ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 16, No. 10 2009

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EFFECT OF VARIOUS DOSES OF NPK FERTILIZERS ON CHLOROPHYLL CONTENT IN THE LEAVES OF TWO VARIETIES OF AMARANTH (*Amaranthus cruentus* L.)

WPŁYW ZRÓŻNICOWANYCH DAWEK NAWOZÓW NPK NA ZAWARTOŚĆ CHLOROFILU W LIŚCIACH DWÓCH ODMIAN AMARANTUSA (*Amaranthus cruentus* L.)

Abstract: The effect of various doses of NPK fertilizers on chlorophyll content in the leaves of two varieties of amaranth, 'Rawa' and Aztek, was investigated. In field experiments amaranth was grown at narrow spacing on good wheat complex soil in South-Eastern Poland. The following combinations of macroelement doses were applied: I – 50 kg N, 40 kg P and 40 kg K · ha^{-1}, II – 70 kg N, 50 kg P and 50 kg K · ha^{-1}, III – 90 kg N, 60 kg P and 60 kg K · ha^{-1} and IV – 130 kg N, 70 kg P and 70 kg K · ha^{-1}. Assessments were made of chlorophyll *a*, *b* and *a*+*b* content in fresh leaf tissue during the full bloom and seed formation stages.

The chlorophyll a content in the 'Rawa' amaranth leaves was found to be higher than in the 'Aztek' leaves. In both varieties analysed, the values for this parameter were higher during seed formation than in the bloom stage. The highest chlorophyll *a* content in the 'Rawa' variety was found with combination III of NPK fertilizer, while for 'Aztek' it was highest with combination II. Chlorophyll *b* content was higher per unit fresh mass of 'Rawa' leaves than in the 'Aztek' variety. The highest chlorophyll *b* content per unit fresh mass of 'Rawa' leaves was found with combination II of macroelement fertilizers, while for 'Aztek' this value was highest with combination III. Statistically significant dependencies were found between the NPK fertilizer doses used and the amount of chlorophyll in the fresh leaf tissue of both amaranth varieties.

Keywords: chlorophyll, amaranth (*Amaranthus cruentus* L.), NPK fertilization, doses

Chlorophylls take part in biosynthesis processes occurring in the green parts of plants. Together with carotenoids, they participate in the process of light energy absorption and its conversion to chemical energy, which is used in the endoergic process of synthesizing organic compounds from the simple substances: carbon dioxide and H_2O [1]. Numerous studies have shown that chlorophyll content in plants increases sharply following fertilization with macroelements, particularly nitrogen [2]. Amaranth

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is a plant that reacts quickly to nitrogen fertilization, and its varieties used as vegetables or animal fodder react particularly well to this macroelement. Most commonly recommended for amaranth cultivation is nitrogen at 80–120 kg N · ha^{-1} in the form of Polifoska or ammonium nitrate, phosphorus at 50–70 kg P · ha^{-1}, in the form of Polifoska or superphosphates, and potassium at 50–70 kg K · ha^{-1} in the form of Polifoska or potassium chloride [3].

The aim of this study was to assess the effect of various doses of NPK fertilizer on chlorophyll content in the leaves of two varieties of amaranth (*Amaranthus cruentus* L.).

Material and methods

A field experiment was conducted in 2007 on a farmer's field situated near Zamosc. The aim of the experiment was to determine the effect of various doses of NPK on chlorophyll content in two varieties 'Rawa' and 'Aztek' of amaranth (*Amaranthus cruentus* L.) cultivated for seed. The brown soil on which the experiment was conducted was characterized by very high N content and high P, K and Mg content. The experiment was set up in a random split-plot design with three replicates. The following combinations of NPK doses were used: I – 50 kg N, 40 kg P and 40 kg K · ha^{-1}, II – 70 kg N, 50 kg P and 50 kg K · ha^{-1}, III – 90 kg N, 60 kg P and 60 kg K · ha^{-1} and IV – 130 kg N, 70 kg P and 70 kg K · ha^{-1}.

Nitrogen fertilizer in the form of ammonium nitrate was applied twice, before sowing and during the intensive growth period. Phosphorus and potassium fertilisers were applied before sowing – P in the form of Polifoska and K in the form of potassium chloride. The results obtained were compared with the control (with no NPK fertilisation). Amaranth seeds were sown during the last decade of May at narrow spacing (every 30 cm). The area of the experimental microplots from which the plants were to be harvested was 1 m^2. The plants were cultivated in accordance with proper horticulture procedures. The spectrophotometric method described by Blamowski and Borowski [4] was used to determine chlorophyll *a* and *b* content as well as the total (*a*+*b*) chlorophyll content in the leaves. The measurements were made during the flowering stage and again at the onset of seed formation, using the third green leaf of the plant counting downward from the inflorescence. All measurements were made in three replicates.

Results and discussion

Fertilization with the various doses of macroelements contributed to an increase in chlorophyll *a* and *b* and total chlorophyll in the amaranth leaves (Table 1), but a statistically significant correlation was found only for they amount in the flowering stage (Table 2).

The high macroelement doses applied in NPK combination IV resulted in lower chlorophyll content than was noted in the samples where less intense fertilization had been applied. However, even for this combination the chlorophyll content was higher than in the control.

Table 1

Effect of NPK fertilization on chlorophyll content in amaranth leaves

Combination	Average chlorophyll content [mg · g^{-1} fresh mass]							
	Flowering stage				Beginning of seed formation			
	a	*b*	total	*a*:*b* ratio	*a*	*b*	total	*a*:*b* ratio
‘Rawa’ variety								
Control	0.356	0.270	0.626	1.32:1	1.025	0.230	1.255	4.47:1
I	0.361	0.282	0.643	1.28:1	1.034	0.240	1.274	4.31:1
II	0.520	0.377	0.897	1.38:1	1.041	0.253	1.294	4.11:1
III	0.588	0.374	0.962	1.57:1	1.448	0.245	1.693	5.91:1
IV	0.510	0.350	0.860	1.46:1	1.032	0.231	1.263	4.47:1
‘Aztek’ variety								
Control	0.230	0.198	0.428	1.16:1	0.750	0.181	0.931	4.14:1
I	0.237	0.208	0.445	1.14:1	0.774	0.184	0.958	4.21:1
II	0.802	0.360	1.162	2.23:1	1.137	0.221	1.358	5.14:1
III	0.760	0.379	1.139	2.01:1	0.997	0.370	1.367	2.69:1
IV	0.710	0.362	1.072	1.96:1	0.921	0.280	1.201	3.29:1

‘Rawa’ amaranth leaves had higher chlorophyll a content than leaves of ‘Aztek’ variety. In both varieties a statistically significant correlation was found between dose of macroelement fertilizers and chlorophyll *a* content in the leaves at flowering stage (Table 2).

Table 2

Correlation coefficients between macroelement doses and chlorophyll content in the leaves

Parameter	Stage of plant growth	
	flowering stage	beginning of seed formation
‘Rawa’ variety		
Chlorophyll *a* content	0.747**	0.268
Chlorophyll *b* content	0.736**	0.138
Total chlorophyll content	0.705**	0.325
‘Aztek’ variety		
Chlorophyll *a* content	0.763**	0.529
Chlorophyll *b* content	0.823**	0.675*
Total chlorophyll content	0.543	0.657

Significance level: * $\alpha = 0.05$, ** $\alpha = 0.01$.

The highest chlorophyll *a* content in the leaves of the ‘Rawa’ variety was noted with NPK applied in dose of 90 kg N, 60 kg P and 60 kg K · ha^{-1} (combination III) (Table 1).

The macroelements application caused a 39.5 % increase in chlorophyll *a* content in the leaves in the flowering stage, and a 41.3 % increase in the seed formation stage, in comparison with the plants of control combination.

The average chlorophyll *a* content for the 'Aztek' variety was the highest after macroelements application in doses of 70 kg N, 50 kg P and 50 kg K · ha^{-1} (combination II) (Table 1) and was by 248.7 % higher than the control plants in the flowering stage, and by 51.6 % at the beginning of seed formation.

The average chlorophyll *b* content was higher in leaves of the 'Rawa' variety than in the 'Aztek' variety. The level of chlorophyll *b* in 'Rawa' leaves measured in the flowering stage was higher than in the seed formation stage. The greatest increase in chlorophyll *b* in the leaves of this variety was found after application of 70 kg N, 50 kg P and 50 kg K · ha^{-1} (combination II) and was by 39.6 % higher than in the control plants (Table 1). Statistical analysis confirmed that chlorophyll *b* content in 'Rawa' leaves was dependent on the NPK fertilizers applied only in the flowering stage (Table 2).

Chlorophyll *b* content in the leaves of the 'Aztek' variety was higher in the flowering stage than in the seed formation stage. Application of macroelements in doses of 90 kg N, 60 kg P and 60 kg K · ha^{-1} (combination III) caused a 91.4 % increase in chlorophyll *b* in the flowering stage and a 104.4 % increase at the beginning of seed formation stage, in comparison with the plants of control combination. The level of chlorophyll *b* in 'Aztek' leaves was positively correlated with the amount of fertilizer added, irrespective of when the plant material was collected (Table 2).

Total chlorophyll content in the plants was also dependent on the variety of amaranth. The average total chlorophyll content was higher in the seed formation stage than in the flowering stage. The highest total chlorophyll content was noted in 'Rawa' leaves during the seed formation stage after application of NPK fertilizers in dose of 90 kg N, 60 kg P and 60 kg K · ha^{-1} (combination III) and amounted 1.693 mg · g^{-1} fresh mass. In the flowering stage the value of this parameter for the same fertilizer dose was by 75.9 % lower.

In the 'Aztek' variety, NPK fertilizers used in dose of 70 kg N, 50 kg P and 50 kg K · ha^{-1} (combination II) had the most beneficial effect on total chlorophyll level in the flowering stage. In this case the chlorophyll content was by 71.5 % higher than in the control plants (Table 1). Fertilizers application in dose of 90 kg N, 60 kg P and 60 kg K · ha^{-1} (combination III) had the most beneficial effect on total chlorophyll content in leaves at the beginning of seed formation stage and caused its increase by 45.9 % in comparison with the control plants. A statistically significant positive correlation ($r_{0.01} = 0.705$) between the total chlorophyll content in the amaranth leaves and the dose of fertilizers applied was found only for the 'Rawa' variety in the flowering stage (Table 2).

The increase in total chlorophyll content in the leaves was probably generated by the level of NPK fertilization. According to Ciecko et al [2], the greater amount of NPK fertilizers is accompanied by the higher total chlorophyll content in plant material. According to Nalborczyk et al [3], nitrogen fertilization affects chlorophyll content in plants. Research by Peyvast et al [5] shows that the level of chlorophyll in plants

increases rapidly following application of organic fertilizer. Coops et al [6] suggest that the level of chlorophyll – *a*, *b* and total – in leaves is dependent not only on the species of plant, but also on the variety. The results of the present study on amaranth confirmed results of other authors [2]. Most varieties of sugar beet, including 'Khazar', react positively to an increase in NPK fertilizer with an increase in chlorophyll *b* in the leaves. Gebczyński [7] suggests that the amount of total chlorophyll in plants can fluctuate. The main factor affecting the changeability of this parameter may be the variety of the plant. It is assumed that chlorophyll *a* and chlorophyll *b* usually occur in plants at a 3:1 ratio [8, 9].

The highest ratio of chlorophyll *a* to *b* was found, both for 'Rawa' and 'Aztek' leaves, at the beginning of seed formation stage after NPK application in dose of 90 kg N, 60 kg P and 60 kg K · ha^{-1} (combination III).

Conclusions

1. The NPK fertilization application cause an increase in chlorophyll content in the amaranth leaves. For the 'Rawa' variety, the highest chlorophyll *a* and total chlorophyll content is noted with NPK application in dose of 90 kg N, 60 kg P and 60 kg K · ha^{-1} (combination III), while the highest chlorophyll *b* content when NPK dose are of 70 kg N, 50 kg P and 50 kg K · ha^{-1} (combination II). For the 'Aztek' variety, the highest chlorophyll *a* content is found with combination II, while the highest chlorophyll *b* and total chlorophyll content with combination III.

2. A statistically significant correlation between the NPK fertilizers doses applied and chlorophyll content in the 'Rawa' and 'Aztek' leaves was found in the flowering stage of the plants.

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WPŁYW ZRÓŻNICOWANYCH DAWEK NAWOZÓW NPK NA ZAWARTOŚĆ CHLOROFILU W LIŚCIACH DWÓCH ODMIAN AMARANTUSA (*Amaranthus cruentus* L.)

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Abstrakt: Badano wpływu zróżnicowanego nawożenia NPK na zawartość chlorofilu w liściach dwóch odmian szarłatu 'Rawa' i 'Aztek'. Szarłat uprawiano w doświadczeniu polowym w rozstawie wąskorzędowej na glebie kompleksu pszennego dobrego, w środkowo-wschodniej części Polski. Zastosowano następujące kombinacje dawek makroskładników: I – 50 kg N, 40 kg P i 40 kg K · ha^{-1}, II – 70 kg N, 50 kg P i 50 kg K · ha^{-1}, III – 90 kg N, 60 kg P i 60 kg K · ha^{-1} oraz IV – 130 kg N, 70 kg P i 70 kg K · ha^{-1}. Oznaczono zawartość chlorofilu *a* i *b* oraz sumę chlorofili *a*+*b* w świeżej masie liści w stadium pełni kwitnienia roślin oraz na początku formowania nasion. Z przeprowadzonych badań wynika, że liście szarłatu odmiany 'Rawa' zawierały więcej chlorofilu niż liście odmiany 'Aztek'. Zawartości chlorofilu w liściach badanych odmian szarłatu były większe w okresie formowania nasion niż w okresie kwitnienia. Liście szarłatu odmiany 'Rawa' zawierały najwięcej chlorofilu *a* po zastosowaniu nawożenia NPK w dawce 90 kg N, 60 kg P i 60 kg K · ha^{-1} (kombinacja III), natomiast liście odmiany 'Aztek' po zastosowaniu 70 kg N, 50 kg P i 50 kg K · ha^{-1} (kombinacja II). Notowane ilości chlorofilu *b* były większe w świeżej masie liści odmiany 'Rawa' w porównaniu z odmianą 'Aztek'. Największą zawartość chlorofilu *b* stwierdzono w świeżej masie liści odmiany 'Rawa' po zastosowaniu II kombinacji nawożenia, a w liściach odmiany 'Aztek' po zastosowaniu III kombinacji nawożenia NPK. Stwierdzono statystycznie istotne zależności pomiędzy zastosowanymi dawkami nawozów NPK a zawartością chlorofilu w świeżej masie liści obu odmian szarłatu.

Słowa kluczowe: chlorofil, szarłat (*Amaranthus cruentus* L.), nawożenie NPK, dawki