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Note

Effect of different fertilization on enzyme activity in rhizosphere and non-rhizosphere of amaranth

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A b s t r a c t. The effect of variations in NPK fertilization on dehydrogenase and catalase activity of rhizosphere and non-rhizosphere of two varieties of amaranth – Rawa and Aztek was determined. In a field experiment, amaranth was grown at wide row spacing on good wheat complex soil in SE Poland. Dehydrogenase and catalase activity in the rhizosphere and non-rhizosphere were determined. The results showed that fertilization with increasing doses of NPK influenced enzyme activity in the rhizosphere and non-rhizosphere of two varieties of amaranth. Fertilization with the highest dose of the macroelements had the greatest effect. Enzyme activity in the rhizosphere of the plants studied was higher than in the non-rhizosphere soil in the case of both amaranth varieties. Significant positive correlations were observed between the NPK doses applied and activity of the enzymes, in the rhizosphere and non-rhizosphere of both amaranth varieties.

K e y w o r d s: amaranth, enzyme activity, rhizosphere, non-rhizosphere

INTRODUCTION

Amaranth (*Amaranthus cruentus* L.) belongs to the class *Dicotyledones*, in the family *Amaranthaceae*. This plant has been known and cultivated for thousands of years in Mexico and many South American countries (Grajeta, 1997). The Incas, Mayas and Aztecs valued its exceptional nutritional qualities (Rutkowska, 2006). Amaranth contains high amounts of protein, sugars and fats, both in the total yield and in the seeds. Compared with other commonly cultivated crops, the chemical composition of amaranth seeds is rich in exogenous amino acids and unsaturated fatty acids (Skwaryło-Bednarz and Nalborczyk, 2006). A particularly valuable component of the lipids occurring in amaranth seeds is squalene (Rutkowska, 2006), used in the production of cosmetics and medications with antioxidant properties (Prokopowicz, 2001). This has been the reason for increasing interest in this plant, in Poland and worldwide.

Preliminary research on the numbers and activity of soil microflora where amaranth is grown suggests that this plant stimulates the biological activity of soil (Skwaryło-Bednarz, 2008). It seems interesting to determine the biological properties of rhizosphere and non-rhizosphere. The rhizosphere is a special environment for mutual influence of microorganisms and plants (Wielgosz and Szember, 2006). This co-dependence of higher plants and rhizosphere microorganisms consists to a very large extent in exchange of specific chemical substances (Bielińska, 2007; Lamb and Dixon, 1990).

MATRIAL AND METHODS

The study was based on a field experiment conducted in 2008 near Zamość. Its aim was to determine the effect of increasing doses of NPK on enzyme activity in rhizosphere and non-rhizosphere on which two varieties of amaranth (Rawa and Aztek) were grown for seed. The experiment was conducted on brown soil derived from loess, characterized by total N content – 1.9 g kg^{-1} and average content of available forms of: P – 55, K – 110, and Mg – 64 mg kg^{-1}.

The experiment was set up in a randomized split-plot design in triplicate. The following combinations of macroelement doses were used:

I: N – 50, P – 40, K – 40 kg ha^{-1};
II: N – 70, P – 50, K – 50 kg ha^{-1};
III: N – 90 , P – 60, K – 60 kg ha^{-1};
IV: N – 130, P – 70, K – 70 kg ha^{-1}.

Nitrogen was applied twice (before sowing and during the intensive growth period) in the form of ammonium nitrate twice. The results obtained were compared with the control soil (without NPK fertilization). The level of phosphorus and potassium fertilization was also varied.

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Amaranth seeds were sown during the last third of May at wide row spacing, 60 cm apart. The area of the microplots from which the plants were to be harvested was 1m^2. The plants were cultivated in accordance with proper horticulture procedures.

Soil samples were taken from the humus horizon by shaking 10 randomly selected plants from each microplot in September. The rhizosphere was soil which was less than 4 mm from the roots (Bielińska, 2007). Soil without roots was also taken from the humus horizon; this was the non-rhizosphere. The soil samples were averaged for each microplot and chemical and enzymatic analyses were performed in triplicate.

Dehydrogenase activity (DA) in the soil samples was determined according to Thalmann method modified by Baran (2000), and catalase activity (CA) by the modified Beck method (Brauner and Bukatsch, 1987). Determinations were also made of pH in 1 mol dm^{-3} KCl and organic carbon (OC) (Ostrowska *et al*., 1991).

Statistical analysis of the results obtained was performed based on correlation coefficients.

RESULTS

The soil samples tested (rhizosphere and non-rhizosphere) had reaction acid (Table 1). Nevertheless, the pH of the rhizosphere samples from the amaranth plants was somewhat lower than that of the non-rhizosphere samples (Table 1). This characteristic was more marked in the case of the Rawa variety.

In the microplots analyzed, organic carbon content in the soil within the rhizosphere was higher than in the other soil. The organic carbon content in the rhizosphere of the Rawa variety of amaranth ranged from 2.8 to 2.85%, while in the case of the Aztek variety it was between 2.81 and 2.86% (Table 1). In the non-rhizosphere, organic carbon content was 2.65-2.67% for Rawa amaranth and 2.64-2.65% for Aztek (Table 1).

The study did not find that varying NPK fertilization had a significant effect on organic carbon content. Other authors have also found that increasing NPK doses did not influence organic carbon content (Hodara, 1994; Łabza, 1995). Bielińska (2007) and Lynch and Whips (1990) determined that rhizosphere contains a higher concentration of soluble carbon than non-rhizosphere. Lynch and Whips (1990) state that the amount of organic carbon released into the rhizosphere by plants can constitute 40% of the total dry weight produced by the plant.

In all the microplots, enzyme activity of the rhizosphere was higher than in the non-rhizosphere. This was true of both dehydrogenase and catalase. Enzyme activity was affected not only by variations in fertilization but also by the variety of amaranth (Table 2).

The soil on which amaranth was grown showed higher dehydrogenase activity in the rhizosphere than in the non-rhizosphere. This was true in the case of both amaranth varieties, but the differences were greater in the soil samples from the Aztek variety. Increasing doses of the macroelements caused successive increases in dehydrogenase activity with respect to the control. Dehydrogenase activity in the rhizosphere of the Rawa variety fertilized with NPK combination I increased by 5.8%, while with combination II the increase was as much as 50.8% compared to the unfertilized control. Combination III caused a 67.8% increase in dehydrogenase activity, while the increase with combination IV was about 71.2% compared with the control (Table 2).

T a b l e 1. Organic carbon content and pH of the soils

Combinations	Organic carbon content (%)		pH_{KCl}	
	Rhizosphere	Non-rhizosphere	Rhizosphere	Non-rhizosphere
		Rawa		
Combination I	2.82±0.07	2.65±0.06	5.7±0.2	5.9±0.1
Combination II	2.83±0.07	2.65±0.06	5.7±0.2	5.9±0.1
Combination III	2.84±0.09	2.66±0.07	5.6±0.2	5.8±0.1
Combination IV	2.85±0.09	2.67±0.08	5.6±0.2	5.8±0.2
Control	2.80±0.06	2.65±0.06	5.7±0.2	5.9±0.1
		Aztek		
Combination I	2.82±0.08	2.64±0.06	5.8±0.2	6.0±0.1
Combination II	2.83±0.09	2.64±0.07	5.8±0.2	6.0±0.1
Combination III	2.86±0.10	2.65±0.07	5.9±0.2	6.1±0.1
Combination IV	2.86±0.10	2.65±0.07	5.9±0.2	6.1±0.1
Control	2.81±0.08	2.64±0.06	5.7±0.1	5.9±0.2

T a b l e 2. Enzyme activity of the soils

Combinations	Dehydrogenase activity (mg TPF kg^{-1} d.m. of soil d^{-1})		Catalase activity (cm min^{-1})	
	Rhizosphere	Non-rhizosphere	Rhizosphere	Non-rhizosphere
		Rawa		
Combination I	3.12±0.22	3.00±0.20	1.20±0.15	1.00±0.10
Combination II	4.45±0.24	3.25±0.20	1.40±0.20	1.10±0.10
Combination III	4.95±0.31	3.50±0.26	1.50±0.20	1.20±0.15
Combination IV	5.05±0.29	3.55±0.27	1.60±0.25	1.30±0.15
Control	2.95±0.20	2.85±0.19	1.10±0.10	0.90±0.10
		Aztek		
Combination I	3.25±0.24	3.10±0.21	1.40±0.15	1.20±0.10
Combination II	4.55±0.25	3.85±0.22	1.50±0.15	1.30±0.15
Combination III	6.10±0.30	4.50±0.26	1.60±0.20	1.45±0.20
Combination IV	6.15±0.29	4.65±0.27	1.75±0.20	1.50±0.20
Control	3.05±0.21	2.95±0.20	1.20±0.15	1.05±0.10

In the microplots with the Aztek variety, fertilization with combination I caused a 6.6% increase in dehydrogenase activity in the rhizosphere compared with the control. Combinations II, III and IV resulted in increases of 49.2, 100, and 101.6%, respectively.

Dehydrogenase activity in the non-rhizosphere was lower than in the rhizosphere. This dependency was affected by the variety of amaranth and by variations in fertilization. The non-rhizosphere on which the Aztek variety was grown showed higher activity of this enzyme than the soil with the Rawa variety. Increasing NPK fertilization caused an increase in dehydrogenase activity with respect to the control in the cases of both varieties of amaranth.

In the microplots with the Rawa variety, fertilization with combination I caused a 5.3% increase in dehydrogenase activity in the non-rhizosphere as compared with the control. Combinations II, III and IV resulted in increases of 14, 22.8, and 24.6%, respectively compared with the control. Dehydrogenase activity in the non-rhizosphere in the microplots with the Aztek variety fertilized with NPK combination I increased by 5.1% with respect to the control. Combinations II, III and IV resulted in increases of 30.5, 52.5, and 57.6%, respectively.

Increasing doses of NPK influenced catalase activity in the case of both amaranth varieties. Rhizosphere from both varieties showed a higher value for this characteristic than the non-rhizosphere.

The tests conducted in this study show that catalase activity (like dehydrogenase activity) was higher in soil with the Aztek variety than in the soil with Rawa.

The highest value for catalase activity in the rhizosphere of the Rawa variety was observed in the microplots with the highest level of NPK fertilization – 45.5% higher than in the control. Where combinations I, II and III of the macroelements were applied, this value was 9.1, 27.3, and 36.4% higher than in the control..

The highest dose of NPK fertilizer applied to the microplots with Aztek amaranth caused the greatest increase in catalase activity – 45.8% higher than the control. Combinations I, II and III caused increases of 16.7, 25, and 33.3%, respectively in comparison with the control..

Catalase activity in the non-rhizosphere on which Rawa amaranth was grown depended on the level of NPK fertilization. The highest value for this parameter was observed in the microplots fertilized with macroelement combination IV – 1.3 cm min^{-1}, which was 44.4% higher than in the control . Levels I, II and III of fertilization caused increases of 11.1, 22.2, and 33.3%, respectively in comparison with the control.

As in the case of the Rawa variety, catalase activity in the non-rhizosphere in the microplots with Aztek amaranth was highest when macroelement combination IV was applied. It was 1.5 cm min^{-1}, which was 42.9% higher than in the unfertilized soil. The lowest level of fertilization caused an increase of 14.3%, while levels II and III caused increases of 23.8 and 38.1%, respectively in comparison with the control (Table 2).

The statistical analysis performed shows that increasing macroelement doses significantly influenced dehydrogenase and catalase activity in the soil on which Rawa and Aztek varieties of amaranth were grown (Table 3).

T a b l e 3. Correlation coefficients between combinations of fertilization and organic carbon (OC), pH, dehydrogenase activity (DA) and catalase activity (CA)

Variety	OC	pH	DA	CA
Rawa	0.137	-0.350	0.709**	0.759**
Aztek	0.117	0.565*	0.811**	0.873**

*p=0.05, **p=0.01.

CONCLUSIONS

1. Fertilization with increasing amounts of NPK influenced enzyme activity in the rhizosphere and non-rhizosphere of the two varieties of amaranth. The highest dose of the macroelements achieved the greatest effect.

2. Enzyme activity in the rhizosphere of the plants studied was higher than in the non-rhizosphere for both varieties of amaranth.

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