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PLANT TOLERANCE TO ALUMINIUM DEPENDING ON NITROGEN FORM

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Introduction

Plants show considerable differentiation in tolerance to Al^{3+} [RENGEL, JURKIC 1992; POKOJSKA 1994; PELLER et al. 1997]. A mobile aluminium content in nutrient solution and its concentration in biomass of even the same plant species do not manifest any regularity. Complexity of physiological processes under changing conditions of nutrient medium, subjected to aluminium ions influence, hinders full explanation of changing plant sensitivity to this metal. The effect of mineral nutrition is well known, in particular of phosphorus and calcium, that it increases plant tolerance to aluminium [MIYASAKA et al. 1989; ŚLARSKI 1992]. It is connected with the increase of capacity for regular membrane potential maintanance and balanced ion exchange [HANG, CALDWELL 1985; TAYLOR 1987]. However, the information on influence of plant nitrogen nutrition on aluminium concerns mainly concentration of this metal in biomass.

The results presented make a part of comprehensive studies aiming at determination of the influence of oxigenated and reduced nitrogen forms on plant tolerance development to Al. Due to direct and indirect influence of aluminium ions to roots, this problem was hoped to be solved on the basis of root physiological indicators as well as Al and carbohydrate content in roots, stems and leaves of three plant species.

Material and methods

Maize (*Zea mays* L. var. *saccharata*), sunflower (*Helianthus annuus* L.), lettuce (*Lactuca sativa* L.), were the experimental plants. The experiment was run in aquatic cultures in jars of 1 dm^3. In which the examined plants at four leave stage were placed. Each jar contained one plant. In this experiment the differentiating factors were aluminium concentrations: 0 (control), 20, 100 and 200 $\mu mol \cdot dm^{-3}$ given as $AlCl_3$ and nitrogen forms: oxygenated ($NaNO_3$), reduced ($(NH_4)_2 SO_4$ with nitropyrine addition), while control was made by nitrogen in the form of NH_4NO_3. The other basic mineral nutrients were applied once in the form of the salts regarding the feeding requirements of the plant species studied. The solution for maize and sunflower contained: N – 250, K – 240, Ca – 200, Mg – 60, P – 50 $mg \cdot dm^{-3}$ as well as 1.5 cm^3 A–Z medium and 1% iron citrate each;

for lettuce: N – 180, K – 160, Ca –140, Mg – 40 and P – 30 mg·dm^{-3} as well as 1 cm^3 of the above mentioned trace elements solution. Each of experimental series covered five replications. The medium pH was adjusted up to 5.8 every week. Medium was aerated every three days. The plants were grown under control conditions set up to 60 W·m^{-2} – luminosity, temperature 26°C day/20°C night, day cycle 14 h day/10 h night and 75% relative air humidity.

The 4-week roots of the studied plants were calculated for: total volume, total adsorptive surface, active adsorptive surface and active surface of 1 cm^3 with Sabinin and Kolosov's method [BASŁAWSKA, TRUBIECKOWA 1964]. In the leaves of maize, sunflower and lettuce there was established aluminium content with atomic spectrophotometric method AAS and of carbohydrates by Dubois method [DUBOIS et al. 1956].

Results and discussion

The results obtained indicate that maize, sunflower and lettuce roots, with reduced nitrogen form available for them, showed smaller volume and general adsorptive surface as well as lower adsorptive activity of 1 cm^3 than plant roots using oxygenated form of nitrogen (Fig. 1–3). The highest values of the above mentioned indicators were recorded when ammonium nitrate was a nitrogen source. Unfavourable and sometimes toxic influence of NH_4 ions on numerous plant species is widely known [MAGALHÃES, HUBER 1989]. Considering root physiological indicators of the plant species in this experiment, the highest sensitivity to reduced nitrogen form was reported for sunflower. It may be interpreted with medium pH drop from 5.8 to 4.6 pH recorded after 7-day vegetation of sunflower. Alike, medium pH fall was noted for maize and lettuce but after 10 vegetation days. Inhibition of root growth of the plant species examined under these conditions did not cause any limitation of shoot growth. Moreover, in the maize leaves there was observed higher carbohydrates content than in control, whereas the changes of medium pH with N-NO_3 were only slight (an average from 5.8 to 6.1 pH).

The obtained results showed a stimulating effect of aluminium at concentration of 20 μmol·dm^{-3} when the plants were fed N-nitrate or ammonium nitrate. It was manifested with an increase of total volume and of adsorptive capacity of root, particularly noted at maize roots (Fig. 1–3). Furthermore, there was stated medium pH increased from 5.8 to 6.4. Similarly, in maize and lettuce roots there was lower aluminium level and at the same time higher carbohydrates concentration. No dependence like that was recorded in the sunflower roots (Fig. 4, 5).

Al^{3+} concentration in medium 100 μmol·dm^{-3} in connection with reduced nitrogen form brought about decrease of volume and adsorptive properties of the examined plant roots, especially sunflower roots (Fig. 1–3). Such specific changes were not noted in the roots at N-NH_4. The highest Al concentration studied (200 μmol·dm^{-3}) caused significant limitation of the root indicators of all the plant species, irrespective of nitrogen form.

The results obtained indicate that the physiological basis for Al tolerance of maize, sunflower and lettuce fed oxygenated or reduced nitrogen form result not only from pH change of rhizosphere due to nitrogen uptake or root cation-exchange property [RAGAB 1980; MIYSAKA et al. 1989]. Undoubtedly, the mentioned

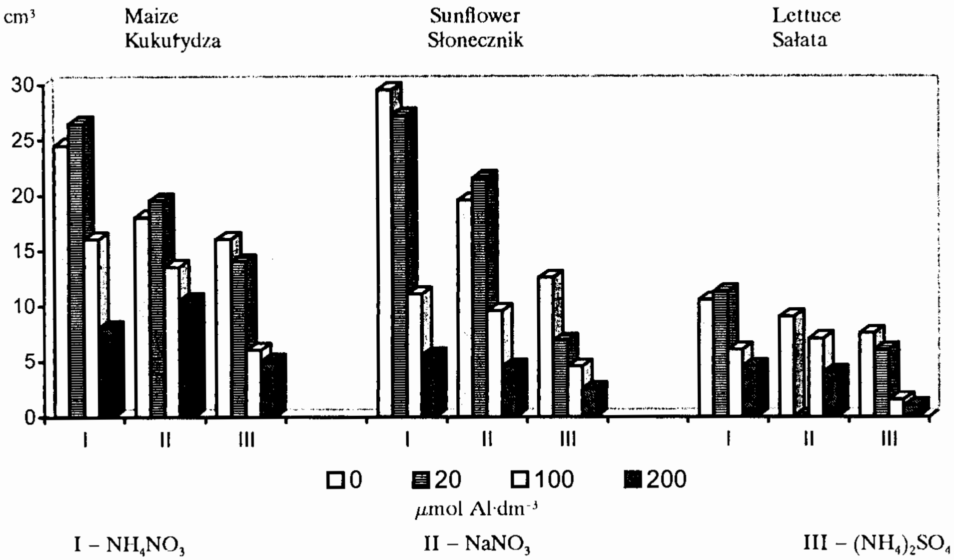
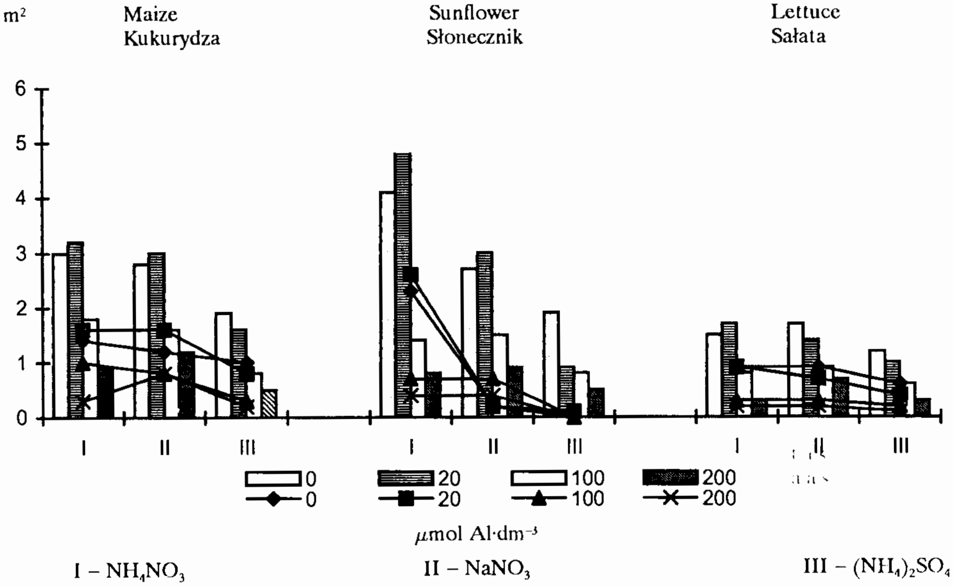


Fig. 1. Total root volume (cm^3) in relation to aluminium concentration and nitrogen form

Rys. 1. Ogólna objętość korzeni (cm^3) w zależności od stężenia aluminium i formy azotu



t.a.s. – total adsorptive surface; ogólna powierzchnia adsorpcyjna
a.a.s. – active adsorptive surface; aktywna powierzchnia adsorpcyjna

Fig. 2. Total and active adsorptive surface of roots (m^2) in relation to aluminium concentration and nitrogen form

Rys. 2. Całkowita i aktywna powierzchnia adsorpcyjna korzeni (m^2) w zależności od stężenia aluminium i formy azotu

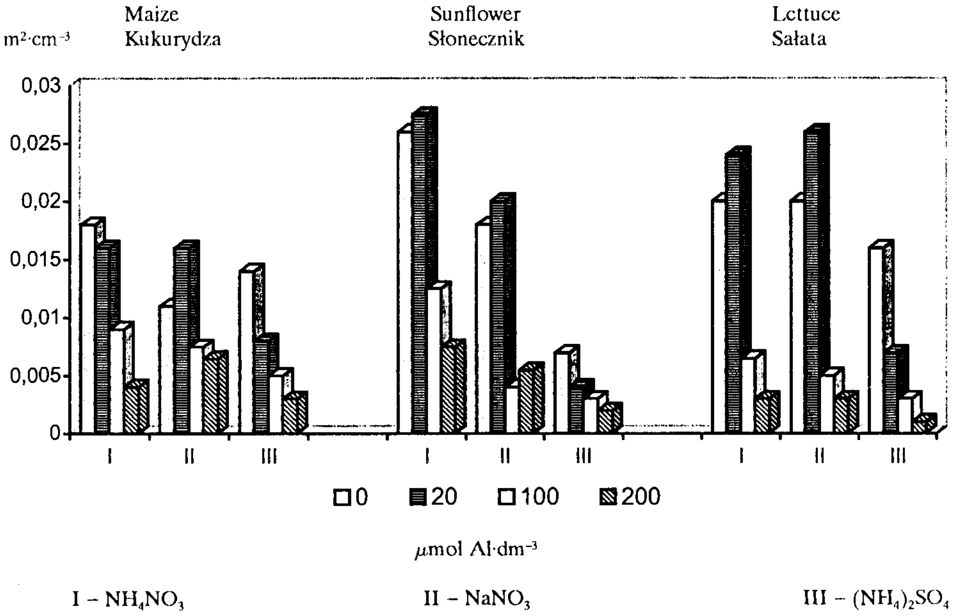


Fig. 3. 1 cm^3 active surface of roots (m^2·cm^{-3}) in relation to aluminium concentration and nitrogen form

Rys. 3. Powierzchnia aktywna 1 cm^3 korzeni (m^2·cm^{-3}) w zależności od stężenia aluminium i formy azotu

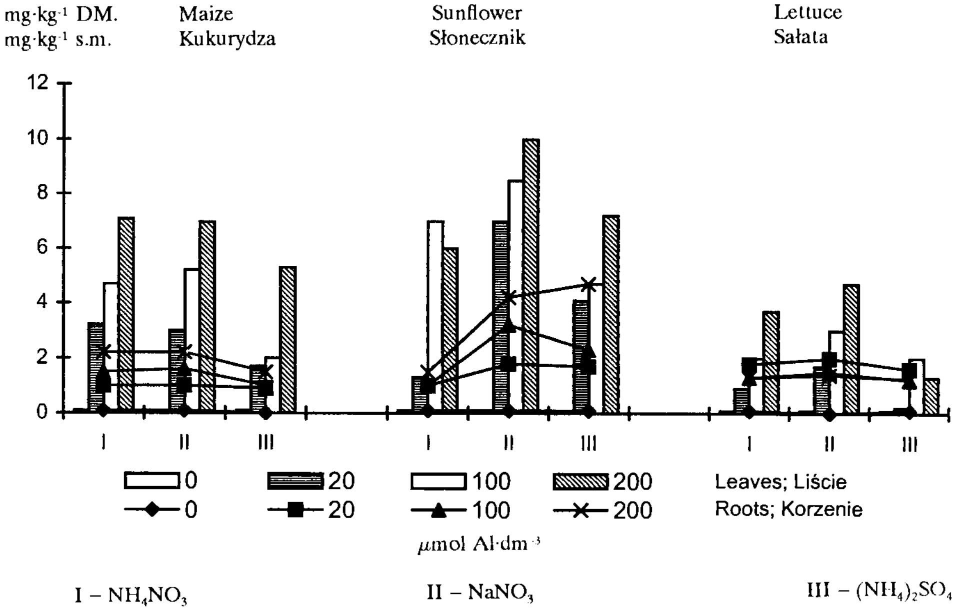


Fig. 4. Al content (mg·kg^{-1} DM) in experimental plants

Rys. 4. Zawartość Al (mg·kg^{-1} s.m.) w badanych roślinach

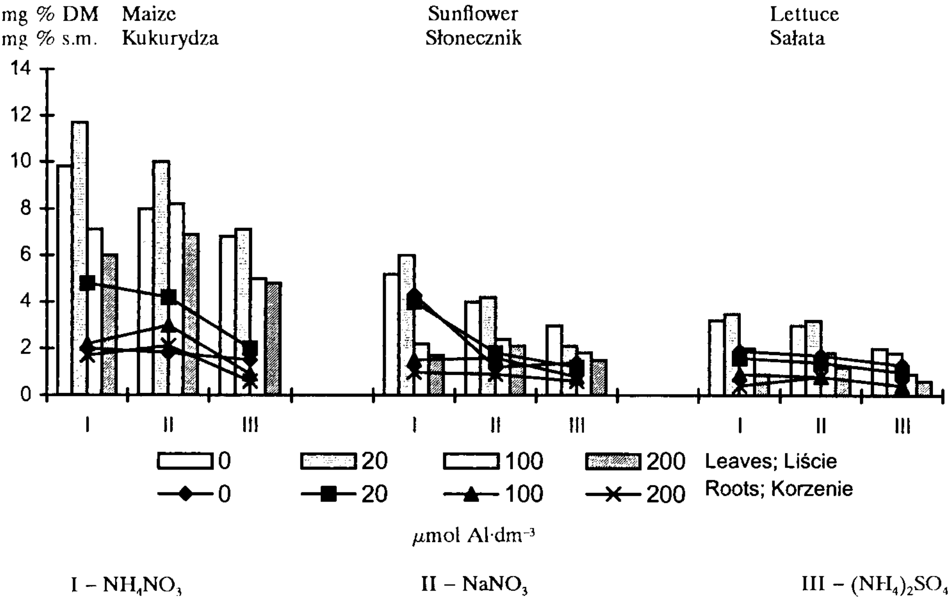


Fig. 5. Carbohydrate content (mg % DM) in experimental plants
Rys. 5. Zawartość węglowodanów (mg % s.m.) w badanych roślinach

factors of aluminium tolerance are of very important but plant selection in respect to sensitivity based on rhizosphere alkalization also divides plants in regard to cation and anion uptake rate. Therefore, this explanation may not concern plants grown at some limitation of nutrient availability. It is possible that tolerant plants are of higher photosynthethic activity e.g. maize, lettuce or indicate higher level of carbohydrates translocation to roots. Increase of aluminium accumulation in roots is consequenced not only of concentration of this element in medium, but also of nitrogen form and plant species as well. Generally, lower aluminium level was registered not only in the roots of plants fed N-NO_4. Particularly effective influence was shown in maize roots, than lettuce and sunflower.

Greater carbohydrates supply to roots means greater availability of carbon skeletons for Al^{3+} cumulation and its deposit in a vacuole. The fact that roots grow better under Al^{3+} contamination conditions at the presence of oxygenated rather than reduced nitrogen forms comes about not only from rhizosphere alkalization results, but also greater accumulation of carbohydrates and decreased Al^{3+} cumulation in roots (Fig. 4, 5). It may be caused by collected NO_3 that blocks negative charges of root spare space and thus facilitate, the taken anion diffusion through root apoplast.

Conclusions

1. Aluminium at concentration of 20 μmol·dm^{-3} increase the adsorptive capacity of roots.

2. Plant tolerance to aluminium toxicity increases with nitrogen nutrition in oxygenated form ($NaNO_3$). Nitrogen in reduced form $(NH_4)_2 SO_4$ causes increase of aluminium phytotoxicity.

3. Plants tolerant to aluminium and reduced nitrogen form show higher carbohydrates content, especially in roots.

4. The plant species studied can be arranged on the basis of changes in the root adsorptive properties that are indicators of plant tolerance to aluminium: maize < lettuce < sunflower.

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Key words: aluminium, nitrogen forms, root adsorption, tolerance, maize, sunflower, lettuce

Summary

In the experiment run at aquatic cultures there was examined sensitivity of 3 plant species (maize, sunflower, lettuce) to aluminium (0 – control, 20, 100, 200 μmol·dm^{-3}) at nitrogen nutrition in reduced and oxygenated form. Tolerance of sunflower, lettuce and maize in particular increases when oxygenated form makes a nitrogen source. Reduced form of nitrogen causes Al^{3+} phytotoxicity increase. Plants tolerant to aluminium and fed reduced nitrogen form demonstrate higher carbohydrates content, especially in roots.

TOLERANCJA ROŚLIN NA GLIN W ZALEŻNOŚCI OD FORMY AZOTU

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Słowa kluczowe: glin, formy azotu, adsorpcja korzenia, tolerancja, kukurydza, słonecznik, sałata

Streszczenie

W doświadczeniu przeprowadzonym w kulturach wodnych badano wrażliwość 3 gatunków roślin (kukurydza, słonecznik, sałata) na stężenie glinu (0 – kontrola, 20, 100, 200 μmol·dm^{-3}) w warunkach żywienia azotem w formie zredukowanej oraz utlenionej. Tolerancja roślin słonecznika, sałaty, a szczególnie kukurydzy wzrasta, kiedy źródłem azotu jest forma utleniona. Azot w formie zredukowanej powoduje wzrost fitotoksyczności glinu. Rośliny tolerancyjne na glin i żywione zredukowaną formą azotu charakteryzują się wyższą zawartością węglowodanów, szczególnie w korzeniach.

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