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GROWTH AND PHOTOSYNTHETIC ACTIVITY OF CUCUMBER AS INFLUENCED BY DIFFERENT FERTILIZATION REGIMES

WZROST ORAZ AKTYWNOŚĆ FOTOSYNTETYCZNA ROŚLIN OGÓRKA W ZALEŻNOŚCI OD ZASTOSOWANEGO NAWOŻENIA

Abstract: The investigation aimed at examining the changes in growth and photosynthetic activity of greenhouse-grown cucumber plants subjected to various fertilization regimes. The plants were subjected to the following treatments: standard fertilization with nutrient solution (control), foliar treatments with two fertilizers (complete or nitrogenous), without any fertilization (non-fertilized plants). The plants without fertilization were supplied with water only.

Lack of fertilization resulted in the reduction of net photosynthesis and leaf chlorophyll content. The lowest rates of photosynthesis and leaf chlorophyll content were observed in the non-fertilized cucumber plants. Also, retardation in plant growth was evident in this group of plants as a result of nutrient deficiency. Foliar application of complete fertilizer (Agroleaf Power Total) had a pronounced effect on photosynthesis and growth of cucumber plants. On the other hand, the plants sprayed with nitrogenous fertilizer (Basfoliar 36 Extra) assimilated with low intensity, and their vigor did not differ significantly from that recorded for plants supplied with water only (non-fertilized).

Keywords: gas exchange, plant vigor, chlorophyll content, foliar fertilization

Fertilization is an important production factor influencing quantity and quality of yield [1, 2]. The basic way of providing plants with essential nutrients is soil fertilization in which mineral elements are taken up by plant root system. However, in certain periods plants require substantially larger quantities of nutrients than available from soil. In such cases foliar nutrition with both macro- and microelements is a method of ensuring that a plant receives a balanced supply of nutrients. The advantage of foliar nutrition is its rapid effect, limitation of nutrient losses, and restriction of environmental pollution (lack of sorption or leaching).

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Formation and the functional state of the plant assimilation apparatus depends on many factors including mineral nutrition. It was shown that carbon dioxide uptake was reduced as a consequence of limited nutrient supply in several experiments [3, 4]. Despite the significant number of investigations on fertilization requirements of cucumber [eg 5, 6], little is known about physiological characteristics of cucumber plants under nutrient deficiency conditions.

The main objectives of the study were: (i) to examine the vegetative growth and photosynthetic activity of greenhouse grown cucumber plants under conditions of low availability of nutrients; (ii) to compare the effect of two types of foliar fertilizers: 'complete fertilizer' (containing nitrogen, phosphorus, potassium and micronutrients) and 'nitrogenous fertilizer' (containing nitrogen and micronutrients) on growth and physiological condition of cucumber plants.

Materials and methods

The experiment was conducted in a greenhouse of the Research Institute of Pomology and Floriculture in Skierniewice, Poland in 2008. A cucumber (*Cucumis sativus* L.) 'Octopus' cultivar was the object of the experiment. In May 2008 seeds were planted in multicell trays (volume of one tray was 50 cm^3) filled with a mixture of sand and perlite (3:1). After sprouting, the plants were moved to pots of higher volume (1500 cm^3) filled with a mixture of sand and perlite. Climatic conditions recorded in a greenhouse chamber were as follows: temperature 16–24 ^oC during a day, 15–18 ^oC at night, relative air humidity maintained at 80 %, PAR (*photosynthetically active radiation*) irradiance minimum 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (during a cloudy day).

The following treatments were applied:

(i) standard fertilization (optimal nutrition, control) – normal fertilization used in greenhouse cucumber production systems; plants were fertigated with nutrient solution of the following content (in 1 dm^3): 0.7 mg NH_4-N, 224 mg NO_3-N, 47 mg P, 313 mg K, 170 mg Ca, 33 mg Mg, 0.84 mg Fe, 0.55 mg Mn, 0.33 mg Zn, 0.27 mg Cu, 0.048 mg B and 0.048 mg Mo [7],

(ii) plants supplied with water only during the experimental period (without any fertilization),

(iii) foliar application of 'complete fertilizer'; Agroleaf Power Total (20:20:20 + B, Cu, Fe, Mn, Zn, Mo) commercial fertilizer was used in a concentration of 1 %,

(iv) Foliar application of 'nitrogen fertilizer'; Basfoliar 36 Extra commercial fertilizer (36.6:0:0:4.3 + B, Cu, Fe, Mn, Zn, Mo) was used in a concentration of 0.55 %.

During the experimental period, the plants treated with foliar fertilizers were supplied with water only (no other fertilization was applied). Foliar application treatments were initiated in July 2008 at the beginning of a blooming stage. Two sprayings with the fertilizers were conducted at an interval of 5 days.

Five days after the first and the second foliar application (two sampling dates), an assessment of physiological status of plants from all combinations was conducted using the following methods:

1. leaf gas exchange – for evaluation of photosynthetic CO_2 assimilation rates (net photosynthesis); the gas exchange rate was measured using an LI-6400 portable photosynthesis system (LI-COR, USA),

2. intensity of leaf greenness (*chlorophyll content index*, CCI); this parameter reflects relative chlorophyll content in leaves; measurements were performed using CCM-200 (Opti-Sciences, USA) analyzer.

Assessment of plant morphology was done after finishing the experiment. Morphological characterization involved measurements of fresh and dry mass of stems and leaves, number of leaves, and total surface area of leaves. The surface area was measured using image analysis system (WinDIAS, Delta-T Devices, UK).

Each treatment combination was replicated twenty times (20 plants per treatment). All data were statistically elaborated using analysis of variance (ANOVA), followed by means separation using Duncan's multiple-range t-test at $p < 0.05$. All calculations were performed with the Statistica software package (StatSoft, USA).

Results and discussion

The gas exchange method was used to determine the photosynthetic activity of plant leaves. Changes in gas exchange rate provide a quick and non-destructive method for estimation of plant response to stress factors [8]. The photosynthetic activity of a plant depends on many factors including mineral nutrition [4, 9].

The highest rates of net photosynthesis were observed in the leaves of cucumber plants fertigated with nutrient solution (control) (Fig. 1). The intensity of photosynthesis recorded for this group of plants was about three times higher compared with the non-fertilized ones. Nutrient deficiency resulted in drastic reduction in net photosynthesis, as it was presented in case of plants supplied with water only (without any fertilization).

Positive effect of spraying with foliar fertilizers on photosynthesis intensity of cucumber plants was found. The most distinct effect was observed in plants treated with complete fertilizer (Agroleaf Power Total), which showed higher level of net photosynthesis compared with the plants sprayed with nitrogen fertilizer (Basfoliar 36 Extra) (Fig. 1). The photosynthetic rate of plants treated with complete fertilizer (measured after the second application) was more than two times higher compared with the non-fertilized plants. Analysis of photosynthesis after the first and the second foliar application revealed that in case of complete fertilizer (Agroleaf Power Total) it was more effective to use two applications (Fig. 1). Unlike this product, an increase in photosynthetic intensity was found only after the first spray with nitrogen fertilizer (Basfoliar 36 Extra). After the second application of this fertilizer net photosynthesis did not differ significantly from the level recorded for plants sprayed with water only (non-fertilized).

The reduction in photosynthetic activity of stressed plants can be attributed both to stomatal (stomatal closure) and non-stomatal (impairments of metabolic processes) factors. High nutrient availability may either increase or decrease the stomatal conductance of plants [4, 10–11]. In our study, foliar fertilization had a slight effect on

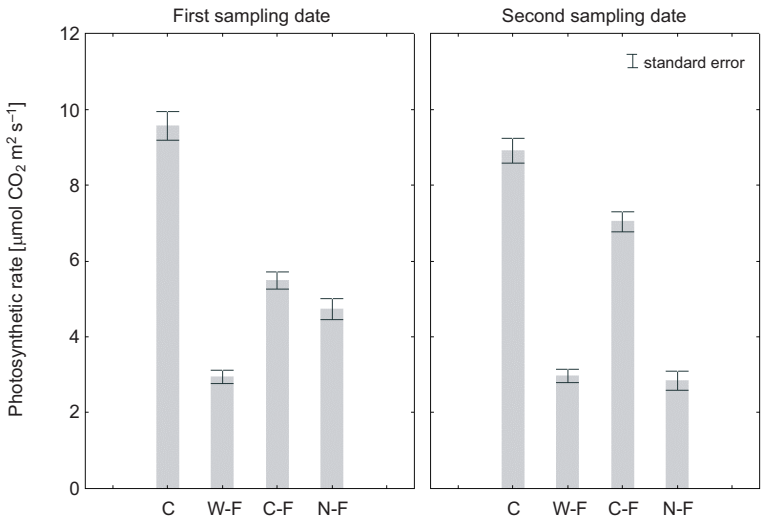

Fig. 1. Net photosynthesis in the leaves of cucumber plants as influenced by fertilization regime and term of sampling; C – control, W-F – without fertilization, C-F – complete foliar fertilizer, N-F – nitrogen foliar fertilizer

stomatal conductance [data not presented]. Thus, an increase in net photosynthesis observed in plants sprayed with complete fertilizer (Agroleaf Power Total) could be attributed to the improvement of the activity of photosynthetic enzymes. The increase in the enzyme activity due to application of mineral nutrients was noted by Siddiqui et al [12].

CCI index was used to determine the relative content of chlorophyll, which is a basic photosynthetic pigment in leaves [13, 14]. It was showed that content of photosynthetic pigments can be decreased under conditions of mineral nutrient deficiency [15, 16].

Relative chlorophyll content in cucumber leaves was diversified depending on an applied fertilization treatment. CCI was the highest in control plants (fertigated with nutrient solution). Intensity of leaf greenness in this combination was more than 4 times higher compared with non-fertilized plants (after the second application) (Fig. 2).

Among the plants treated with foliar fertilizers, higher CCI values were recorded in cucumber sprayed with complete fertilizer (Agroleaf Power Total) (Fig. 2). The increased amount of chlorophyll in leaves can explain an enhanced photosynthetic activity observed in plants treated with this fertilizer.

Changes in amount of leaf chlorophyll are often regarded as mechanism of photosynthetic acclimation to environmental factors [17]. In the present experiment, alterations in leaf chlorophyll content could be a part of a regulative system of photosynthesis to changes in plant nutritional status. An increase of chlorophyll content in leaves was recorded also in other crop species treated with different foliar fertilizers [18, 19].

Nutrient deficiency leads to reduced growth and productivity of plants [20, 21]. As photosynthesis is a major determinant of plant productivity, it was no surprise that the

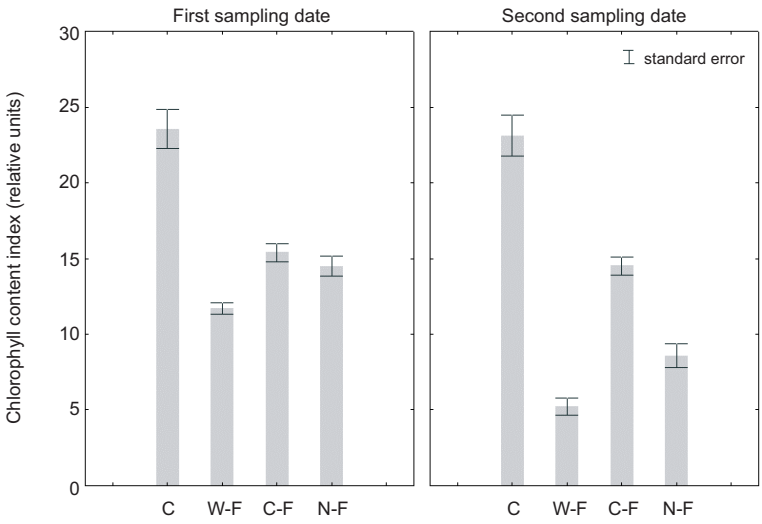

Fig. 2. Intensity of leaf greenness (CCI index) of cucumber plants as influenced by fertilization regime and term of sampling; C – control, W-F – without fertilization, C-F – complete foliar fertilizer, N-F – nitrogen foliar fertilizer

optimally fertilized (control) plants were characterized by the most intensive growth (Table 1).

Table 1

Growth related parameters of cucumber plants as influenced by fertilization regime

Treatment	Stem mass [g]		Leaf mass [g]		Number of leaves	Total leaf area [$cm^2 \cdot plant^{-1}$]
	fresh	dry	fresh	dry		
Control	42.87 c	3.10 a	47.92 b	7.04 a	24.10 b	3189.44 c
Without fertilization	17.89 a	2.43 a	18.58 a	4.97 a	14.30 a	889.04 a
Complete fertilizer	31.15 b	4.25 b	42.03 b	11.43 b	23.30 b	1761.16 b
Nitrogenous fertilizer	23.28 ab	3.26 ab	22.41 a	5.59 a	16.10 a	1048.23 a

Means within the columns marked with the same letter are not significantly different (5 %) according to Duncan's multiple range-test.

Foliar application of complete fertilizer caused a significant increase in fresh weight of cucumbers stems and leaves (compared with the non-fertilized plants) (Table 1). The lowest values of these parameters were found within the combinations in which no fertilization or application of nitrogen fertilizer (Basfoliar 36 Extra) was applied. Foliar application of Agroleaf Power Total fertilizer caused increased dry matter accumulation (Table 1) indicating efficient nutrient uptake by treated plants. It was confirmed by analysis of mineral element content of plant tissue [data not presented].

Similarly to the mass, the leaf area was dependent upon the applied fertilizer. The total leaf area was the highest among the plants which were fertigated with nutrient

solution (control) followed by those sprayed with Agroleaf Power Total. Plants from these two combinations were also characterized by the highest average number of leaves (Table 1).

Conclusions

Complete lack of fertilization resulted in drastic reduction in photosynthetic CO_2 assimilation and severe retardation in plant vegetative growth. The study confirmed high efficiency of complete foliar fertilizer in diminishing the negative effects of nutrient stress. It seems that in case of plants grown under conditions of low nutrient availabilities the positive impact of sprays with Agroleaf Power Total (complete fertilizer) on plant performance was related to improved nutrition. Besides trace elements, this fertilizer contains nitrogen, phosphorus and potassium. Basfoliar 36 Extra fertilizer contains nitrogen and magnesium (and trace elements). An inadequate supply of phosphorus and potassium resulted in decreased photosynthetic activity and poor vigor of the plants treated with this fertilizer.

The results also support the potential usage of non-destructive methods to characterize selected plant physiological processes. As a result of applying these methods it was possible to assess the physiological state of plants grown under nutrient stress and evaluate the efficiency of application of different foliar fertilizers.

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WZROST ORAZ AKTYWNOŚĆ FOTOSYNTETYCZNA ROŚLIN OGÓRKA W ZALEŻNOŚCI OD ZASTOSOWANEGO NAWOŻENIA

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Abstrakt: W doświadczeniu szklarniowym oceniono wzrost i aktywność fizjologiczną roślin ogórka w reakcji na zastosowane nawożenie. Kombinacje doświadczalne obejmowały rośliny nawożone dokorzeniowo (fertygacja pożywką płynną), rośliny nienawożone w trakcie trwania uprawy oraz rośliny nawożone dolistnie jednym z dwóch nawozów: wieloskładnikowym (zawierającym makro i mikroelementy) lub azotowym (zawierającym azot i mikroelementy). Rośliny nienawożone zasilane były tylko wodą.

Najmniejsze natężenie fotosyntezy i zawartość chlorofilu w liściach wykazano w przypadku roślin nienawożonych. U tej grupy roślin stwierdzono także najsilniejsze zahamowanie wzrostu. Spośród zastosowanych nawozów dolistnych, wyższą skuteczność wykazano w przypadku nawozu wieloskładnikowego. U roślin opryskiwanych tym nawozem stwierdzono większą zawartość chlorofilu w liściach oraz wysokie wartości fotosyntezy netto. Rośliny traktowane nawozem wieloskładnikowym charakteryzowały się także bardziej intensywnym wzrostem.

Słowa kluczowe: wymiana gazowa, wzrost roślin, zawartość chlorofilu, nawożenie dolistne