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EFFECT OF FERTILIZATION ON CONTENT AND UPTAKE OF CHLORINE BY OILSEED RAPE UNDER POT EXPERIMENT CONDITIONS

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Abstract

At present, chlorine counts as one of the elements which are essential for growth and development of plants because it plays an important role in main physiological processes as well as in plant protection against diseases. In Poland, the problem of chlorine shortage does not appear, therefore there are no studies on its present concentration and accumulation in field crops. However, the content of chlorine in plants and their tolerance to its excess in soil are varied. Under conditions of its high availability in the environment, its excessive accumulation is possible because chlorine is easily taken up from soil and directly from air. The aim of this study has been to find out the concentration and accumulation of chlorine in winter oilseed rape organs in dependence on N and Cl supply from the flowering up to the full maturity phase. The experiment was conducted in a greenhouse of IUNG-PIB, in Mitscherlich pots, where winter oilseed rape was cultivated. The first experimental factor was nitrogen fertilization (1.4 and 2.8 g pot^{-1}) and the second was chlorine application (0, 0.47, 0.97 and 1.42 g pot^{-1}). Chlorine concentration in plants was dependent on N dose, which caused its decrease, and on Cl dose, which resulted in its increase. The most abundant in chlorine were leaves while flowers and developing siliques contained the least of this element. Chlorine accumulated mainly in rape leaves. The accumulation of chlorine in oilseed rape increased under higher plant supply in N and Cl. The experimental plants showed a moderate supply in Cl, except the object fertilized with the highest dose of chlorine.

Key words: nitrogen, chlorine doses, yielding, dynamic of chlorine uptake.

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WPŁYW NAWOŻENIA NA ZAWARTOŚĆ I POBIERANIE CHLORU PRZEZ RZEPAK OZIMY W WARUNKACH DOŚWIADCZENIA WAZONOWEGO

Abstrakt

Obecnie chlor zaliczony jest do grupy składników pokarmowych niezbędnych do wzrostu i rozwoju roślin, ponieważ odgrywa ważną rolę w głównych procesach fizjologicznych w roślinach oraz w ich ochronie przed chorobami. W Polsce nie występuje problem niedoboru tego składnika, w związku z czym nie są prowadzone badania nad jego aktualną zawartością i akumulacją w roślinach uprawy polowej. Jednakże zawartość chloru w roślinach, a także ich tolerancja na jego nadmiar w glebie jest zróżnicowana. W warunkach dużej dostępności w środowisku może dojść do jego nadmiernej akumulacji, ponieważ chlor jest łatwo pobierany przez rośliny z gleby i bezpośrednio z powietrza. Celem badań było poznanie zawartości i akumulacji chloru w organach rzepaku ozimego, w zależności od zaopatrzenia w N i Cl, w czasie od kwitnienia do dojrzałości pełnej roślin. Doświadczenie prowadzono w hali wegetacyjnej IUNG-PIB, w wazonach Mitscherlicha, w których uprawiano rzepak ozimy. Pierwszym czynnikiem doświadczenia było nawożenie azotem (1,4 i 2,8 g wazon^{-1}), a drugim – stosowanie chloru (0, 0.47, 0.97 i 1.42 g Cl wazon^{-1}). Zawartość chloru w roślinach rzepaku zależała przede wszystkim od dawki N, która wpływała na jej obniżenie, i dawki Cl, która wpływała na wzrost koncentracji tego składnika. Najbardziej zasobne w chlor były blaszki liściowe, a najmniej – kwiaty i rozwijające się łuszczyny. Głównym miejscem gromadzenia chloru były liście. Akumulacja chloru w rzepaku wzrastała w warunkach większego zaopatrzenia roślin w azot i chlor. Rośliny doświadczalne wykazywały średnie zaopatrzenie w chlor z wyjątkiem obiektu nawożonego najwyższą dawką chloru.

Słowa kluczowe: azot, dawki chloru, plonowanie, dynamika pobierania Cl.

INTRODUCTION

Although information relating to chlorine appeared as early as the mid-19th century (TOTINGHAM 1919 – after FIXEN 1993), this element was not taken into consideration in plant cultivation until the 1970s, when it was demonstrated that it could play an important role in plant production and this finding stimulated further studies on Cl^- effect on the growth and development of some crops (JOHNSON et al. 1957, FIXEN 1993). Nowadays, chlorine as a microelement is considered as one of the 16 nutrients essential for plant growth. The main physiological role of chlorine is its participation in photosynthesis, activation of some enzymes, management of water status in the plant and plant protection against diseases (FIXEN 1993). Under the conditions present in Poland, chlorine deficit in plants practically does not occur, which is why it is not taken into consideration during preparation of field crops fertilization plans. In Polish literature, there are only few reports related to chlorine concentration in field crops. However, chlorine is the aim of studies as a fertilizer component in cultivation of some vegetables (NURZYŃSKI 1974, UZIAK et al. 1982, KOWALCZYK et al. 2008) or fodder plants (MICHAŁEK 1992). Is it also examined as a biomass element of energy plants (BORKOWSKA, LIPIŃSKI 2007).

The aim of this study has been to find out the concentration and accumulation values of chlorine in oilseed rape organs in dependence on plants' supply with N and Cl.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse, in Mitscherlich pots filled with 6.5 kg of soil. Winter oilseed rape var. Liropa was grown, with 5 plants per pot. The first experimental factor was nitrogen dose: 1.4 and 2.8 g N per pot and the second factor was chlorine application (g per pot): 0.47, 0.97 and 1.44, which were compared to an object without chlorine supply (control). Phosphorus, potassium, magnesium and some microelements were applied in the same doses to all the pots, and plants were watered with distilled water. Plants were harvested during the following developmental stages assigned according to BBCH scale: T1 – 61 (flowering), T2 – 71 (beginning of seed development), T3 – 81 (beginning of seed maturity) and T4 – 89 (full maturity). Chlorine concentration was analyzed using an X-Unique II device produced by Philips. Three pots from each fertilizer object were harvested on each term of harvest. The data presented in this paper are mean values for objects and years of the study. The results were statistically calculated with using of Statgraphics Plus 5.1 program.

RESULTS AND DISCUSSION

It is known nowadays that chlorine occurs in plants as free anions or loosely bound with places of exchange and is presents in more than 130 organic compounds (Engvild 1986). Chlorine concentration in cv. Liropa oilseed rape was dependent on nitrogen and chlorine doses, plant organs and, to a smaller degree, developmental phases of plants (Table 1). These observations are in accord with the research completed by Bar-Tsur and Rudich (1987) and Fixen (1993). The richest in Cl were leaves, and the poorest – flowers and developing siliques. The Cl content in stems and leaves was in the middle position. According to Kowalczyk et al. (2008) and Van Steveninck et al. (1988), concentration of chlorine in leaves reflects its availability in soil or nutrient solution. Chlorine content in leaves is closely connected with its concentration in chloroplasts because when chlorine deficiency occurs in nutrient solution, its concentration in chloroplasts decreases. High concentration of chlorine in leaves reflects its important role in photosynthesis and can have a close relationship with plants' resistance against diseases (Fixen 1993), analogously to sulphur (Podleśna et al. 2005). Accord-

Table 1

Concentration and uptake of chlorine in dependence of fertilization and developmental stage of oilseed rape

Factor	Chlorine concentration ($g \cdot kg^{-1}$)					Chlorine uptake ($g\ pot^{-1}$)					
	leaves	stems	flowers/ /siliques*	seeds	roots	leaves	stems	flowers/ /siliques*	seeds	roots	total
Nitrogen fertilization											
N dose ($g\ pot^{-1}$)											
1.4	11.2a	3.5b	0.9a	2.6a	2.8b	0.21a	0.01a	0.02a	0.07a	0.03b	0.34a
2.8	10.3a	2.3a	0.9a	3.2b	1.6a	0.25b	0.01a	0.05b	0.14b	0.02a	0.47b
Plant harvests:											
T1	9.4a	2.7a	0.4a	0.0a	2.7b	0.23a	0.10a	0.01a	0.00a	0.04d	0.38a
T2	11.1b	2.5a	0.5a	0.0a	1.7a	0.24a	0.14b	0.03b	0.00a	0.02a	0.43b
T3	11.4b	2.8a	1.2b	0.0a	1.8a	0.24a	0.13b	0.05c	0.00a	0.02a	0.44b
T4	11.2b	3.6b	1.4b	2.9b	2.7b	0.21a	0.16c	0.05c	0.10b	0.03c	0.55c
Chlorine fertilization											
Cl dose ($g\ pot^{-1}$)											
0	0.5a	0.3a	0.4a	2.7a	0.4a	0.01a	0.01a	0.01a	0.09a	0.01a	0.13a
0.47	7.9b	2.0b	0.4a	2.8a	1.0b	0.17b	0.09b	0.02a	0.10a	0.01a	0.39b
0.95	13.7c	3.5c	1.2b	3.2a	3.1c	0.31c	0.17c	0.05b	0.12b	0.04b	0.69c
1.42	21.1d	6.9d	1.4b	3.2a	3.9d	0.44d	0.26d	0.07b	0.12b	0.05b	0.94d
Plant harvests:											
T1	9.4a	2.8a	0.6a	0.0a	2.5b	0.24a	0.05a	0.01a	0.00a	0.04c	0.34a
T2	11.2b	2.5a	0.5a	0.0a	1.3a	0.24a	0.14b	0.02a	0.00a	0.02a	0.42b
T3	11.4b	3.8b	0.6a	0.0a	1.8a	0.24a	0.13b	0.05b	0.00a	0.02a	0.44b
T4	11.2b	3.7b	1.7b	3.0b	2.8b	0.22a	0.16b	0.06b	0.11b	0.03b	0.58c

*T1 – flowers, T2 and T3 – siliques with seeds, T4 – siliques without seeds

ing to Xu et al. (2000), flowers have less Cl than the other organs. Besides, these authors stated that fruits and seeds, which are predominantly fed by phloem, are characterized by low concentration of Cl ions. The chlorine concentration determined in seeds remained on a level of an average concentration found in stems and was not dependent on this nutrient's dose while wheat straw contained more chlorine than grain. Higher nitrogen fertilization increased chlorine concentration in seeds but decreased it in leaves, stems and roots, which can be explained by dilution effect in the enlarged mass of plants (the data are not presented). Chlorine concentration in oilseed rape increased under conditions of its greater availability, like in spring wheat (Fixen 1993) and cotton (Bar-Tsur, Rudich 1987), which results from the ease at which chlorine ions are taken up by plants and from efficient translocation of chlorine over short and long distances in plants (Marschner 1995). As oilseed rape plants matured, an increase of Cl concentration in some organs was observed, which can be explained by its passive uptake by roots and high mobility (Marschner 1995). However, Schumacher (1988 – after Fixen 1993) found that its content in spring wheat had an increasing tendency 1-2 weeks before heading and then decreased. According to Uziak et al. (1982), chlorine concentration in plants is an important indicator of their supply in this element with respect to their sensitivity to Cl. These authors observed a close relationship between retarded growth as well as inferior yielding and high chlorine concentration in bean plants. According to Johnson et al. (1957), concentration about 0.007-0.01% Cl indicates shortage of this element, while White and Broadley (2001) recognize that deficit symptoms are observed when Cl concentration in tissues is lower than 0.1-5.7 $mg \cdot g^{-1}$ dry mass. Toxicity occurs if chlorine content ranges between 4-7 $mg \cdot g^{-1}$ dry mass in chlorine sensitive plants and 15-50 $mg \cdot g^{-1}$ dry mass in Cl tolerant species. Based on these values and assuming that rape is not sensitive to Cl, it is possible to state that the experimental plants showed a moderate supply in Cl with the exception of oilseed rape, which received the highest dose of chlorine. Arnold (1955 – after Nurzyński 1974) maintains that the degree of plants' sensitivity to chlorine ions is not motivated because for chlorine there is no upper or lower limit of tolerance. However, its excess causes harm due to high salt concentration in general or to the shortage of other nutrients.

The higher dose of nitrogen applied in the experiment caused an increase of chlorine accumulation, mostly in leaves and seeds of oilseed rape (Table 1), an effect that was also found in sugar beet (Morangan 1987). Furthermore, it was observed that the total uptake of this element increased together with a Cl dose and progressing growing season. This was the consequence of elevated chlorine accumulation in leaves and stems. The smallest amounts of Cl were found in flowers, which is in agreement with the observations of White and Broadley (2001).

CONCLUSIONS

1. The biggest concentration and accumulation of chlorine was found in leaves and the smallest - in flowers and young siliques.

2. Higher doses of N and Cl applied in the experiment had varied effects on chlorine concentration in oilseed rape organs: chlorine caused an increase in its concentration in plants while nitrogen had a depressing effect.

3. The highest dose of chlorine caused excessive Cl concentration in oilseed rape plants, in contrast to its lower doses, which positively influenced the mineral composition of plants.

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