The fertilization impact on garden cress resistance to substrate acidity and heavy metal cadmium

Irena Januškaitienė
Vytuutas Magnus university, Daukanto 28, Kaunas LT-3000, Lithuania, e-mail: I.Januskaitiene@gmf.vdu.lt

This study aimed to investigate the impact of different concentrations of nutrients on garden cress resistance to substrate acidity and heavy metal cadmium. Laboratory experiments with Lepidium sativum L. were performed at the Department of Environmental Sciences, Vytautas Magnus University. Garden cress was grown in optimal 23 ± 2 °C temperature on sterile cotton wool flooded with different concentrations of ammonium nitrate (as a fertilizer) and cadmium. There was investigated impact of ammonium nitrate on the garden cress resistance to medium acidity and cadmium. Garden cress was grown on medium with various pH values (6.0 – optimal, 3.5 – acid and 9.0 – alkaline) and with different concentrations of ammonium nitrate, also parallel with 0.05 mM concentration of cadmium.

Fertilization decreases negative effect of substrate acidity. In neutral pH 6.0 medium optimal (0.1 mM) ammonium nitrate concentration stimulated seedlings growth about 5 % (p < 0.05), but the highest positive effect of 0.1 mM ammonium nitrate on seedlings growth was in acidified (pH 3.5) medium, where garden cress seedlings height increased about 242 % comparing to the control (p < 0.05). It shows that in acidified substrate fertilization optimum moved to higher concentrations. In acidified medium the effect of fertilization on garden cress resistance to cadmium was positive but statistically not significant.

Key words: garden cress, Lepidium sativum L., fertilization, substrate acidity, cadmium.

Introduction. In many areas of the world, soil acidity limits agricultural yield. The low content of base cations and heavy metals toxicity affect root growth and the absorption of water and nutrients by plants, usually causing a reduction in crop yields on acid soils (Marsh and Grove, 1992; Tang et al., 2003; Caires et al., 2008).

Nutrient status, soil acidity and pollution are the major factors in plant development and productivity. The plant develops best with an optimal concentration of mineral substances. Plants suffering from nutrition deficiency are stunted; their development proceeds abnormally. If nutrient elements are taken up beyond optimal concentration they bring no additional benefit (surplus nutrition) and excessive quantities of many mineral substances have a depressive or toxic effect (Larcher, 2003).

The assimilation of nutrition depends on substrate acidification status, salinity and other factors of environment (Grattan and Grieve, 1999). The hydrogen-ion
concentration in the surroundings of a plant is an important factor influencing its nutrition and distribution (Larcher, 2003). Increased atmospheric deposition has caused a reduction in pH and exchangeable base cations in soils (Westling and Hultberg, 1990). A decrease in soil pH can be achieved through application of mineral acids, organic acids and acid-producing fertilizers (Cui et al., 2004; Gramss et al., 2004; Kayser et al., 2001; Zaccheo et al., 2006). When soil pH drops below 5.0, the availability of aluminum (Al) and manganese (Mn) to plants increases (Meiwes et al., 1986). Other changes in soils that may occur during soil acidification include loss of nutrients due to leaching and competition between the base cations (calcium (Ca), magnesium (Mg), and potassium (K)) and toxic elements (Al and Mn) (Robarge and Johnson, 1992).

One of the most harmful heavy metals for plants is cadmium. Important sources of Cd contamination are industry of non-ferrous metals, mining production, metal-contaminated wastes, application of pesticides and phosphate fertilizers. Cadmium is one of the most toxic metals and due to its mobility it is easily absorbed by roots and can cause heavy damage to plants (Zornoza et al., 2002). Exposure to cadmium inhibits activity of photosynthetic enzymes, decreases chlorophyll content, increases membrane conductance and causes oxidative stress, resulting in inhibition of photosynthesis and growth (Chugh and Sawhney, 1999; Sliesaravičius et al., 2002; Duchovskis et al., 2006).

The negative impact of cadmium ions is usually modified by other factors (Duchovskis et al., 2003). A very important component of this integrated impact is soil acidity, which determines heavy metals content, mobility and the possibility to pass into production the system of a plant (Mažvila et al., 2001). The highest amount of mobile cadmium is found in acidic soil, with pH values of 4.5–5.5. In such soils plants accumulate much more cadmium (Duchovskis et al., 2006; Zaccheo et al., 2006).

It is important to decrease the negative effect of various stresses. Agrochemical measures, for example, fertilizers enhance plant resistance to the impact of anthropogenic stressors. Some investigations carried out in damaged forest corroborated this theory (Stravinskiene, 2000). Also the fertilization and liming of soils is a proposed remedy to soil acidification (Hendershot and Jones, 1989). These treatments have resulted in increased concentrations of Ca$^{2+}$ and Mg$^{2+}$, increased pH (Swistock et al., 1999), and decreased extractable Al (Demchik and Sharpe, 1999). Liming and vitality fertilization have been suggested as countermeasures to soil acidification and nutrient depletion from forest soils, but also as means of increasing the nutrient status of the plants (Gronflaten et al., 2005).

In the present study, there was investigated the impact of fertilization (different concentrations of ammonium nitrate) on garden cress resistance to substrate acidity and heavy metal cadmium.

**Object, methods and conditions.** Laboratory experiments with garden cress *Lepidium sativum* L. were performed at the Department of Environmental Sciences, Vytautas Magnus University (VMU).

Investigations with garden cress were carried out in three stages. In the first stage of experiment, garden cress was grown in optimal $23 \pm 2$ °C temperature in Petri dishes, 30 seeds per dish, on sterile cotton wool flooded with 100 ml of a solution containing 0.01; 0.05; 0.1; 0.2; 0.4; 0.6; 0.8; 1.0; 5.0; 10.0; 20.0; 30.0 and 40.0 mM
concentrations of ammonium nitrate (as a fertilizer). To the next stage of experiment there were taken 0 mM (distilled water); 0.1 mM (the closest to the optimum), 1.0 mM and 10.0 mM ammonium nitrate concentrations. In the second stage, garden cress was grown in the same temperature, but on medium with 0.05 mM cadmium concentration, which decreased garden cress growth about fifty percents.

In the third stage, there was studied impact of fertilizer (ammonium nitrate) on the garden cress resistance to medium acidity and cadmium. Garden cress was grown on medium with various pH values (6.0 – optimal, 3.5 – acid (H₂SO₄ was used), 9.0 – alkaline (NaOH was used)) and with 0.0; 0.1; 1.0 and 10.0 mM concentrations of ammonium nitrate. Thus, twelve combinations of ammonium nitrate and medium pH were established.

Parallel garden cress was grown on medium with the same pH values and ammonium nitrate content, and also with 0.05 mM concentration of cadmium.

Height of garden cress seedlings was measured at the end (5 days) of all experiments. The experiments were carried out in three replications.

Programs “SATISTICA” and “EXEL” were used for mathematic analysis and graphic presentation of the data.

Results. While studying the response of garden cress to fertilization, first there was determined the ammonium nitrate tolerance area (Fig. 1). At the optimum temperature (23 ± 2 °C) and neutral acidity (pH 6.0), the ammonium nitrate tolerance limits for garden cress was between 0 and 40 mM, and the optimum concentration – 0.1 mM. This amount of fertilizer increased garden cress growth 13.5 % (p < 0.05). And in medium with 1.0 mM to 40 mM concentrations of ammonium nitrate garden cress growth decreased statistically significantly comparing to the optimum. So to the next stage of experiment there were taken 0 mM (distillated water); 0.1 mM (the closest to the optimum), and 1.0 mM and 10.0 mM ammonium nitrate concentrations. Impact of fertilizers on the garden cress resistance to medium acidity and heavy metal cadmium was studied further.

![Fig. 1. Ammonium nitrate impact on garden cress height (mean ± SE*1.96)](image)

1 pav. Amonio nitrate poveikis sėjamosios pipirnės aukščiui (vidurkis ± Std. pakl.*1,96)
Height of garden cress seedlings in different acidity and ammonium nitrate concentrations in medium is presented in Figure 2. In neutral pH 6.0 medium optimal (0.1 mM) ammonium nitrate concentration stimulated seedlings growth about 5 % (p < 0.05). The highest positive effect of 0.1 mM ammonium nitrate on seedlings growth was in acidified (pH 3.5) medium, garden cress seedlings height increased 3.4 times (about 242 %) comparing to the control. Optimal nitrogen concentration decreased negative impact of substrate acidity considerably. In acidified medium even highest concentrations of ammonium nitrate stimulated garden cress growth comparing to the control (0 mM distilled water). However, in alkaline (pH 9.0) medium optimum ammonium nitrate concentration stimulated garden cress growth only 0.4 % (p > 0.05).

![Fig. 2. The effect of various ammonium nitrate concentrations on garden cress seedling height (mean ± SE*1.96) at different substrate acidity](image)

According to our previous research results, 0.05 mM cadmium concentration decreased garden cress growth for about fifty percents (Žukauskaitė, 2003), so this concentration was taken to the next stage of the experiment. Data about fertilizer impact on the garden cress resistance to medium acidity and heavy metal cadmium (0.05 mM) is presented in Figure 3.

Under additional cadmium pollution, fertilization effect on seedling growth was rather different, and in all medium acidity variants garden cress grew higher without ammonium nitrate. So, there was no positive effect of fertilization on garden cress resistance to cadmium. In acidified medium garden cress grew weakly both without cadmium (Fig. 2) and with it (p > 0.05) (Fig. 3). But in neutral and alkaline mediums with cadmium, increase of ammonium nitrate in medium decreased seedling height statistically significantly (p < 0.05).
Fig. 3. The effect of various ammonium nitrate concentrations on garden cress seedling height (mean ± SE*1.96) at different substrate acidity and 0.05 mM cadmium impact

Discussion. The plant develops best with an optimal concentration of mineral substances. Plants suffering from nutrition deficiency are stunted; their development proceeds abnormally (Larcher, 2003). Liming and fertilization is in use in various European countries to increase tree production and regeneration (Persson et al., 1990; Gronflaten et al., 2005). Supplementary amount of Ca, S, and other elements decreased cadmium toxicity for plants too (Chen and Huerto, 1997; Cirkova et al., 1997; Das et al., 1997). Soil solution composition provides an important index of the availability of different ions to plants. Various soil factors known to affect the availability of metals, soil pH is considered as one of the most important. Plant tissue concentrations of metals typically decrease with increased soil pH provided that other soil parameters remained unchanged (Singh et al., 1995).

Research data about fertilization impact on plants resistance to various unfavorable environmental factors are different. As it was presented above, the highest positive effect of 0.1 mM ammonium nitrate on seedling growth was in acidified (pH 3.5) medium (Fig. 2). Our other experiments with tomato showed, that nutrients simulated tomato growth for about 5% (p > 0.05) in acidified substrate also, i.e. fertilization optimum of tomato moved to higher concentrations in acidified substrate (Januškaitienė et al., 2004).

Some researchers state that, for example, nitric fertilizers can reduce cadmium access to plant (Balík et al., 1995). Fertilizers increase tomato plant resistance to the impact of heavy metal cadmium, but oversupply of nutrients had negative effect on
growth (Žukauskaitė, 2003; Januškaitienė et al., 2004). Ammonium nutrition is known to reduce the uptake of several cations in plants (Zaccheo et al., 2006). But Kashem and Singh (2002) had established that fertilizers with cations increase the uptake of metals by improving growth conditions, but the magnitude of increase depended on plant species.

Other data presents that nutrition with various environmental factors effect plants differently (Zhang, 1996). Cadmium uptake was increased by 50 % following application of NH4, but no increase was seen after P application. Eriksson (1990) observed that an increase in fertilizer dose (NPK) generally resulted in an increase in the levels of soil Cd and in Cd concentration in plants.

Ammonium nitrate had no positive effect on garden cress resistance to cadmium (Fig. 3). When additional 0.05 mM cadmium concentration was added to the growth medium, ammonium nitrate effect on seedlings growth was rather different comparing to the treatment without heavy metal. And in all medium acidity variants garden cress grew higher without fertilizer. In acidified medium garden cress grew weakly both without cadmium (Fig. 2) and with it (p > 0.05) (Fig. 3). In neutral and alkaline mediums garden cress seedling height decreased (p < 0.05) with increase of ammonium nitrate in medium. Fertilizers with high NH4 content lead to an increase in plant uptake of Cd (Kashem and Singh, 2002; Wangstrand et al., 2007) and increase its negative effect on plant growth.

Conclusions. Ammonium nitrate decreases negative effect of substrate acidity on garden cress growth. In neutral pH 6.0 medium optimal (0.1 mM) ammonium nitrate concentration stimulated seedlings growth for about 5 % (p < 0.05), but the highest positive effect of 0.1 mM ammonium nitrate on seedling growth was in acidified (pH 3.5) medium, where garden cress seedling height increased about 242 % comparing to the control (p < 0.05). It shows that in acidified substrate fertilization optimum moved to higher concentrations.

There wasn’t found any positive effect of ammonium nitrate on garden cress resistance to cadmium. Only in acidified medium the effect of fertilization on garden cress resistance to cadmium was positive but statistical not significant.

References

Tręšimo poveikis sėjamosios pipirnės atsparumui substrato rūgštumui ir sunkiajam metalui kadmiui

I. Januškaitienė

Santrauka

Tyrimų tikslas buvo ištirti skirtingo trąšų kiekio poveikį sėjamosios pipirnės (Lepidium sativum L.) atsparumui substrato rūgštumui ir sunkiajam metalui kadmiui. Bandymai buvo atliekami Vytauto Didžiojo universiteto Aplinkotyro katedros laboratorijoje. Sėjamoji pipirnė sēta ir auginta optimalioje 23 ± 2 °C temperatūroje ant sterilios vatos, sudrėkintos skirtingomis amonio nitrato (kaip trąšos) ir kadnio koncentracijos tirpalais. Sėjamoji pipirnė augo skirtingo rūgštumo terpėse (6,0 pH – optimali, 3,5 pH – rūgšti ir 9,0 pH – šarminė) su skirtingu amonio nitrato kiekiu kartu veikiant 0,05 mM kadnio koncentracijai.

Trąšos mažino neigiamą rūgštaus substrato poveikį sėjamajai pipirnei. Didžiausią teigiamą efektą trąšos (šiuo atveju – amonio nitratas) duoda, esant rūgščiai (3,5 pH) augimo terpei. 0,1 mM amonio nitrato kiekis neutralioje pH 6,0 augimo terpėje sėjamosios pipirnės augimui paskatino tik +5 % (p > 0,05), o rūgščioje – net +242 % (p < 0,05), palyginti su kontrole. Papildomai veikiant kadmiu, rūgščioje (pH 3,5) augimo terpėje 0,1 mM ir 10mM amonio nitrato kiekiai daro statistiškai nereikšmingą (p > 0,05) teigiamą poveikį sėjamosios pipirnės augimui, o neutralioje (pH 6) ir šarminėje (pH 9) terpėse jokio teigiamo tręšimo (amonio nitrato) poveikio nenustatyta.

Reikšminiai žodžiai: sėjamoji pipirnė, Lepidium sativum L., tręšimas, substrato rūgštumas, kadmis.