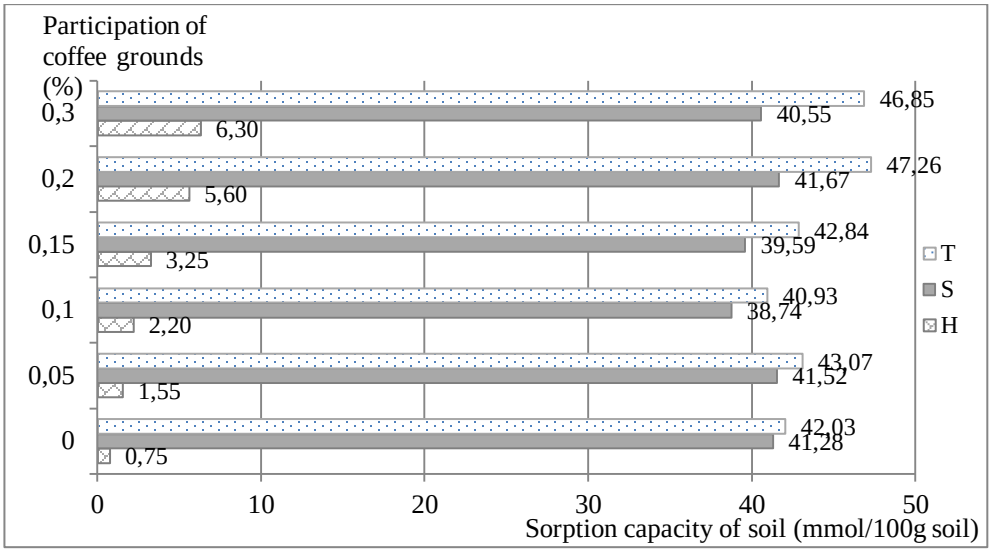

Figure 2. Relation of soil sorption capacity to the amount of added coffee grounds (H – the use of acidic cations; S – the sum of exchangeable bases; T – total sorption capacity)

Another soil parameter which has changed after addition of granulated coffee grounds was the phenol compounds content (Fig. 3). According to the research results, coffee grounds after brewing have a high content of polyphenol compounds (60.727 mg·g^{-1}_{soil}), and their addition to soil causes significant increase of the content of these compounds, which is confirmed by the correlation coefficient r=0.98. According to Wichrowska and Żary-Sikorska (2015), also other agri-food waste such as apple pomace and natural apple fiber which can be used as an additive to soil, have high polyphenol content.

The period of intense plant growth which is accompanied by decomposition of plant residues under the influence of edaphon favours natural collection of phenol compounds in soil, according to the research by Furczak and Turska (2006), and Natywa et al., (2014).

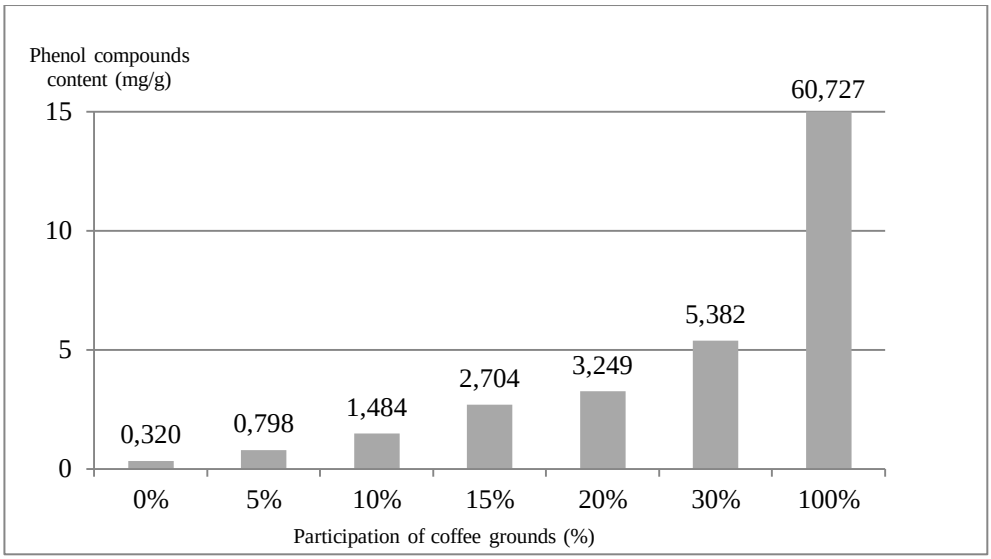

Figure 3. Relation of the phenol compounds content in the investigated soil assays to the granulate content obtained from coffee grounds

Phenol compounds which naturally occur in organic waste are released to soil during hydrolysis of these compounds. Released polyphenols are subjected to oxidization reactions that are catalyzed by oxidase to chinones. Formed chinones are polymerised and form humus compounds together with sugars, carboxylic acids and other organic compounds (Park et al., 2000; Skiba, 2002). Polyphenol compounds in soil are also enzymes that are responsible for stimulation of formation of reactive oxygen forms. They also function as compounds that chelate metals which catalyse formation of reactive oxygen forms (Ostrowska and Skrzydlewska, 2005; Stręk and Telesiński, 2014).

Figure 4 presents relation of speed and amount of germination of winter wheat caryopses to the percentage share of granulated coffee grounds in soil. After caryopses were sowed on the prepared soil mixtures with coffee grounds and control soil, their germination in all assays was determined. Germination of caryopses was the fastest and the most numerous on the control soil. Among the facilities which had coffee grounds added, the fastest and the most numerous germinating wheat caryopses were in case of their 15% share.

Moreover, an initial root system of winter wheat caryopses was researched (Fig. 5). The highest increase of the root length was proved in caryopes sowed to the base without the addition of coffee grounds (8.66 cm) whereas in pots with addition of coffee grounds the highest increase of the root system was in case of soil with 5 and 10% addition of coffee grounds, respectively 6.63 and 6.66 cm. The most probably, soil environment reaction, which in our case was within 6.27-6.67 and which was optimal for wheat growth, was responsible for this effect.

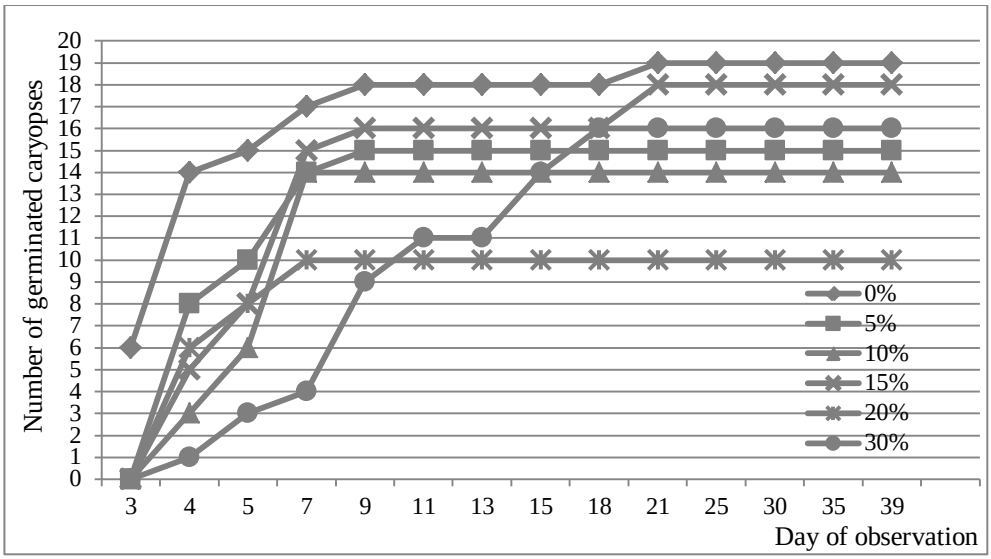

Figure 4. Dynamics of germination and the number of germinated winter wheat caryopses in relation to the percentage share in the bed made of coffee grounds granulate

Except for a relevant reaction, the following could have induced germination: suitable soil humidity that increases germination energy and nutrients stored in the seed endosperm and in soil (Nadulski et al., 2012; Wesołowski and Cierpiała, 2011). The smallest results of wheat caryopses germination and the shortest roots were obtained in assays with 20% addition of coffee grounds. At the same time, we should emphasise that each addition of coffee grounds caused reduction of root lenght. However, these relations were not proportional (Fig. 5) and coefficient of correlation is r=0.71. Soil reaction is this case was of the secondary impact. With a high degree of probability, it may be assumed that polyphenols present in the ground were responsible for the reduction of the length of roots. Moreover, reactive oxygen forms take part in these processes. They may influence seeds germination by oxidization of phenol compounds present for example in pericarp and recognized as germination inhibitors, as in case of common zinnia seeds (*Zinnia elegant*) (Bailly et al., 2008).

The increase of interest in the protection of environment and organic agriculture and in the possibility of disposing various wastes caused that solutions limiting the application of chemical substances with simultaneous maintenance of high yield are searched for. Therefore, artificial fertilizers are more often replaced by substances which improve soil properties at the simultaneous increase of the amount of nutrients which plants can obtain from the soil environment (Jadczyszyn et al., 2010).

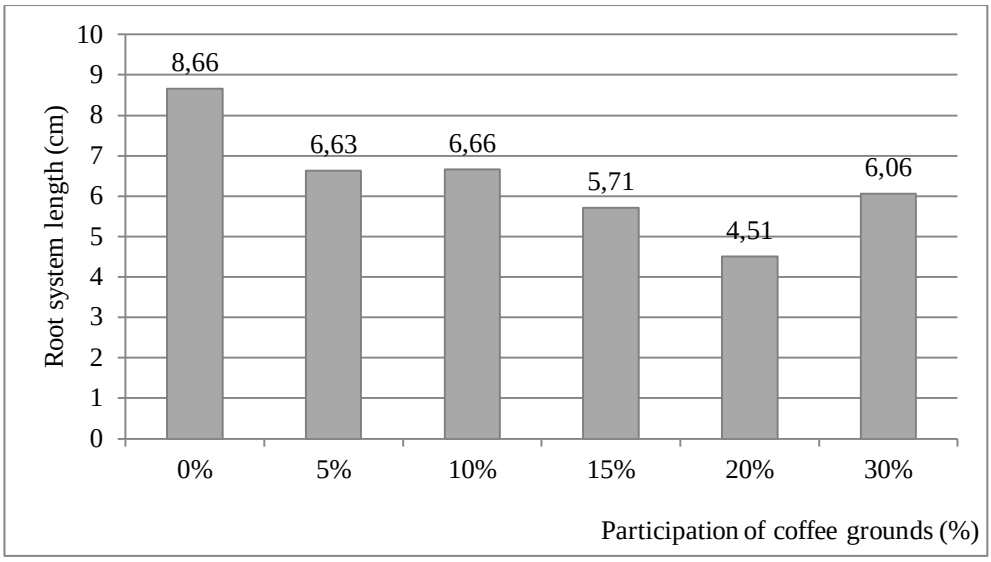

Figure 5. Length of the root system of winter wheat caryopses in relation to the percentage share in the bed made of coffee grounds granulate

On the retail and wholesale market, there are many substances which aim at improvement of soil properties. They are advertised as organic fertilizers, the so-called biohumus, which formed as an effect of digestion of California earthworm of manure, muskeg, food waste and municipal sewage sludge. These substances, except for providing nutrients to plants, aim at improvement of the soil structure, regulation of its pH and increase of water and sorption capacity affecting the same the plant growth. Except for substances made on the base of coprolite, there are also mineral substances which improve soil properties or rock flour (e.g. basaltic, granite or bentonite). They include oxygen and carbonate mixtures which contain calcium oxide, chloride. The application of these fertilizers according to the producer, improves the physico-chemical soil properties by maintenance of an optimal crumbly structure and water and air soil conditions (Jadczyszyn et al., 2010; Biały, 2013).

Conclusions

1. Addition of granulated coffee grounds to soil influences the increase of sorption properties, in particular of acidic cations content, which results in the decrease of soil reaction.
2. Coffee grounds had high phenol compounds content and their addition to soil causes the increase of the content of these compounds in the soil environment. Unfortunately, it results in the decrease of germination ability and reduction of the test plant root length, namely of winter wheat.
3. The highest increase of the root length was reported in caryopses sowed to the base without the addition of coffee grounds, whereas in pots with addition of coffee grounds

the highest increase of the root system was in case of soil with 5 and 10% addition of coffee grounds.

4. Each addition of coffee grounds granulate caused reduction of the root length. The smallest number of wheat caryopses germination and the shortest roots were obtained in assays with 20% addition of coffee grounds. Probably, phenol compounds present in the bed were responsible for such a state.

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References

Andreetta, A., Macci, C., Giansoldati, V., Masciandaro, G., Carnicelli, S. (2013). Microbial activity and organic matter composition in Mediterranean humus forms. *Geoderma*, *209*, 198-208.

Bailly, C., El-Maarouf-Bouteau, H., Corbineau, F. (2008). From intracellular signaling networks to cell death: the dual role of reactive oxygen species in seed physiology. *Comptes Rendus Biologies*, *331*, 806-814.

Biały, M. (2013). *Preparaty poprawiające żyzność gleb*. Obtained from: http://rolnictwo.com.pl/preparaty-poprawiajace-zyznosc-gleb,n8640.html.

Bogacz, A., Przybylska, M. (2010). Właściwości fizykochemiczne wybranych gleb torfowych na polach irygacyjnych Wrocławia. *Woda-Środowisko-Obszary Wiejskie*, *T.10*, *3*(31), 33-40.

Furczak, J., Turska, B. (2006). Wpływ różnych systemów uprawy soi na rozwój mikroorganizmów i zawartość fenoli w glebie płowej. *Acta Agrophysica*, *8*(1), 59-68.

Gondek, K., Mierzwa, M. (2014). Quantity and Quality of Organic Matter in Soil after Application of Various Organic Materials/Ilość i Jakość Materii Organicznej w Glebie po Aplikacji Różnych Materiałów Organicznych. *Ecological Chemistry and Engineering*, *21*(3), 477-485.

Gonet, S., Smal, H., Chojnicki, J. (2015). *Właściwości chemiczne gleb.* W: *Gleboznawstwo*. Mocek A., (red.), PWN Warszawa, 189-232.

Hejft, R., Leszczuk, T. (2011). Dobór parametrów procesu bezciśnieniowej aglomeracji (otoczkowania nasion). *Inżynieria i Aparatura Chemiczna, 1*/201, 15-16.

Jadczyszyn, T., Kowalczyk, J., Lipiński, W. (2010). *Zalecenia nawozowe dla roślin uprawy polowej i trwałych użytków zielonych*. Materiały szkoleniowe nr 95, IUNG-PIB Puławy.

Jakubus, M. (2015). Zmiany wybranych właściwości gleb jako konsekwencja przemian urbanizacyjnych przestrzeni miejskiej Poznania. *Problemy Rozwoju Miast Kwartalnik Naukowy Instytutu Rozwoju Miast*. Zeszyt IV, 19-25.

Kwiatkowska-Malina, J. (2014). *Skład gleb* W: Podstawy gleboznawstwa z elementami kartografii gleb. Skłodowski P., (red.) Oficyna Wydawnicza PW Warszawa, 103-160.

Lehmann, J., Kleber M. (2015). The contentious nature of soil organic matter. *Nature*, 528, 60-68, Doi:10.1038/nature16069.

Leszczuk, T. (2011). Metodyka badań nawozów granulowanych rolniczych i ogrodniczych. *Technika Rolnicza Ogrodnicza Leśna*, *3*, 20-22.

Nadulski, R., Kusińska, E., Guz, T., Kobus, Z. (2012). Wpływ wilgotności ziarniaków i nacisku pionowego na ich energię i zdolność kiełkowania. *Inżynieria Rolnicza*, *2*(137), 221-229.

Natywa, M., Selwet, M., Maciejewski, T. (2014). Wpływ wybranych czynników agrotechnicznych na liczebność i aktywność drobnoustrojów glebowych. *Fragmenta Agronomica*, *31*, 56-63.

Ostrowska, J., Skrzydlewska, E. (2005). Aktywność biologiczna flawonoidów. *Postępy Fitoterapii*, *3-4*, 71-79.

Park, J. W., Dec, J., Kim, J., Bollag, J. (2000). Transformation of chlorinated phenols and anilines in the presence of humic acid. *Journal of Environmental Quality, 29,* 214-220.

Polskie Towarzystwo Gleboznawcze. (2008). *Klasyfikacja uziarnienia gleb*. PTG 2008.

Singleton, L.,Orthofer, R., Lamuela-Raventions, R. M. (1999). Analysis of Total phenols and Rother oxidation substrates and antioxidants by means of Folin-Ciocaltue reagent. *Methods Enzymology, 299,* 152-178.

Skiba, S. (2002). Gleba w środowisku przyrodniczym. W: *Aktywność drobnoustrojów w różnych środowiskach.* Barabasz W. (red.), Wyd. AR Kraków, 157-169.

Stręk, M., Telesiński, A. (2014). Badania nad możliwością wykorzystania selenu w ograniczeniu oddziaływania ołowiu na wybrane przemiany metaboliczne związków fenolowych w glebie i siewkach pszenicy jarej (*Triticum aestivum* L.). *Polish Journal of Agronomy*, *18*, 45-51.

Wesołowski, M., Cierpiała, R. (2011). Plonowanie pszenicy ozimej w zależności od sposobu wykonania uprawy przedsiewnej. *Fragmenta Agronomica*, *28*(2), 106-118.

Wichrowska, D., Żary-Sikorska, E. (2015). Właściwości prozdrowotne jabłkowych wytłoków poprasowych. *Inżynieria i Aparatura Chemiczna, 54, 5,* 286-287.

WPŁYW GRANULOWANYCH FUSÓW POWSTAJĄCYCH PO PARZENIU KAWY NA WYBRANE WŁAŚCIWOŚCI FIZYKO-CHEMICZNE I FUNKCJONALNE GLEBY

Streszczenie. Celem przeprowadzonych badań była ocena wykorzystania granulowanych fusów po zaparzeniu kawy naturalnej jako dodatku do gleby. Analizie poddano wybrane parametry fizykochemiczne i funkcjonalne gleby umożliwiające ocenę jej żyzności oraz mających potencjalny wpływ na wzrost i rozwój roślin. Przeprowadzone badania wykazały, że dodatek do gleby granulowanych fusów z kawy powoduje wzrost właściwości sorpcyjnych oraz obniża pH roztworu glebowego. Ponadto stwierdzono wzrost zawartości związków fenolowych, które spowodowały obniżenie zdolności kiełkowania jak i redukcje długości korzeni rośliny testowej, którą była pszenica ozima.

Słowa kluczowe: bioodpady, dodatki do gleby, granulowane "fusy" z kawy, gleba