ACTA SCIENTIARUM POLONORUM Acta Sci. Pol., Agricultura 10(3) 2011, 93-100

RESPIRATORY AND DEHYDROGENASE ACTIVITIES IN THE SOIL UNDER MAIZE GROWTH IN THE CONDITIONS OF IRRIGATED AND NONIRRIGATED FIELDS

Małgorzata Natywa, Marek Selwet
Poznań University of Life Sciences

Abstract. The aim of the study was to ascertain the impact of irrigation or its absence on respiratory and dehydrogenase activities in soils under maize growth. Investigations were carried out in years 2007-2009 at six times of analysis during the maize growth season. The experiment included experimental plots on which maize of Clarica hybrid (FAO 220, Pioneer) intended for CCM was grown. The experimental plots were irrigated with the use of semi-permanent sprinkling machines. Dehydrogenase activity in the soil was determined colorimetrically, and soil respiratory activity was determined with the titration method. Soil respiratory activity did not exhibit significant variability during the growth season with the exception of 2009 at the second time of analysis (at the 2-3 maize leaf stage), when the highest average values in the season were recorded. In the third year of the analysis (2009), practically speaking, no significant differences were observed in the activity of the examined enzymes between irrigated and nonirrigated plots. The comparison of the dates of the analyses showed that the highest activity of the investigated enzymes occurred in the spring before sowing and in the summer. Mean values of the respiratory activity did not show large differences in the individual seasons.

Key words: developmental stage, microbiological activity, water shortages

INTRODUCTION

In agriculture, one aims at maximising yields. This makes it necessary to apply appropriate growth operations and, in the case of fields characterized by poor retention capabilities, also irrigation. Periodical water shortages during growth occur, primarily, in light soils suitable for maize growth [Żarski *et al.* 2004]. Sulewska [1997] states that decreased yields of this plant should be attributed to water storages. When assessing soil fertility, a significant role is played by such microbiological indices as respiratory or enzymatic activities [Corstanje and Reddy 2006]. The above parameters are considered

Corresponding author – Adres do korespondencji: dr hab. inż. Marek Selwet, Department of General and Environmental Microbiology, Poznań University of Life Sciences, Szydłowska 50, 60-656 Poznań, e-mail: mselwet@jay.au.poznan.pl

to be very sensitive and describe well the conditions of soil environment, since they are directly associated with soil microorganisms which, together with growth, determine the direction and character of basic transformations linked with soil biogeochemistry and physicochemical properties. In the soils of high ground water levels, CO_2 concentrations frequently reach their peaks in the central part of their profiles. The level of carbon dioxide depends, among other factors, on moisture content, the presence of plant cover, and fertilization with fresh plant material. It is thought that respiration in soil is determined, to the highest degree, by the respiration activity of soil microorganisms and plant roots [Stępniewska *et al.* 2004]. Soil dehydrogenase activity is used as a measure of total microbiological activity [Januszek *et al.* 2007]. Their overall activity comprises the action of a large group of intracellular enzymes, which are constituents of living cells and are responsible for the process of biological oxidation [Ghaly and Mahmoud 2006]. The analysis of dehydrogenase activity provides information on the changes in soil microbiological activity, in this case utilized agriculturally under the influence of agrotechnical treatments (including irrigation), aiming at increasing its fertility. A wide range of dehydrogenase activities means that this is a commonly applied parameter used in the evaluation of the conditions of soil environment [Nwanyanwu and Abu 2010].

MATERIAL AND METHODS

The discussed experiment was conducted at the Experimental-Didactic Station in Złotniki, which is part of the Poznań University of Life Sciences. The experiment was conducted on typical grey-brown podzolic soils developed from light loamy sand and strongly sandy light clay of IVa and IVb soil quality classes. Analyses were carried out in years 2007-2009 at six times of analysis in the course of the maize growth season: prior to sowing (I), at the 2-3 leaf stage (II), at the 7-8 leaf stage (III), at the tasseling stage (IV), at the milk stage (V) and at full maturity (VI). The trial comprised experimental plots on which maize of Clarica hybrid (FAO 220, Pioneer) intended for CCM was grown. The experimental plots were irrigated with the use of semi-permanent irrigation machines equipped with sprinklers of 7 mm nozzles and the operational pressure of 3.5 to 4 atmospheres. Single water discharge amounted to 40 mm. Dehydrogenase activity was determined colorimetrically in accordance with the methodology recommended by Thalmann [1968] using TTC (2.3.5- triphenylformazan chloride) as a substrate ($\mu g\ TPF \cdot g^{-1}$ soil $DM \cdot 24\ h^{-1}$). Soil respiratory activity was determined with the titration method [Pędziwilk and Gołębiowska 1984] and expressed in mg $CO_2 \cdot kg^{-1} \cdot 24\ h^{-1}$. Statistical analysis of the obtained results was carried out with the assistance of Statistica 8.0 software, and the differences between mean values were assessed with the Tukey's test.

RESULTS AND DISCUSSION

Soil reaction in the experimental plot ranged from acid to mildly alkaline. The determined pH values from the individual experimental combinations fluctuated from 5.17 to 7.27 (Figs. 1-3). Higher soil pH was recorded in irrigated plots, which could have also affected dehydrogenase activity. The activity of enzymes characterized by higher optimum pH (dehydrogenase, protease, and urease) correlated with the level of soil reaction [Furczak *et al.* 1997]. In addition, reduced microbiological activity and unfavourable changes of chemical properties were observed in acid soils.

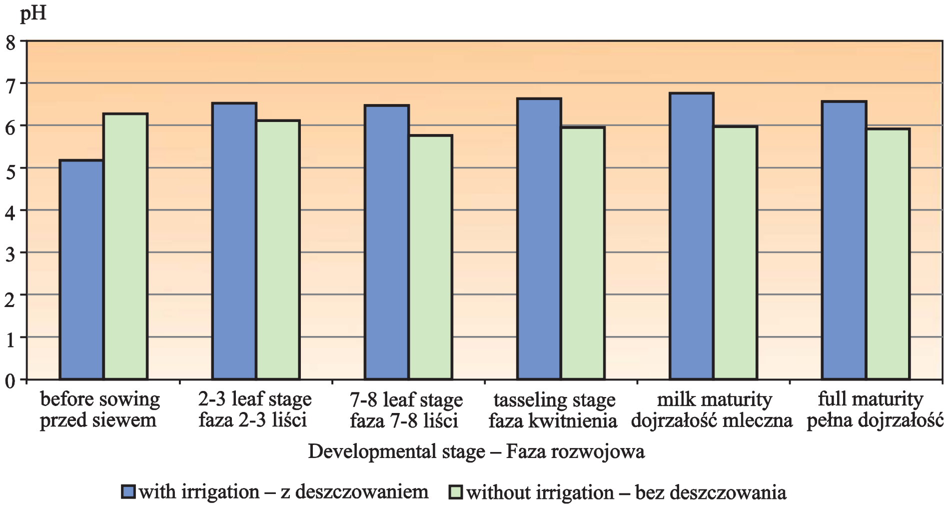

Fig. 1. Soil pH value under maize cropping in 2007
Rys. 1. Wartość pH gleby pod uprawą kukurydzy w 2007 roku

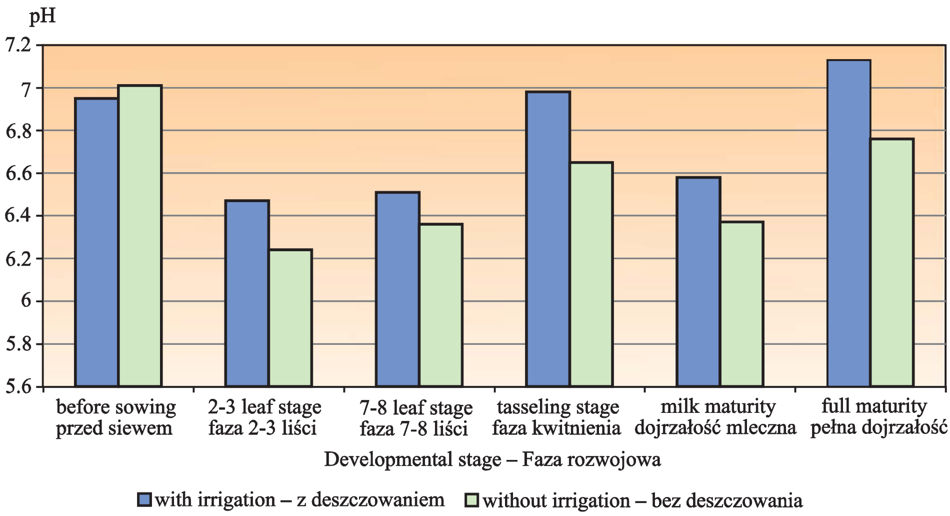

Fig. 2. Soil pH value under maize cropping in 2008
Rys. 2. Wartość pH gleby pod uprawą kukurydzy w 2008 roku

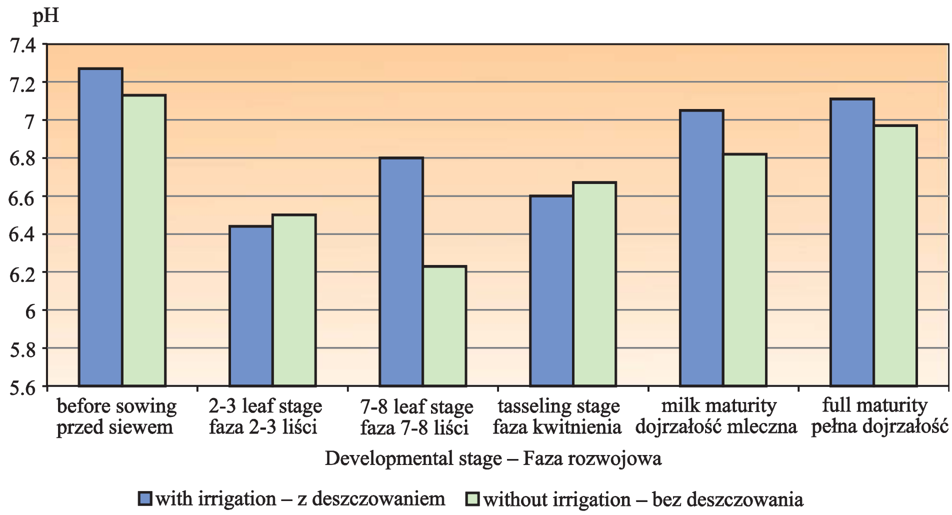

Fig. 3. Soil pH value under maize cropping in 2009
Rys. 3. Wartość pH gleby pod uprawą kukurydzy w 2009 roku

Values of the investigated parameters varied and depended on the analysis date in the individual years of the study. Soil respiratory activity did not exhibit significant variations during the growth seasons. The highest mean values per season were recorded in 2009 at the second time of analysis (maize at the 2-3 leaf stage) (Table 1).

Table 1. Effect of irrigation and maize developmental stage on soil respiratory activity
Tabela 1. Wpływ deszczowania i fazy rozwojowej kukurydzy na aktywność respiracyjną gleby

Stage of maize growth Faza wegetacji kukurydzy	Irrigation Deszczowanie	Soil respiratory activity Aktywność respiracyjna gleby mg $CO_2 \cdot kg^{-1} \cdot 24\ h^{-1}$		
		2007	2008	2009
Before sowing – Przed siewem	D	30.08 a-c	244.23 a	40.05 b
	ND	42.11 a	245.95 a	28.36 ab
2-3 leaf stage – Faza 2-3 liści BBCH 12-13	D	41.89 a	245.95 a	237.64 d
	ND	42.11 a	244.23 a	239.76 d
7-8 leaf stage – Faza 7-8 liści BBCH 17-18	D	28.70 a-c	245.78 a	19.42 a
	ND	36.41 ac	243.20 ab	18.73 a
Tasseling stage – Faza kwitnienia	D	32.14 a-c	244.58 a	4.81 c
	ND	18.39 b	241.48 ab	5.84 c
Maturity milk – Dojrzałość mleczna BBCH 75	D	28.01 a-c	240.97 ab	30.08 ab
	ND	43.66 a	241.66 ab	28.36 ab
Full maturity – Pełna dojrzałość BBCH 89	D	19.24 b	235.98 bc	22.34 a
	ND	24.23 bc	230.14 c	24.41 a

D – with irrigation – z deszczowaniem
ND – without irrigation – bez deszczowania
mean values marked with the same letters did not differ significantly at the level of probability of P = 0.05 – średnie wartości oznaczone tymi samymi literami nie różniły się znacząco na poziomie prawdopodobieństwa P = 0,05

Year 2008 was characterized by the highest mean values of soil respiratory activity. Analysing the weather pattern (Table 2), it can be stated that it was a year with the lowest total precipitation, and therefore this factor could have had the strongest influence on the mineralization rate of soil organic matter.

Table 2. Weather conditions at the ZDD Złotniki in years 2007-2009
Tabela 2. Warunki pogodowe w ZDD Złotniki w latach 2007-2009

Month Miesiąc	2007		2008		2009	
	Temperature Temperatura °C	Precipitation Opady mm	Temperature Temperatura °C	Precipitation Opady mm	Temperature Temperatura °C	Precipitation Opady mm
January Styczeń	4.6	76.3	2.4	72.8	-2.4	16.3
February Luty	1.4	54.0	4.4	15.4	0.1	32.9
March Marzec	7.9	65.3	5.4	54.8	4.5	56.8
April Kwiecień	12.7	7.4	10.0	77.5	14.2	16.0
May Maj	17.0	73.1	16.2	9.5	15.1	92.3
June Czerwiec	20.6	44.3	20.6	8.4	16.7	129.1
July Lipiec	19.9	72.2	22.2	46.6	21.7	104.6
August Sierpień	20.5	65.7	19.7	88.6	21.4	26.1
September Wrzesień	14.6	32.6	14.4	16.8	17.0	53.9
October Październik	9.0	20.3	9.9	69.4	7.9	59.4
November Listopad	2.8	46.6	5.4	20.5	6.6	38.2
December Grudzień	1.5	36.7	0.0	0.0	0.0	0.0
Mean temperature – Średnia temperatura						
January – December Styczeń – grudzień	11.0		10.9		10.2	
April – October Kwiecień – październik	16.3		16.1		16.3	
Total precipitation – Opady całkowite						
January – December Styczeń – grudzień		594.5		480.3		625.6
April – October Kwiecień – październik		315.6		316.8		381.4

Box and Meentemeyer [1993] observed that, with appropriate soil moisture content, the intensity of CO_2 release is determined by temperature and during dry spells by moisture. On the other hand, other researchers [Dziadowiec and Kaczmarek 1998] failed to note any relation between the quantities of the released carbon dioxide and the amount of atmospheric precipitation. According to Ding et al. [2007], seasonal changes in respiratory activity under maize growth are associated significantly with soil temperature, and the temperature increase results in the enhanced intensity of carbon dioxide release. Dehydrogenase activity was characterized by seasonal changes and differed in the individual years of the study (Table 3).

Table 3. Effect of irrigation and maize developmental stage on the activity of dehydrogenases in the soil
Tabela 3. Wpływ deszczowania i fazy rozwojowej kukurydzy na aktywność dehydrogenaz w glebie

Stage of maize growth Faza wegetacji kukurydzy	Irrigation Deszczowanie	Dehydrogenase activity Aktywność dehydrogenaz µg TPF·g^{-1} DM of soil·24 h^{-1}		
		2007	2008	2009
Before sowing	D	5.11 e	2.76 a-d	3.96 a
Przed siewem	ND	3.49 a	3.08 a-c	4.67 a
2-3 leaf stage	D	0.93 d	2.49 b-d	1.34 bc
Faza 2-3 liści	ND	1.11 bd	3.40 ab	1.82 c
7-8 leaf stage	D	1.96 b-d	1.35 e	3.56 a
Faza 7-8 liści	ND	1.54 bd	2.20 c-e	3.95 a
Tasseling stage	D	3.51 a	2.99 a-c	4.71 a
Faza kwitnienia	ND	2.97 ac	3.23 ab	4.46 a
Maturity milk	D	2.91 ac	3.66 a	4.54 a
Dojrzałość mleczna	ND	2.28 a-c	3.62 a	4.68 a
Full maturity	D	3.55 a	3.45 ab	0.21 b
Pełna dojrzałość	ND	2.39 a-c	1.92 de	0.22 b

D – with irrigation – z deszczowaniem
ND – without irrigation – bez deszczowania
mean values marked with the same letters did not differ significantly at the level of probability of P = 0.05 – średnie wartości oznaczone tymi samymi literami nie różniły się znacząco na poziomie prawdopodobieństwa P = 0,05

In 2009, practically speaking. no significant differences were found in the dehydrogenase activity between the irrigated and nonirrigated plots. The highest total precipitation was recorded in 2009, and consequently the soil could have been characterized by optimal moisture content conditions. High dehydrogenase activity was recorded at nearly all times of the analyses in 2007, as well as at the two last times (at the milk stage (V) and at full maturity (VI)) in 2008. In terms of the times of analyses, the highest activity of these enzymes was observed in the spring (before sowing), as well as in the summer. Siwik-Ziomek and Koper [2006] maintain that changes in enzyme activities during the growth season are probably caused by changes in the substrate content in the soil, as well as fluctuations in temperature and moisture content. Dkhar and Mishra [1983] reported increased dehydrogenase activity in irrigated soils in comparison with nonirrigated soils. Okazaki et al. [1983] claim that increased activity of these enzymes on irrigated plots is associated with a reduced soil redox potential. Periodic soil flooding is associated with oxygen deficit, which can activate anaerobes and, as indicated by Włodarczyk [2000], the majority of dehydrogenases is synthesized by anaerobic organisms.

CONCLUSIONS

Time of collecting soil samples for the analyses and the application of irrigation exerted a significant impact on the respiratory and dehydrogenase activities on the examined soil plots. The highest soil respiratory activity was recorded in 2008, as well as at the second time of the analyses in 2009. Mean values of the respiratory activity failed to show high variability in the individual seasons. Values of the examined parameters were influenced by the weather course in the individual years of the experiment.

REFERENCES

Box E.O., Meentemeyer V., 1993. Soil carbon dioxide evolution: environmental controls. world patterns and amounts. Conference Papers 18 Geography of organic matter production and decay, PAN IGiPZ Warszawa, 21-49.

Corstanje R., Reddy K.R., 2006. Microbial indicators of nutrient enrichment. Soil Sci.Soc. Am. J. 70, 1652-1661.

Ding W., Cai Y., Cai Z., Yagi K., Zheng X., 2007. Soil respiration under maize crops: effect of water, temperature and nitrogen fertilization. Soil Biol. Biochem. 3, 944-951.

Dkhar M.S., Mishra R.R. 1983. Dehydrogenase and urease activities of maize (*Zea mays* L.) field soils. Plant Soil 70, 327-333.

Dziadowiec H., Kaczmarek J., 1998. Wpływ składu gatunkowego drzewostanu na ogólną aktywność biologiczną gleb rdzawych w borze mieszanym świeżym [Effect of typical species composition of trees on the general biological activity of rusty soil in fresh mixed coniferous forest]. [In:] Ekologiczne aspekty mikrobiologii gleby [Ecological aspects of soil microbiology], A. Sawicka, G. Durska eds., Wyd. AR Poznań, 119-124 [in Polish].

Furczak J., Gostkowska K., Szwed A., 1997. Próba wykorzystania odpadów organicznych do poprawy aktywności mikrobiologicznej zdegradowanej gleby użytkowanej sadowniczo [Attempt of organic waste utilization for the correction of the microbiological activity of soil used for fruit-growth]. [In:] Drobnoustroje w środowisku. Występowanie, aktywność i znaczenie [Microorganisms in the environment. Occurrence, activity, and significance], W. Barabasz eds., Wyd. AR Kraków, 159-167 [in Polish].

Ghaly A.E., Mahmoud N.S., 2006. Optimum conditions for measuring dehydrogenase activity of *Aspergillus niger* using TTC. Am. J. Biochem. Biotech. 2, 186-194.

Januszek K., Błońska E., Stanik P., 2007. Uwagi dotyczące oznaczania aktywności dehydrogenaz w glebach testem TTC – formazan [Comments concerning determination of dehydrogenase activity in soil with the ttc-formazan test]. Acta Agrophys. 9, 635-644 [in Polish].

Nwanyanwu Ch.E., Abu G.O., 2010. In vitro effect of petroleum refinery wastewater on dehydrogenase activity in marine bacterial strains. Ambi-Agua, Taubaté 5, 21-29.

Okazaki M., Hirata E., Tensho K., 1983. TTC reduction in submerged soils. Soil Sci. Plant Nutr. 29, 489-497.

Pędziwilk Z., Gołębiowska J., 1984. CO_2 release as an index of biological activity of cultivated soils. Acta Microbiol. Pol. 33, 249-256.

Siwik-Ziomek A., Koper J., 2006. Kształtowanie aktywności dehydrogenaz w glebie płowej po zmianie nawożenia [Effect of fertilization change on the activity of dehydrogenase in orthic luvisol]. Zesz. Probl. Post. Nauk Rol. 512, 521-527 [in Polish].

Stępniewska Z., Przywara G., Bennicelli R.P., 2004. Plant response in anaerobic conditions [Reakcja roślin w warunkach anaerobiozy]. Acta Agrophysica 7, 1-85 [in Polish].

Sulewska H., 1997. Środowiskowe i ekonomiczne uwarunkowania uprawy i kierunków użytkowania kukurydzy w Polsce [Environmental and economic conditions of maize growth in Poland]. Zesz. Probl. Post. Nauk Rol. 450, 15-29 [in Polish].

Thalmann A., 1968. Zur Methodik der Bestimmung der Dehydrogenase Aktivität in Boden mittels Triphenyltetrazoliumchlorid (TTC) [Methods of dehydrogenase activity determination with triphenyltetrazoliumchlorid (TTC)]. Landwirtsch. Forsch. 21, 249-258 [in German].
Włodarczyk T., 2000. Some of aspects of dehydrogenases activity in soils. Int. Agrophysics 14, 365-376.
Żarski J., Dudek S., Grzelak B., 2004. Rola czynnika wodnego i termicznego w kształtowaniu plonów ziarna kukurydzy [Role of water and thermal factors in affecting maize grain yield]. Acta Agrophys. 3, 189-195 [in Polish].

AKTYWNOŚĆ RESPIRACYJNA I DEHYDROGENAZOWA W GLEBIE POD UPRAWAMI KUKURYDZY W WARUNKACH PÓL DESZCZOWANYCH I NIEDESZCZOWANYCH

Streszczenie. Celem badań było określenie wpływu deszczowania lub jego braku na aktywność respiracyjną i dehydrogenaz w glebie pod uprawą kukurydzy. Badania prowadzono w latach 2007-2009, w 6 terminach, w sezonie wegetacyjnym kukurydzy. Eksperyment obejmował poletka doświadczalne z uprawą kukurydzy odmiany Clarica (FAO 220, Pioneer) przeznaczoną na CCM. Na poletkach, które podlegały procesowi deszczowania, zainstalowano deszczownie typu półstałego. Aktywność dehydrogenaz w glebie ustalono kolorymetrycznie, a respiracyjną oznaczano metodą miareczkową. Aktywność oddechowa gleby nie wykazywała znacznego zróżnicowania w sezonach wegetacyjnych, z wyjątkiem roku 2009, gdzie w II terminie analiz (kukurydza w fazie 2-3 liści) odnotowano najwyższe średnie w sezonie. W trzecim roku analiz (2009) praktycznie nie stwierdzono istotnych różnic w aktywności tych enzymów między obiektami deszczowanymi a niedeszczowanymi. Analizując terminy analiz, największą aktywność tych enzymów stwierdzano wiosną, przed siewem roślin oraz latem. Średnie wartości aktywności oddechowej nie wykazywały dużego zróżnicowania w sezonach.

Słowa kluczowe: aktywność mikrobiologiczna, faza rozwojowa, niedobór wody

Accepted for print – Zaakceptowano do druku: 10.08.2011