EFFECT OF IRRIGATION ON THE BIOLOGY OF SOIL

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Abstract

Soil enzyme activities are the direct expression of the soil community to metabolic requirements and available nutrients. A short field assay was established to study the potential of soil biological parameters as early and sensitive indicators of the effects of agricultural practices on soil properties.

We have determined five enzymatic activities (actual and potential dehydrogenase, catalase, acid and alkaline phosphatase) and one nonenzymatic catalytic activity (H_2O_2 splitting in autoclaved samples) in the 0–10–, 10–20– and 20–30–cm layers of a preluvosoil submitted to a complex irrigation and crop rotation (2– and 3–crop rotations) experiment.

Non-irrigation – in comparison with irrigation – resulted in significantly higher soil phosphatase activities in the 0–10–, 10–20– and 20–30–cm layers, whereas dehydrogenase and catalase activities were significantly higher in irrigated soil. The soil under wheat or maize was more enzyme-active in the 3– than in the 2–crop rotation and in the monoculture. In the monoculture and in the 2–crop rotation, higher enzymatic activities were registered for wheat followed by maize. In the 3–crop rotation, higher enzymatic activities were recorded maize after wheat. The enzymatic indicators of soil quality decreased depending on the nature of crops and kind of irrigation in the following order: maize (3–crop rotation) > wheat (3–crop rotation) > wheat (2–crop rotation) > maize (2–crop rotation) > wheat (monoculture) > maize (monoculture).

Keywords: catalase, crop rotation, dehydrogenase, irrigation, phosphatase

INTRODUCTION

Any management practice that affects the biological populations of soil could be expected to result in some change in soil enzyme levels. This would apply especially to intracellular enzymes and to extracellular enzymes either in soil solution or attached to living cells (Castaldi et al., 2009; Costa-Martinez and Tabatabai, 2000).

Soil microorganisms, the living component of the soil, usually occupy less than 1% of the soil volume, while their number and efficiency are very high. They colonize mainly the organic matter at the microsites (Freney et al, 2005). Clay minerals also serve as carrier of organisms, enzymes and metabolic products. The number and activity of soil microorganisms are dependent on plant growth (species composition, soil cover, root penetration of the soil), soil type, soil treatment, soil cultivation as well as on the macro- and microclimate at each location (Angers et. al, 2000; Dick, 1992; Dick. et al, 1994; Dormaar and Sommerfeldt., 2006). The metabolic activity of soil microorganism is essential for organic matter turnover. The mobilization and immobilization of inorganic nutrients and trace elements are also mainly a result of microbial activities (Dobler et al., 2000).

It is well known that the dehydrogenase activity of a soil is thus the result of the activity of different dehydrogenases, which are an important component of the enzyme system of all microorganisms (enzymes of respiratory metabolism, citrate cycle, and nitrogen metabolism) (Lovell et al, 2005; Kannan and Oblisami., 2000; Pulford and Tabatabai, 2008; Zelles et al, 2007). Dehydrogenase activity is thus an indicator of

biological redox-systems, and can be taken as a measure for the intensity of microbial metabolism in soil (Samuel et al, 2008).

The catalase of aerobic organisms splits the toxic H_2O_2 produced from the mitochondrial electron transport and from various hydroxylation and oxygenation reactions into water and oxygen. Since aerobic organisms predominate in non-waterlogged soils, catalase activity was used to characterize soil microbial activities (Őhlinger R., 1996).

Phosphatases are inducible enzymes that are produced predominantly under conditions of low phosphorus availability (Samuel et al, 2005; Wright and Reddy K.R., 2001). Phosphomonoesterase enzymes play an important role in P cycling in soil and, consequently, in P nutrition of plants, as these hydrolytic enzymes release plant-available, mineral o-phosphate from organic P compounds, namely from P monoesters.

We have determined five enzymatic activities (actual and potential dehydrogenase, catalase, acid and alkaline phosphatase) and one non-enzymatic catalytic activity in a preluvosoil submitted to a complex irrigation and crop rotation experiment at the Agricultural Research and Development Station in Oradea (Bihor county).

It is well know that the dehydrogenase and catalase activities are considered as indicators of the global and respiratory activity of soil, whereas phosphatase activities are related to the P cycling in soil.

MATERIAL AND METHODS

The ploughed layer of the studied soil is of mellow loam texture, it has a pH value of 5.5, medium humus (2.32 %) and P (22 ppm) contents, but it is rich in K (83 ppm).

The experimental field was divided into plots and subplots for comparative study of irrigation and non-irrigation and rotations of 2– and 3–crops. The crops of the 2– and 3–crops rotations are specified in Table 1.

Table 1

Crops of the two rotations

Year	Monoculture	Rotation of 2 crops	Rotation of 3 crops
	Plots	Plots	Plots
2012	Wheat Maize	Wheat Maize	Wheat Maize Soybean

Each plot consisted of two subplots representing the irrigation and non-irrigation variants. The plots (and subplots) were installed in three repetitions.

In September 2013, soil was sampled from the 0–10–, 10–20– and 20–30–cm depths of the subplots under wheat and maize crops. The soil samples were allowed to air-dry, then ground and passed through a 2–mm sieve and, finally, used for enzymological analyses.

We have determined five enzymatic activities (actual and potential dehydrogenase, catalase, acid and alkaline phosphatase) and one non-enzymatic catalytic activity (H_2O_2 splitting in autoclaved samples).

Actual and potential dehydrogenase activities were determined according to the methods described in (Drăgan-Bularda M., 1983). The reaction mixtures consisted of 3.0 g soil, 0.5 ml TTC (2, 3, 5- triphenyltetrazolium chloride) and 1.5 ml distilled water or 1.5 ml glucose. All reaction mixtures were incubated at 37º C for 24 hours. After incubation, the triphenylformazan produced was extracted with acetone and was measured spectrophotometrically at 485 nm. The reaction mixtures for catalase activities consisted of 3.0 g soil and 2 ml H_2O_2 3% and 10 ml buffer solution. The buffer solution was prepared as recommended by (Drăgan-Bularda., 1983).

Disodium phenylphosphate served as enzyme substrate (Drăgan-Bularda M., 1983; Őhlinger R., 1996). Two activities were measured: acid phosphatase activity in

reaction mixtures to which acetate buffer (pH 5.0) was added and alkaline phosphatase activity in reaction mixtures treated with borax buffer (pH 9.4).

The reaction mixtures consisted of 2.5 g soil, 2 ml toluene (antiseptic), 10 ml buffer solution and 10 ml 0.5 % substrate solution. Reaction mixtures without soil or without substrate were the controls. All reaction mixtures were incubated at 37º C for 2 hours. After incubation, the phenol released from the substrate under the action of phosphatases was determined spectrophotometrically (at 614 nm) based on the colour reaction between phenol and 2,6-dibromoquinone-4-chloroimide.

Dehydrogenase activities are expressed in mg of triphenylformazan (TPF) produced from 2, 3, 5-triphenyltetrazolium chloride (TTC) by 10 g of soil in 24 hours.

Catalase and non-enzymatic catalytic activities are recorded as mg of H_2O_2 decomposed by 1 g of soil in 1 hour. Phosphatase activities are expressed in mg phenol / g soil / 2 hours.

The activity values were submitted to statistical evaluation by the two *t*-test (Sachs L., 2000).

RESULTS AND DISCUSSION

The effect of irrigation on the enzymatic activities in soil

Actual and potential dehydrogenase and catalase activities were significantly higher (at least at $p < 0.05$) in the three soil layers analysed of the non-irrigated soil, excepting potential dehydrogenase activity in the deeper layer and catalase activity in the intermediate layer which were insignificantly higher ($p > 0.05$). Non-enzymatic catalytic activity was significantly higher (at least at $p < 0.01$) in the three soil layers of the non-irrigated soil. These findings are valid under each crop (Figures 1, 2, 3 and 4).

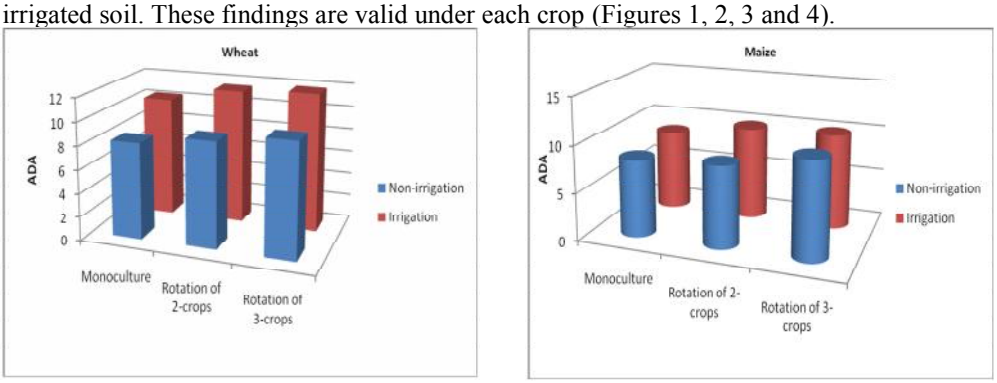

Figure 1. The effects of soil management practices on actual dehydrogenase activity

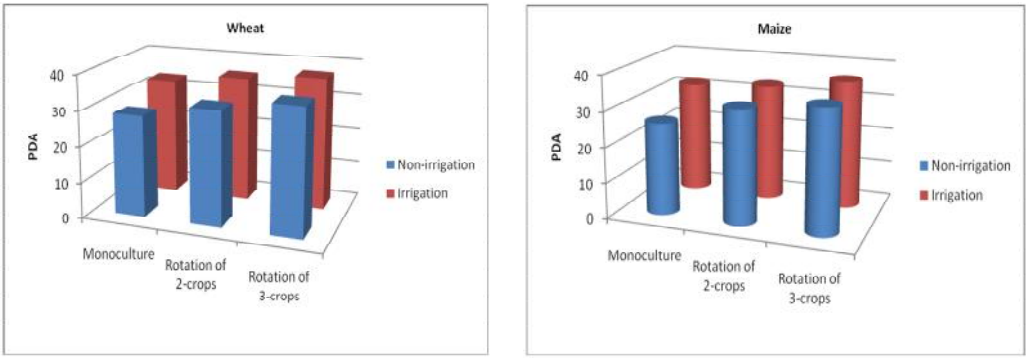

Figure 2. The effects of soil management practices on potential dehydrogenase activity

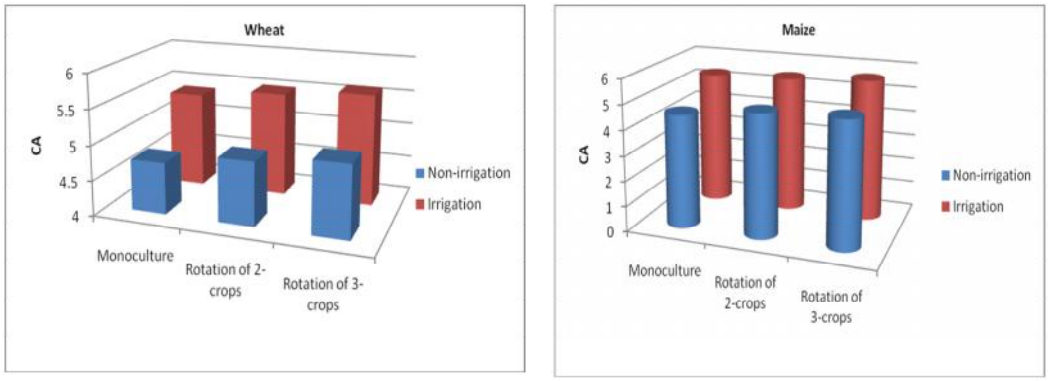

Figure 3. The effects of soil management practices on catalase activity

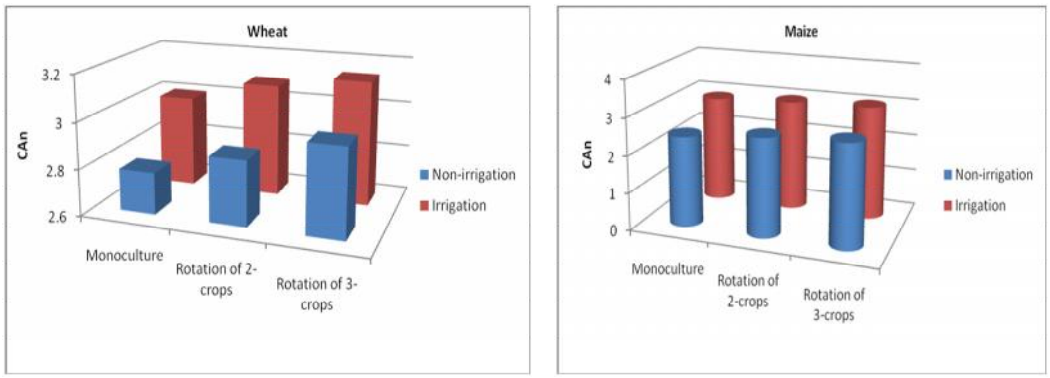

Figure 4. The effects of soil management practices on non-enzymatic catalytic activity

The effect of crop rotations on the enzymatic activities in soil

For the evaluation of this effect, the results obtained in the three soil layers analysed in the two subplots of each plot were considered together (Figures 5 and 6).

The soil enzymological effect of the same crop in the two rotations

As wheat and maize were crops in monoculture and both rotations, it was possible to compare the soil enzymological effect of the monoculture and of the 2– and 3–crop rotations. The soil under both plants was more enzyme-active in the 3–crop rotation. In the soil under wheat, the enzymatic activities were significantly higher in the 3–crop rotation, excepting catalase activity which was insignificantly higher in the 3–crop rotation than in the monoculture. In the soil under maize, the differences between the rotations was significant (at least at $p < 0.05$) in the 3–crop rotation than in the monoculture. Non-enzymatic catalytic activity was significantly higher (at least at $p < 0.01$) in the 3– than in the 2–crop rotation and monoculture under each crops.

The soil enzymological effect of different crops in the same rotation

The monoculture. Potential dehydrogenase and non-enzymatic catalytic activities measured in the wheat soil exceeded significantly ($p < 0.02$ and $p < 0.05$, respectively) the corresponding activities recorded in the maize soil, whereas actual dehydrogenase and catalase activities were insignificantly higher ($p > 0.05$ and $p > 0.10$, respectively) in the wheat soil. Acid and alkaline phosphatase activities were higher for maize.

The 2–crop rotation. Each enzymatic activity and non-enzymatic catalytic activity measured in the wheat soil exceeded significantly (at least at $p < 0.05$) the corresponding

activity recorded in the maize soil, excepting acid phosphatase activity which was higher for maize.

The 3–crop rotation. Significant ($p < 0.05$ to $p < 0.001$) and insignificant ($p > 0.05$ to $p > 0.10$) differences were registered in the soil enzymatic activities depending on the kind of enzymatic activity and the nature of crop. Dehydrogenase activities and non-enzymatic catalytic activity were significantly higher (at least at $p < 0.01$) in the wheat soil, while catalase and phosphatase activities were higher in the maize soil.

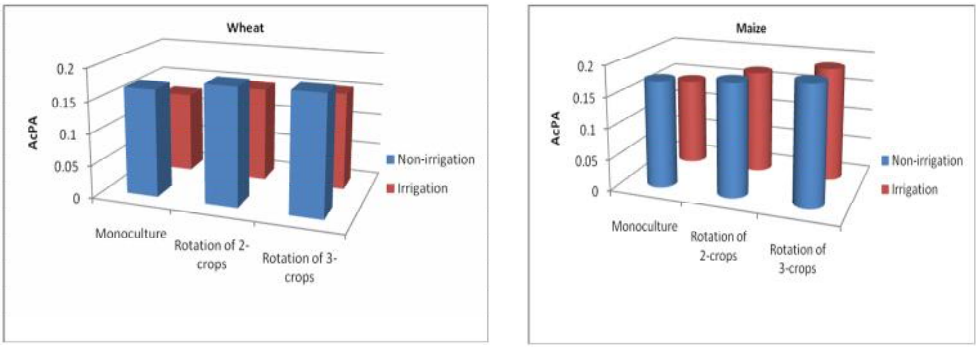

Figure 5. The effects of soil management practices on acid phosphatase activity

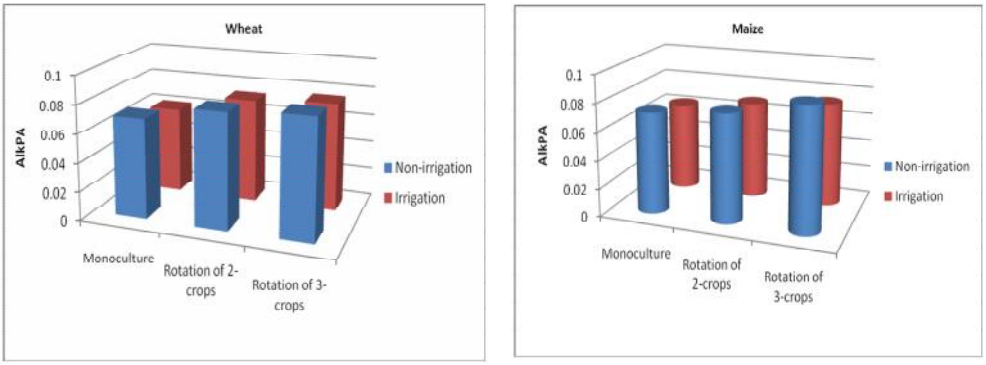

Figure 6. The effects of soil management practices on alkaline phosphatase activity

Enzymatic indicators of soil quality

For establishing a hierarchy of the plots admitting equal importance for the enzymatic activities, we have used the method, referred to in (Samuel A.D. et al, 2011), to calculate the enzymatic indicators of soil quality. The results obtained (Table 2) show that in the hierarchy of the six plots, the first positions are occupied by the crops of the 3–crop rotation, while the last positions are occupied by the crops of the monoculture.

Table 2

Enzymatic indicators of soil quality

Position	Plot	Enzymatic indicator of soil quality
1	Maize (3–crop rotation)	492.41
2	Wheat (3–crop rotation)	487.41
3	Wheat (2–crop rotation)	468.47
4	Maize (2–crop rotation)	455.98
5	Wheat (monoculture)	425.86
6	Maize (monoculture)	418.17

CONCLUSIONS

Non-irrigation – in comparison with irrigation – resulted in higher phosphatase activities, whereas dehydrogenase and catalase activities were higher in irrigated soil.

The 3–crop rotation – as compared to the 2–crop rotation and monoculture – led to higher enzymatic activities in the soil layers for maize or wheat. In the monoculture and in the 2–crop rotation, higher enzymatic activities were registered for wheat than for maize. In the 3–crop rotation, higher enzymatic activities were recorded maize after wheat.

The enzymatic indicators of soil quality calculated from the values of enzymatic activities determined showed the order: maize (3–crop rotation) > wheat (3–crop rotation) > wheat (2–crop rotation) > maize (2–crop rotation) > wheat (monoculture) > maize (monoculture).

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