Barbara FUTA[1], Agnieszka MOCEK-PŁÓCINIAK[2]
[1] Uniwersytet Przyrodniczy w Lublinie, Instytut Gleboznawstwa, Inżynierii i Kształtowania Środowiska
ul. kr. St. Leszczyńskiego 7, 20-069 Lublin, Poland
e-mail: barbara.futa@up.lublin.pl
[2] Uniwersytet Przyrodniczy w Poznaniu, Wydział Rolnictwa i Bioinżynierii, Katedra Mikrobiologii Ogólnej i Środowiskowej
e-mail: agnieszka.mocek-plociniak@up.poznan.pl

THE INFLUENCE OF UNCONTROLLED GRASS BURNING ON BIOCHEMICAL QUALITIES OF SOIL

Summary

Measurements of soil enzymatic activity enable determination of the rate of regeneration of soils destroyed by fire. The aim of the study was to assess the influence of uncontrolled grass burning in spring on soil enzymatic activity. The object of the study was soil in the grassland ecosystem located in Turowola Kolonia near the town of Łęczna, Poland. Every year in spring uncontrolled grass burning is practised there. Soil samples for investigations were collected in May, July and October 2015, from depths of 0-5 and 5-10 cm, from three places: burnt soil, ecotone and area without fire. The activity of the following enzymes was measured in the samples: dehydrogenases, phosphatases, urease and protease. Grass burning had negative influence on the biological state of the soil under study, which was manifested by reduced activity of the enzymes catalysing the most important processes of transformation of organic matter. The investigations conducted 6 months after grass burning revealed that both in the ecotone and in the soil with burnt surface the enzymatic activity was similar to the activity in the control soil sample. This observation shows that soil with burnt surface achieves the state of relative biological balance, which is necessary for normal functioning of a grassland ecosystem.
***Key words**: soil, grassland ecosystems, grass burning, enzymatic activity*

WPŁYW NIEKONTROLOWANEGO WYPALANIA TRAW NA WŁAŚCIWOŚCI BIOCHEMICZNE GLEBY

Streszczenie

Pomiary aktywności enzymatycznej gleb dają możliwość określenia tempa regeneracji gleb zniszczonych przez pożar. Celem pracy była ocena wpływu niekontrolowanego, wiosennego wypalania traw na aktywność enzymatyczną gleby. Obiektem badań była gleba w obrębie ekosystemu łąkowego zlokalizowanego w miejscowości Turowola Kolonia k. Łęcznej. Na łące tej corocznie stosowane jest niekontrolowane, wiosenne wypalanie traw. Próbki glebowe do badań pobrano w maju, lipcu i październiku 2015 roku, z głębokości 0-5 i 5-10 cm, z trzech miejsc: z gleby spalonej, ekotonu i z miejsca poza pożarem. W pobranych próbkach oznaczono aktywność następujących enzymów: dehydrogenaz, fosfataz, ureazy i proteazy. Wypalanie traw miało negatywny wpływ na stan biologiczny badanej gleby, wyrażający się obniżeniem aktywności enzymów katalizujących najważniejsze procesy przemiany substancji organicznej. Badania przeprowadzone 6 miesięcy po wypaleniu traw, wykazały, że zarówno w ekotonie, jak i glebie na powierzchni spalonej aktywność badanych enzymów dorównywała ich aktywności oznaczonej w glebie kontrolnej. Świadczy to, że gleba na powierzchni spalonej uzyskuje stan względnej dynamicznej równowagi biologicznej, niezbędnej dla prawidłowego funkcjonowania ekosystemu łąkowego.
***Słowa kluczowe**: gleba, ekosystemy łąkowe, wypalanie traw, aktywność enzymatyczna*

1. Introduction

Although uncontrolled grass burning is forbidden by law in Poland [6, 7, 9], it is a common procedure applied in agriculture and forestry [16]. In Polish farmers' opinion, burning grass and crop residues in spring is a specific type of soil fertilisation [26]. The European Union joined the struggle to eliminate this practice as the assumptions of the EU agricultural policy also regulate the issues of environmental protection in agriculture [16]. The farmers who burn grass and wasteland may have restricted access to direct payments and agri-environmental subsidies from the EU [8, 10, 11, 19].

Grass burning in spring destroys biological life in soil and considerably inhibits natural humification processes, which guarantee maintenance of soil fertility. Direct influence of high temperature reduces the count of soil microorganisms considerably. Populations of microorganisms are an integral part of soil and their activity is very important for its normal functioning [2, 13, 19, 22]. Microorganisms and the enzymes they produce are decisive to the transformation of organic matter, influence the humification process, play a key role in biogeochemical cycles of many macro- and microelements. Thanks to the presence of microorganisms, soil can regenerate its resources which are necessary for the growth and development of plants and other organisms existing in it. Changes in soil enzymatic activity reflect environmental disorders affecting both soil and plants [1]. Measurements of enzymatic activity enable determination of the rate of regeneration of soil destroyed by fire [2, 3, 18]. The aim of the study was to assess the influence of uncontrolled grass burning in spring on soil enzymatic activity in a used grassland ecosystem.

2. Material and methods

The object of the study included soil in the grassland ecosystem located in Turowola Kolonia near the town of Łęczna, Poland. Every spring uncontrolled grass burning is practised there. The soil collected for analysis was typical podzolic soil with granulometric composition similar to silt loam. Table shows the essential chemical properties of the soil collected from the area under study.

Table. Characteristics of the soil from the area under study
Tabela. Charakterystyka gleby z obszaru badań

Object	pH_{KCl}	C ($g \cdot kg^{-1}$)	N ($g \cdot kg^{-1}$)	C:N	$N\text{-}NH_4^+$ ($mg \cdot kg^{-1}$)	$N\text{-}NO_3^-$ ($mg \cdot kg^{-1}$)
Grassland	6,65	9,12	0,84	10,86	18,56	17,64

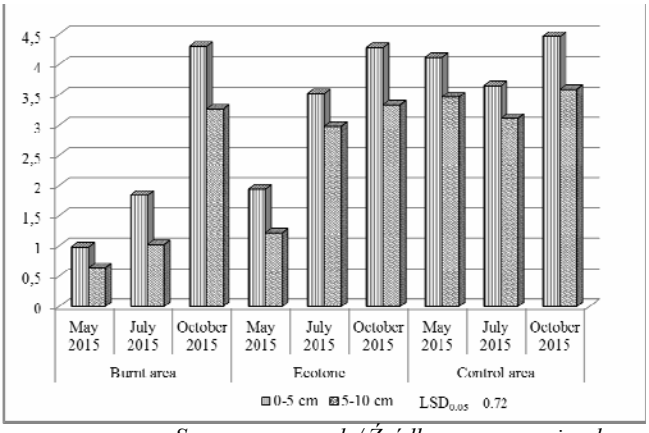
Source: own work / Źródło: opracowanie własne

Soil samples for investigations were collected in May, July and October 2015, from depths of 0-5 and 5-10 cm, from three places: burnt soil, ecotone (border area) and area without fire. The soil sample subjected to analysis was a mean of 5 samples collected from each place. The activity of the following enzymes was measured in the samples: dehydrogenases [25], phosphatases [24], urease [27] and proteases [15]. These enzymes directly participate in mineralisation and circulation of carbon, nitrogen and phosphorus in soil and exhibit noticeable reactions to environmental factors. The activity of dehydrogenases, phosphatases and urease was analysed in soil of natural humidity and the results were converted into dry weight of soil with measurement of soil humidity. All measurements were made in three parallel replications. The results were analysed statistically. The significance level assumed in the analysis was typical of life science investigations, i.e. $\alpha = 0.05$ (the probability of occurrence $p = 0.95$).

3. Results and discussion

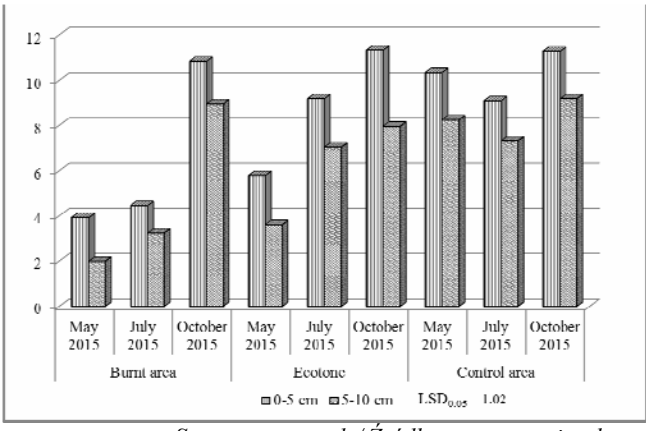
During the first research period (May 2015) the enzymatic activity in the soil on the burnt surface and in the ecotone was significantly lower than in the soil without fire (Fig. 1-4). Very low enzymatic activity in the burnt soil must have been caused by destruction of higher plants and their rhizosphere as well as the microflora inhabiting superficial soil layers. This suggestion is confirmed by the findings of studies conducted by Hamann et al. [13] Rau et al. [23] Lemanowicz & Bartkowiak [16] and Bielinska et al. [2]. The study by Prądecka & Russel [20] proved that the counts of bacteria, actinobacteria and fungi were reduced both in the burnt area and on the border between this area and the place without fire. Prędecka et al. [19] observed an inversely proportional relationship between the flame temperature and enzymatic activity – the lowest enzyme activity was in the centre of fire, whereas the highest was in the ecotone. Variation in the flame temperature and speed of fire caused by diversified soil humidity may influence the range of variations in the content of soil nutrients [12]. The inactivation of soil enzymes by fire may cause a deficit of essential nutrients, especially mineral phosphorus [16]. Boerner & Brinkman [4] and Olszowska [17] observed a similar dependence in their studies on forest soils. They attributed this effect to the influence of high temperature on the destruction and reduction of soil microorganisms. Simultaneously, it reduced the intensity of microbiological processes of organic matter decomposition, including reduction of the activity of soil enzymes [5].

In May 2015 at the depth of 0-5 cm the activity of dehydrogenases, phosphatases and protease was about 1.5 times greater, whereas urease activity was more than 3 times greater than in the subsuperficial layer (5-10 cm). High urease inactivation which could be observed in the subsuperficial layer of soil was caused by grass burning and resulted in inactivation of urease of plant origin or urease connected with the rhizosphere of higher plants. This observation was confirmed in the study conducted by Hauke-Pacewiczowa and Trzcińska [14].



Source: own work / Źródło: opracowanie własne

Fig. 1. Dehydrogenase activity [$cm^3\ H_2 \cdot kg^{-1} \cdot d^{-1}$]
Rys. 1. Aktywność dehydrogenaz [$cm^3\ H_2 \cdot kg^{-1} \cdot d^{-1}$]

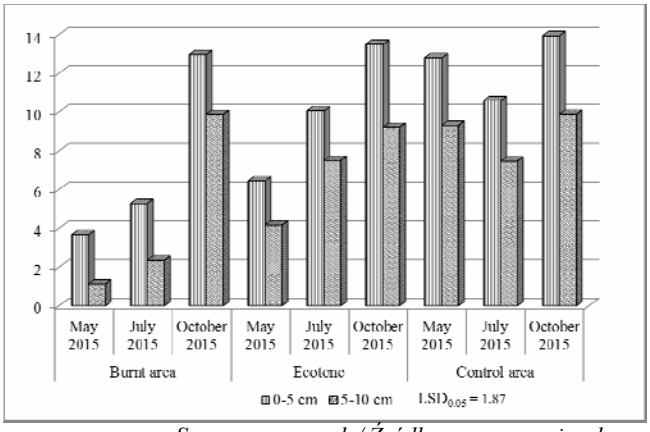


Source: own work / Źródło: opracowanie własne

Fig. 2. Phosphatase activity [mmol $PNP \cdot kg^{-1} \cdot h^{-1}$]
Fig. 2. Aktywność fosfataz [mmol $PNP \cdot kg^{-1} \cdot h^{-1}$]

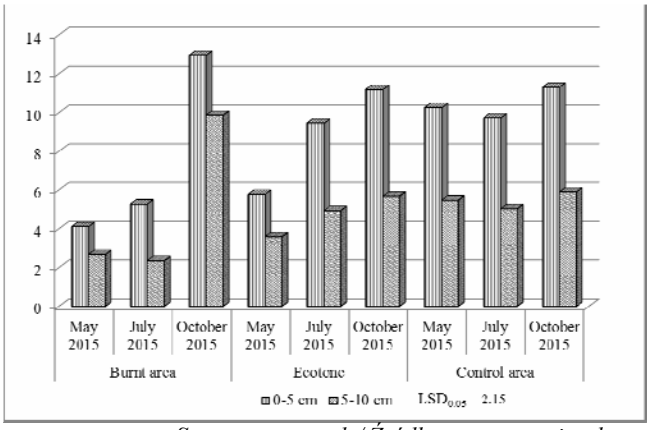
At the next study period (July 2015) the enzymatic activity in the burnt soil was noticeably lower than in the soil beyond the range of fire. However, the enzymatic activity in the ecotone was similar to the value noted in the control soil sample (Fig. 1-4). The investigations conducted 6 months after grass burning (October 2015) revealed that both in the ecotone and in the soil with burnt surface the enzymatic activity in both soil layers under study was comparable to the activity measured in the control sample (Fig. 1-4). It shows that the soil with burnt surface achieved a state of relative dynamic biological balance, which is necessary for normal functioning of the grassland ecosystem. On the other hand, Prędecka et al. [21] proved that the process of regeneration of enzymatic activity in grassland ecosystems on burnt surfaces and in ecotones of peat-muck soils and pseudogley soils was completed after one year. According to Prędecka et al. [19], favourable changes in soil enzymatic activity are directly proportional to an in-

crease in the biomass of microorganisms on a surface destroyed by fire.



Source: own work / Źródło: opracowanie własne

Fig. 3. Urease activity [mg $N\text{-}NH_4^+ \cdot kg^{-1} \cdot h^{-1}$]
Rys. 3. Aktywność ureazy [mg $N\text{-}NH_4^+ \cdot kg^{-1} \cdot h^{-1}$]



Source: own work / Źródło: opracowanie własne

Fig. 4. Protease activity [mg tyrozyny$\cdot kg^{-1} \cdot h^{-1}$]
Rys. 4. Aktywność proteaz [mg tyrozyny$\cdot kg^{-1} \cdot h^{-1}$]

4. Conclusions

1. Grass burning had negative influence on the biological state of the soil under study because it reduced the activity of the enzymes catalysing the most important processes of transformation of organic matter.
2. Six months after the fire the soil with burnt surface achieved a state of relative dynamic biological balance, which is necessary for normal functioning of the grassland ecosystem.
3. Observations of enzyme reactions gave a possibility to identify and specify temporary trends in transformations of the soil environment.
4. Measurements of soil enzymatic activity enable determination of the rate of regeneration of soils destroyed by grass burning.

5. References

[1] Bielińska E. J., Futa B., Mocek-Płóciniak A.: Enzymy glebowe jako bioindykatory jakości i zdrowotności gleby, Monografia naukowa. Lublin: Libropolis, 2014.
[2] Bielińska E.J., Futa B., Kołodziej B., Mocek-Płócinik A., Kaczmarek Z.: Przeobrażenia ekochemicznego stanu gleb leśnych na pożarzysku wielkoobszarowym w wieloleciu, Monografia naukowa. Lublin: Libropolis, 2016.
[3] Bielińska E.J., Mocek-Płóciniak A., Kaczmarek Z.: The influence of the Method of Reclamation and Selection of Tree Species for Afforestation on Changes in Landscape Degraded by Fire. Archives of Environmental Protection, 2008, 35, 2, 105-113.
[4] Boerner R.E.J., Brinkman J.A.: Fire frequency and soil enzyme activity in southern Ohio oak–hickory forests. Applied Soil Ecology, 2003, 23, 137-146.
[5] Boerner R.E.J., Brinkman J.A. Smith A.: Seasonal variations in enzyme activity and organic carbon in soil of a burned and unburned hardwood forest. Soil Biol. Biochem., 2005, 37, 1419-1426.
[6] Official Journal, 2004, No. 92, Pos. 880: Nature Conservation Act of 16 April 2004.
[7] Official Journal, 1991, No. 101, Pos. 444: Forest Act of 28 September 1991.
[8] Official Journal, 2004, No. 73, Pos. 657: Regulation of the Council of Ministers of 14 April 2004 on Detailed Conditions and Procedures for Granting Financial Aid to Support Agricultural Activity in Less-Favoured Areas under the Rural Development Plan.
[9] Official Journal 2010, No. 109, Pos. 719: Regulation of the Minister of Internal Affairs and Administration of 7 June 2010 on Fire Protection of Buildings, Structures and Areas.
[10] Official Journal, 2010, No. 39, Pos. 210: Regulation of the Minister of Agriculture and Rural Development of 11 March 2010 on Detailed Requirements for Applications for Payments to Implement Agri-Environmental and Animal Welfare Projects and Their Action Plans.
[11] Official Journal, 2015, Pos. 308: Act of 5 February 2015 on Payments under Direct Support Schemes.
[12] Galang M.A., Markewitz D., Morris L.A.: Soil phosphorus transformations under forest burning and laboratory heat treatments. Geoderma, 2010, 155, 401-408.
[13] Hamman S.T., Burke I.C., Knapp E.E.: Soil nutrients and microbial activity after early and late season prescribed burns in a Sierra Nevada mixed conifer forest, Forest Ecology Management, 2008, 256, 367-374.
[14] Hauke-Pacewiczowa T., Trzcińska M.: Wpływ pożaru dna lasu na aktywność mikrobiologiczną gleby, Rocz. Glebozn., 1980, 31, 2, 33-41.
[15] Ladd N., Butler J.H.A.: Short-term assays of soil proteolytic enzyme activities using proteins and dipeptide derivatives as substrates, Soil Biol. Biochem., 1972, 4, 19-30.
[16] Lemanowicz J., Bartkowiak A.: Zmienność aktywności fosfataz oraz zawartości fosforu i węgla w wierzchniej warstwie gleby rok po pożarze lasu, Prz. Nauk. Inż. Kszt. Środ., 2015, 68, 145-154.
[17] Olszowska G.: Enzyme activity of soils after large-scale fi res under varying habitat conditions using different methods of forest regeneration, Forest Research Papers, 2009, 70, 183-188.
[18] Olszowska G.: Wpływ pożaru w Nadleśnictwie Rudy Raciborskie na aktywność enzymatyczną gleb, Rocz. Glebozn., 2002, 53(3/4), 97-104.
[19] Prędecka A., Chojnicki J., Russel S.: Wpływ wiosennego wypalania traw na liczebność bakterii i aktywność dehydrogenaz glebowych, Nauka Przyroda Technologie, 2010, 6, 4 #93, 1-9.
[20] Prędecka A., Russel S.: Wpływ wybranych środków gaśniczych na mikroflorę gleby. Rocz. Glebozn., 2007, 58, 93-98.
[21] Prędecka A., Russel S., Chojnicki J.: Wpływ doświadczalnego palenia jesiennego traw na biologiczną aktywność gleb łąkowych. Rocz. Glebozn., 2009, 60, 4, 71-78.
[22] Prędecka A., Russel S., Chojnicki J., Charmuszko N.: Wpływ kontrolowanego wypalania traw na liczebność grzybów glebowych, Woda-Środowisko-Obszary Wiejskie, 2010, 10, 2 (30), 133-141.
[23] Rau B.M., Chambers J.C., Blank R.R., Jonson D.W.: Effects of fire on soil respiration, ATP content and enzyme activities in Mediterranean maquis. Rangeland Ecol. Manag., 2008, 61, 3, 169-181.
[24] Tabatabai M.A., Bremner J.M.: Use of p-nitrophenol phosphate for assay of soil phosphatase activity, Soil Biol. Biochem., 1969, 1, 301-307.
[25] Thalmann A.: Zur Methodik derestimmung der Dehydrogenase Aktivität in Boden mittels Triphenyltetrazoliumchlorid (TTC), Landwirtsch. Forsch., 1968, 21, 249-258.
[26] Waniek E., Oględcki P.: Wypalanie traw i pożary zagrożenie dla bioróżnorodności i zasobów przyrody nieożywionej. In: Zasoby przyrodnicze szansą zrównoważonego rozwoju, ed. P Hewelke, Warszawa: Wyd. SGGW, 2007, 209-215.
[27] Zantua M.I., Bremner J.M.: Comparison of methods of assaying urease activity in soils, Soil Biol. Biochem., 1975, 7, 291-295.