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DEVELOPMENT OF CALCIUM DEFICIENCY SYMPTOMS IN CHERVIL (*Anthriscus cerefolium* (L.) Hoffm.) AND CURLED PARSLEY (*Petroselinum crispum* (Mill.) Nym. convar. *crispum*)

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Introduction

In a search for new greenhouse crops at the Agricultural University of Norway in 1994, it was observed that chervil (*Anthriscus cerefolium* (L.) Hoffm.) was susceptible to calcium deficiency [Balvoll, unpublished 1981]. The plants were grown in a circulating nutrient solution with a normal level of calcium. Plants sprayed with calcium chloride did not develop tipburn symptoms. Accordingly, the damage was considered as a physiological disorder. The damage has also been observed in the Norwegian production of chervil in peatmoss in pots, but most likely the disorder has not been described in the literature before, although chervil is commercially grown in greenhouses in Germany [Vogel 1996], and Benoit & Ceustermans [1993] conducted experiments with the plant in recirculating NFT-solution.

In Apiaceae, celery (*Apium graveolens* L.) [Geraldson 1952] and fennel *Foeniculum vulgare* (Mill.) [Broek 1995] are also susceptible to physiological calcium deficiency, while parsley (*Petroselinum crispum* (Mill.) Nym.) is not reported to be damaged by the disorder. Although much grown in greenhouses in Norway under different growing condition, parsley rarely shows tipburn or other damages that can be associated with calcium deficiency.

Because parsley and chervil are quite similar in growth habit, comparison between the two crops with respect to calcium deficiency may add new knowledge about factors affecting the disorder.

The objective of this investigation was to observe the development of calcium deficiency in chervil and compare the development and symptoms of chervil with those in plants of curled parsley given low levels of calcium.

Materials and methods

The investigation was carried out in a conventional greenhouse at the Agricultural University of Norway. All experiments included in three replicates.

In the first experiment chervil seeds were sown in plastic trays filled with limed and fertilized peat on 11 December 1995. The seedlings were supplied with a complete nutrient solution until transplanting. The seedlings were transplanted to 12 cm plastic pots (capacity 0.6 L) filled with limed and fertilized peat on 4 January 1996. The trial design was a split plot. Four harvesting times composed the main treatments. Two spraying treatments were the subplot treatments. Each main plot included 24 plants. Half of the plants were sprayed with a solution containing 1.5 g $CaCl_2 \cdot dm^{-3}$ every morning (control unsprayed). Plants were harvested at 4 different times after sowing: 31, 36, 41 and 46 days.

In the first and second experiment the plants were supplied with a complete nutrient solution, which contained the followed concentrations of nutrients ($mg \cdot dm^{-3}$): N 213, P 45, K 239, Ca 188, Mg 44, Na 17, S 57, Fe 2.2, Mn 1.2, Si 1.6, B 0.4; Zn 0.3, Cu 0.09 and Mo 0.03. The nutrient solution had an electrical conductivity (EC) of 2 $mS \cdot cm^{-1}$.

In the second experiment chervil seeds were sown in plastic seedling trays on 7 January 1998. The seedlings were transplanted to plastic pots on 28 January 1998. The experiment consisted of 72 plants. The number of tipburned leaves was counted every second or third day. The plants were harvested on 18 February 1998.

In the third experiment parsley seeds were sown in rock wool cubes (4x4x4 cm) on 13 January 1997. The seedlings were supplied with a complete nutrient solution and watered sufficiently until transplanting. The seedlings were planted in NFT channels on 13 February 1997. Different nutrient solutions composed the main plots, which contained 144 plants.

The nutrient solutions were prepared in distilled water. The basic nutrient solution (0 mg $Ca \cdot dm^{-3}$) contained the followed nutrients ($mg \cdot dm^{-3}$): N 215, P 45, K 233, Mg 37, Na 183, S 50, Fe 1.8, Mn 1.0, Zn 0.2, B 0.4, Cu 0.09 and Mo 0.03. To obtain concentrations of calcium of 0, 10, 20 and 30 $mg \cdot dm^{-3}$ and to keep the concentration of N constant some of the $NaNO_3$ was replaced by an equivalent amount of $Ca(NO_3)_2$. The concentration of Ca and Na ($mg \cdot dm^{-3}$) in the solutions were:

A. 0 Ca, 183 Na;
B. 10 Ca, 172 Na;
C. 20 Ca, 161 Na;
D. 30 Ca, 150 Na.

The ion concentration and salinity (2 $mS \cdot cm^{-1}$) level were the same in all solutions. There were three spraying treatments: with water (control), every morning with $CaCl_2$ solution 1.5 $g \cdot dm^{-3}$ or every morning and afternoon with $CaCl_2$ solution 1.5 $g \cdot dm^{-3}$. The plants were harvested on 2 April 1997.

In the fourth experiment parsley seeds were sown in rock wool cubes on 7 January 1998. The seedlings got different nutrient solutions, which contained different amount of calcium: 0, 20, 40 and 80 $mg \cdot dm^{-3}$. The basic nutrient solution contained the same amount of nutrients ($mg \cdot dm^{-3}$) as described for the previous experiment. In the other nutrient solutions $NaNO_3$ was replaced by $Ca(NO_3)_2$ in equivalent amounts to give the following concentrations ($mg \cdot dm^{-3}$):

A. 0 Ca, 183 Na;
B. 20 Ca, 161 Na;
C. 40 Ca, 139 Na;
D. 80 Ca, 117 Na.

The ion concentration and salinity (2 $mS \cdot cm^{-1}$) level were the same in all solutions. Each treatment consisted of 30 plants.

The number of injured leaves was counted every third or fourth day. The plants from the treatment without calcium (A) died and were harvested on 23

February 1998, while the plants in the other treatments were harvested on 12 March 1998.

In all experiments the plants were grown with minimum day and night temperatures of 20°C and 15°C, respectively. Supplementary light of about 12000 lux from Philips SON/T lamps was given in the day period (04.00–20.00).

In all experiments the plants were weighed and the number of fresh leaves, the number of leaves with injured tissue and the number of wilted leaves were counted at harvest. After harvest, plant parts were observed with a microscope and photographs made. Analyses of variance were carried out on the data obtained using Minitab for Windows.

Results

Calcium deficiency symptoms on chervil

In the experiments with chervil the disorder appeared on plants in the control only. The first symptoms of physiological calcium deficiency appeared on younger leaves. The margins of leaves or whole leaves became first slightly brown and the disorder progressed to blackened necrosis, which is the result of tissue collapse (Figure 1). In severe cases there was a complete death of leaf and necrosis moving down the petiole (Figure 2 and 3). Sometimes this injury was expressed when youngest leaves failed to grow, followed by death of the meristem. If the growing point was killed, the plant could not produce more new leaves from the top of the plant, and growth was stunted.

Fig. 1. Microscope photo (x 10) of chervil leaf with tipburn symptoms. The margins of leaves or whole leaves became first slightly brown. The damage progressed to blackened necrosis

Rys. 1. Zdjęcie mikroskopowe (x 10) liścia trybuli z objawami zgorzeli. Brzegi liści lub całe liście początkowo stawały się lekko brązowe. Uszkodzenie liści postępowało aż do wystąpienia czarnych plam nekrotycznych

Fig. 2. Microscope photo (x 10) of chervil leaf with tipburn symptoms. The death of leaf

Rys. 2. Zdjęcie mikroskopowe (x 10) liścia trybuli z objawami zgorzeli. Martwy liść

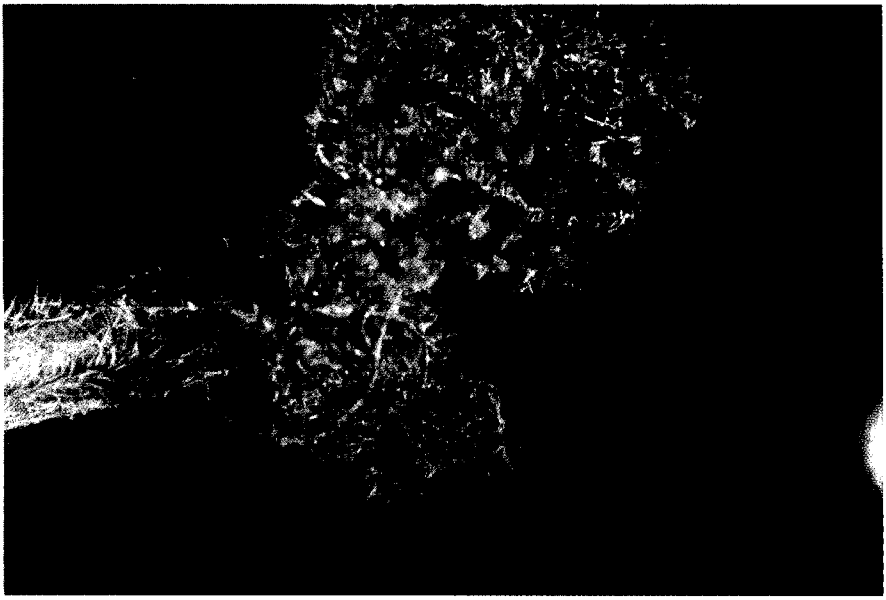

Fig. 3. Microscope photo (x 10) of chervil leaf with tipburn symptoms. The death of leaf and necrosis moving down petiole

Rys. 3. Zdjęcie mikroskopowe (x 10) liścia trybuli z objawami zgorzeli. Zamieranie liścia i nekroza postępująca w dół do szypułki liściowej

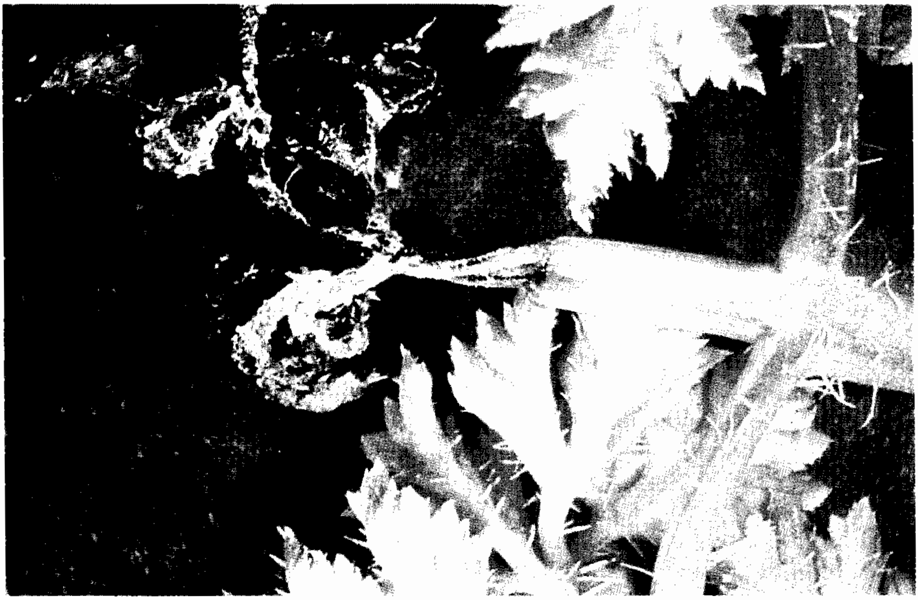

Fig. 4. Microscope photo (x 10) of chervil leaf with tipburn symptoms. Blackening and dieback of leaflets

Rys. 4. Zdjęcia mikroskopowe (x 10) liścia trybuli z objawami zgorzeli. Zaczernienie i zamieranie listków

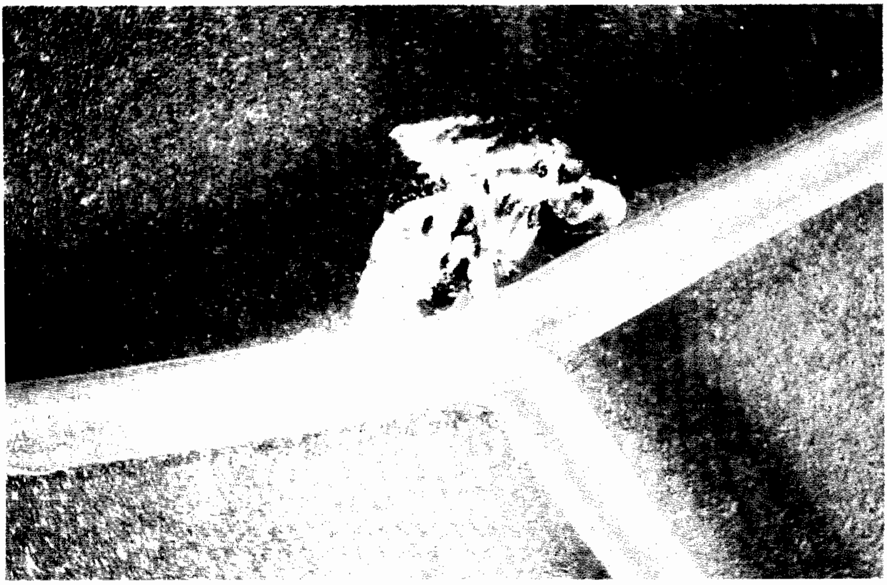

Fig. 5. Microscope photo (x 10) of chervil leaf with tipburn symptoms. Blackening and dieback of leaflets

Rys. 5. Zdjęcie mikroskopowe (x 10) liścia trybuli z objawami zgorzeli. Zaczernienie i zamieranie listków

On petioles of older leaves, watersoaked areas sometimes appeared leading to collapse, while the distal part remained green followed by drying out. Sometimes the deficiency symptoms were seen as blackening and dieback of leaflets (Figure 4 and 5), yellowing of leaf margins and interveinal areas. Old leaves had a «rusty» appearance, which means brown specks on the leaves.

Deficiency symptoms were most pronounced on young tissues (young leaves) where cell division is occuring. Parts of young leaves, or whole young leaves, were blackened and necrotic. Young leaves were almost always injured. Old leaves were dark green and some of them had also deficiency symptoms.

Development of calcium deficiency symptoms on chervil

Chervil develops quite quickly. About 33 days after sowing the number of leaves increased at the rate of about 0,4 leaf per 24 hours (Figure 6). The leaves developed quickest (ca. 0.8 leaf per 24 hours) 38–39 days after sowing. In the experiment the development of new leaves slowed down from about 40 days after sowing. The first leaves with injury symptoms were seen 31 days after sowing (Figure 6). About 33 days after sowing the number of injured leaves increased at the rate of about 0.26 leaf per 24 hours. The damaged leaves developed quickest (0.4 leaf per 24 hours) 38–39 days after sowing. The number of injured leaves increased during the development of plants (Figure 6).

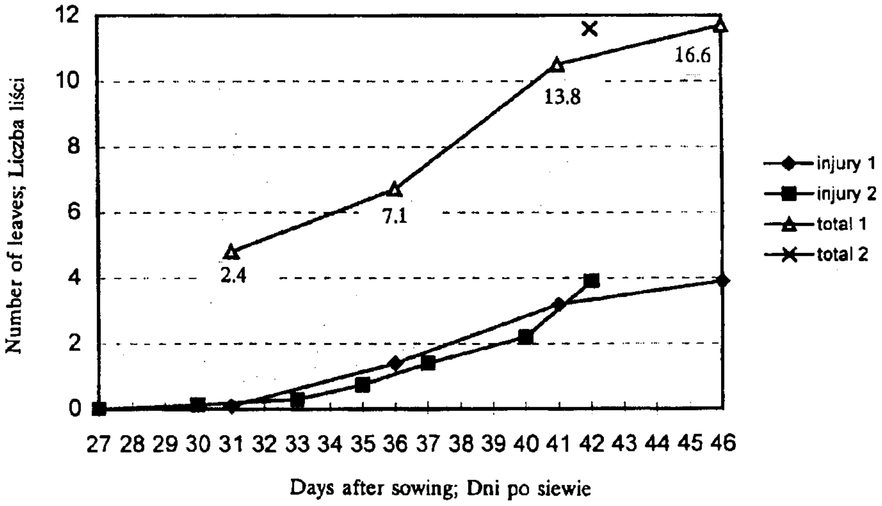

Fig. 6. The development of chervil and the symptoms of tipburn injury on plants according to the time (injury – the number of injured leaves; total – the number of total leaves; 1=Experiment 1; 2=Experiment 2. The 4 numbers on the figure are the mean weights (g) of chervil plants at harvest)

Rys. 6. Rozwój trybuli i objawy uszkodzeń zgorzelowych na roślinach z upływem czasu (uszkodzenie – liczba uszkodzonych liści; całkowite – całkowita liczba liści; 1= pierwsze doświadczenie; 2=drugie doświadczenie. Liczby oznaczone 4 – średnia masa (g) roślin trybuli przy zbiorze

At harvesting 50–60% of the three youngest leaves were damaged, while the fourth and fifth leaf showed the disorder on almost every plant (Figure 7). The four oldest leaves were almost free of injury.

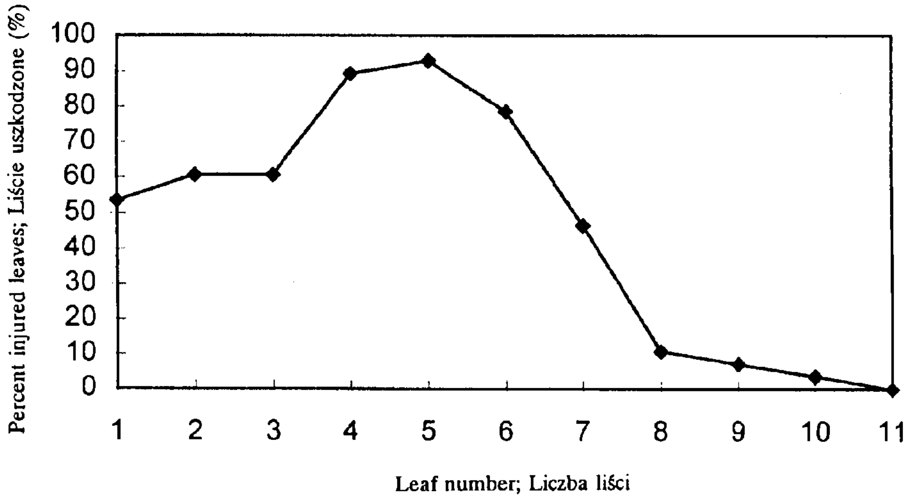

Fig. 7. The frequency of tipburned leaves according to the leaf placement. The youngest leaf more than 5 mm long is number 1. Means for 30 plants (Experiment 2)

Rys. 7. Częstotliwość występowania liścia z objawami zgorzeli według rozmieszczenia. Najmłodszy liść o długości 5 mm oznaczony 1. Średnia z 30 roślin (Doświadczenie 2)

Calcium deficiency symptoms on parsley

Calcium deficiency injury on parsley appeared only with use of no or very low concentration of calcium in the nutrient solution. In the third and fourth experiment the first symptoms on leaves were seen at the beginning as bleaching of leaves and chlorotic spots. Those spots progressed to larger chlorotic areas (Figure 8 and 9).

The margins of one or more leaves lost turgor, turned dry and became thin and papery. The leaf margin became chlorotic. A narrow chlorotic border of the leaf moved in stepwise toward the attachment point with the petiole and in extreme cases covered the entire leaf blade (Figure 10 and 11). Besides chlorotic leaf margins reddening near margins also appeared (Figure 12). Calcium deficiency resulted in slow growth.

In severe cases death of young leaves was seen (Figure 11). Later the youngest leaves sometimes failed to grow, which was followed by death of growing point (Figure 11).

Immature leaves often failed to unfold and then were deformed and chlorotic (Figure 10). On petioles of immature leaves watersoaked areas sometimes appeared and led to collapse, while distal part remained green and it was followed by drying out. Leaflets of older leaves rarely had chlorotic areas.

In experiment 3 complete nutrient solutions were used for seedlings, but in experiment 4 different nutrient solutions were used from sowing. The main difference in the symptoms of calcium deficiency between those experiments was in the growth of the plants, which was larger in experiment 3.

Fig. 8. Photo of parsley leaves with calcium deficiency symptoms. Chlorotic spots on the leaves (Experiment 3)

Rys. 8. Zdjęcie liści pietruszki z objawami niedoboru wapnia. Chlorotyczne plamy na liściach (Doświadczenie 3)

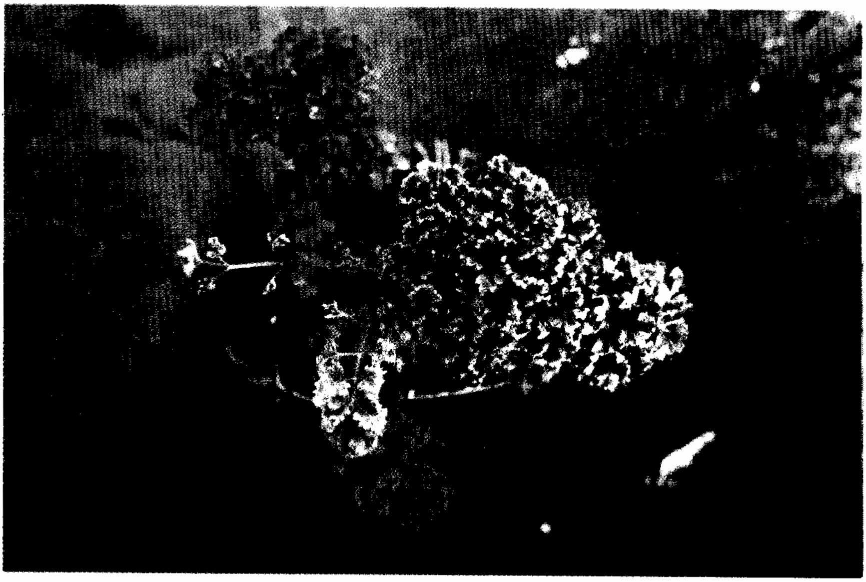

Fig. 9. Photo of parsley leaves with calcium deficiency symptoms. Chlorotic spots on the leaves (Experiment 4)

Rys. 9. Zdjęcie liści pietruszki z objawami niedoboru wapnia. Plamy chlorotyczne na liściach (Doświadczenie 4)

Fig. 10. Photo of parsley leaves with calcium deficiency symptoms. Chlorotic leaves and chlorotic areas on the leaves (Experiment 3)

Rys. 10. Zdjęcie liści pietruszki z objawami niedoboru wapnia. Chlorotyczne liście i powierzchnie chlorotyczne na liściach

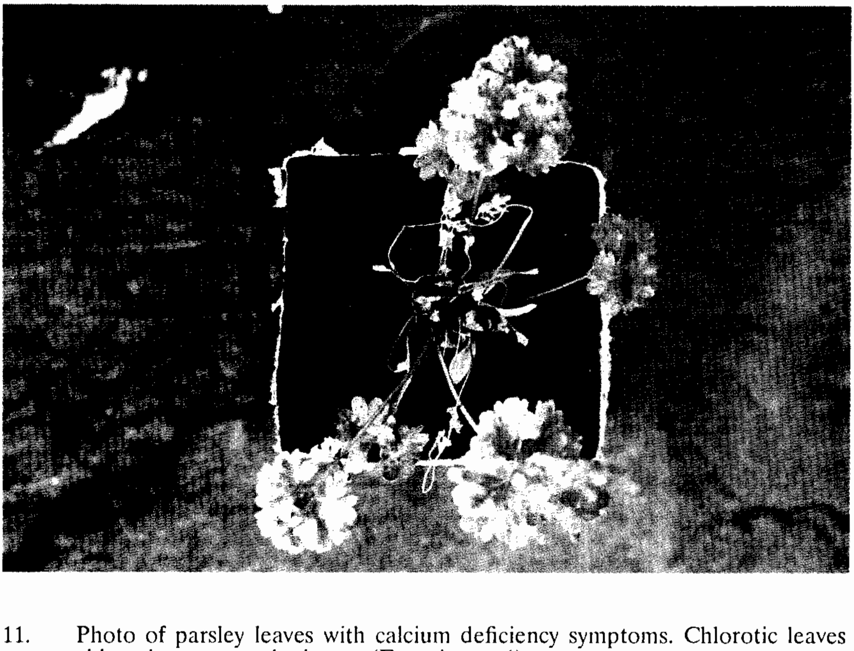

Fig. 11. Photo of parsley leaves with calcium deficiency symptoms. Chlorotic leaves and chlorotic areas on the leaves (Experiment 4)

Rys. 11. Zdjęcie liści pietruszki z objawami niedoboru wapnia. Chlorotyczne liście i powierzchnie chlorotyczne na liściach

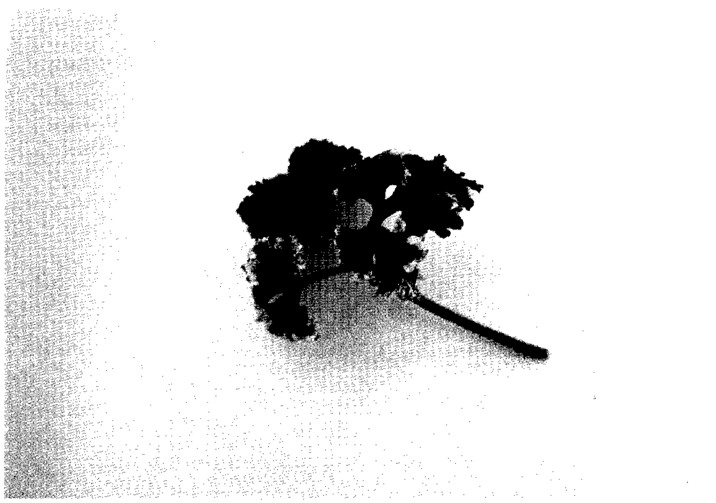

Fig. 12. Photo of parsley leaf with calcium deficiency symptoms. Reddening near margins

Rys. 12. Zdjęcie liści pietruszki z objawami niedoboru wapnia. Zaczernienie przy brzegach liści

The development of calcium deficiency symptoms on parsley

Without calcium in the nutrient solution the first symptoms of calcium deficiency on parsley plants appeared 30 days after sowing (Figure 13).

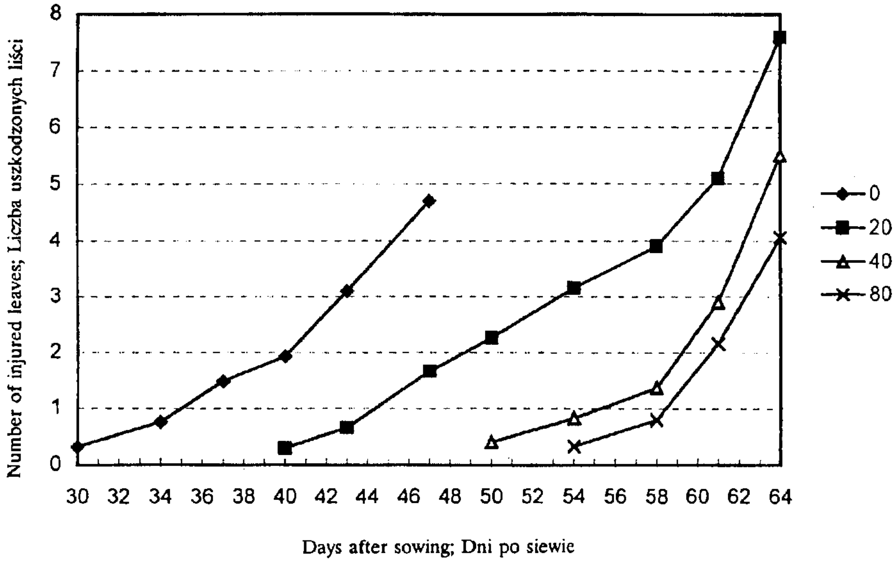

Fig. 13. The development of calcium deficiency injury on parsley plants over time. The numbers 0, 20, 40, 80 are the concentrations of Ca in mg·dm^{-3} in the nutrient solution (Experiment 4)

Rys. 13. Rozwój uszkodzeń spowodowanych niedoborem wapnia z upływem czasu. Liczby 0, 20, 40, 80 oznaczają stężenia wapnia w mg·dm^{-3} w roztworze ze składnikami pokarmowymi (Doświadczenie 4)

The injury symptoms developed quickly until plants were almost dead at harvesting (45 days after sowing). At that time 88% of leaves were affected and growing points of all plants were killed.

The parsley plants which were placed in a nutrient solution without calcium quickly developed the injury symptoms and were seriously injured 47 days after sowing. The mean weight (at harvest 47 days after sowing) was on average 0.27 g, the number of fresh leaves 0.67 per plant and the number of injured leaves 4.70 per plant. Almost all leaves had calcium deficiency symptoms.

Parsley fresh weight increased by increasing Ca level in nutrient solution (Table 1). The number of fresh leaves of parsley increased with increase in Ca concentration from 20 to 80 mg·dm^{-3}. The incidence of injury decreased by increasing Ca concentration in the nutrient solution.

Table 1; Tabela 1

The weight, total number of leaves, the number of fresh and injured leaves per plant of parsley according to the treatments (Experiment 4); plants were harvested 64 days after sowing

Masa, całkowita liczba liści, liczba liści świeżych i uszkodzonych na roślinie według poszczególnych testów (Doświadcazenie 4); zbioru roślin dokonano 64 dni po wysianiu

Ca (mg·dm^{-3}) in nutrient solution Ca (mg·dm^{-3}) w roztworze ze składnikami pokarmowymi	Weight Masa (g)	Number of leaves; Liczba liści		
		total całkowita	fresh liści świeżych	injured liści uszkodzonych
20	3.7	9.0	1.1	7.6
40	9.4	8.1	2.0	5.6
80	18.9	8.5	4.0	4.1
Statistical differences Różnice statystyczne	$p<0.001$	$p=0.096$	$p<0.001$	$p<0.001$

Discussion

Because the deficiency also appears when there is enough calcium in nutrient solution, tipburn on chervil is a physiological disorder. If the leaves were sprayed with $CaCl_2$ solution, symptoms of calcium deficiency were not observed.

Chervil developed injury symptoms quickly, but parsley developed those symptoms only when concentration of Ca was very low in nutrient solution.

Heading crops, such as cabbage, Chinese cabbage and lettuce, are in general more susceptible to physiological calcium deficiency than crops with an open growing point. Tipburn in those crops is induced by low transpiration rate of the inner leaves. Of the Apiaceae crops, celery has many erect leaves and leafstalks around the inner leaves. This covering reduces the transpiration of the leaves close to the growing point, while carrot and parsley have leaves in a rosette. This difference might explain why celery is susceptible to calcium deficiency, and why carrot and parsley are not affected by the disorder. But this theory can not explain the difference in susceptibility between parsley and chervil. It is even more surprising that chervil can show tipburn already on leaf number 4–5 after the cotyledon. In comparison, celery normally shows symptoms of physiological calcium deficiency only after having initiated about 20 leaves.

Conditions giving rapid growth normally promotes tipburn [Cox et al., 1976]. Accordingly, a fast growing crop might be more susceptible than a slow growing crop. Chervil develops leaves and grows faster than parsley and carrot. About 30 days after sowing the number of leaves of chervil in experiment 1 increased by 0.5 per day (Figure 6), while parsley normally develops 0.20–0.25 leaves per day [Balvoll 1981]. In an experiment in hydroculture, Benjamin & Wren [1978] found that carrot plants had 4 leaves 30 days after germination, while chervil in experiment 1 had about 6 leaves 30 days after germination.

The results in experiment 1 and 2 confirm that under greenhouse conditions chervil is extremely susceptible to physiological calcium deficiency. The experiments were carried out in the middle of the winter with short days and low natural light intensity and with supplementary light. This condition might promote tipburn, but even in experiments in the summer time chervil was susceptible to calcium deficiency [Kleemann 1999]. In all experiments the temperature in the night was rather high, and it might be that a small difference in transpiration between day and night can be responsible for the high susceptibility. But such conditions can also occur in the field, and it is therefore surprising that tipburn is not reported to be a problem in field-grown chervil.

The first deficiency symptoms were quite different on the two species. On chervil the leaves became slightly brown and the disorder progressed to blackened necrosis. Anonymous [1933] and Geraldson [1954] found similar Ca deficiency symptoms on leaves of celery. In parsley the first symptoms were chlorotic spots on leaves, and those spots progressed to larger chlorotic areas. Both injuries forms ended up with tissue collapse. In serious cases it was followed by death of the growing point.

Scaife & Turner [1983] described that celery grown in a medium with very low supply of calcium, showed symptoms of calcium deficiency very early in development. Leaflet tissue collapsed and the apical point died. Similar calcium deficiency symptoms were also found in the present investigation on young plants of parsley, when the disorder was induced by very low Ca levels in nutrient solution.

On chervil the physiological disorder sometimes appeared as watersoaked areas on petioles, leading to collapse, while the distal part was still green. The same symptoms also appeared on immature leaves of parsley, when the plants were grown in a nutrient solution with very low level of calcium. Similar symptoms were also described by Scaife & Turner [1983] on carrot grown with a very low supply of calcium.

Conclusions

1. Chervil and parsley plants shoved different reaction to calcium deficiency. Chervil plants supplied with a complete nutrient solution developed physiological calcium deficiency quickly under normal greenhouse conditions, while parsley shoved symptoms only under very low concentration of calcium in nutrient solution.

2. Characteristic symptoms of calcium deficiency on chervil were visible on young leaves while symptoms on parsley were located on older leaves.
3. Results shoved that chervil grew faster and developed the disorder symptoms faster than parsley.

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Key words: chervil, tipburn, parsley, calcium deficiency, development, physiological disorder, calcium, nutrient solution

Abstract

Experiments were carried out to observe the development and to describe the symptoms of injured tissue on leaves caused by calcium deficiency on chervil and parsley. Chervil plants supplied with a complete nutrient solution developed physiological calcium deficiency under normal greenhouse conditions, while parsley showed symptoms only when grown at a very low level of calcium. A full description of tipburn of chervil and calcium deficiency in parsley is given. On chervil characteristic symptoms were visible on young leaves. The leaf tip became

burned, and in advanced stages the entire leaf died, leaving only the petiole. Typical symptoms of calcium deficiency on parsley were randomly located chlorotic spots on older leaves, deformation of the affected leaves as well as general chlorosis, and killing of growing points. Injured plants attempted to form more lateral leaves to compensate for the loss of terminal leaves, but these leaves often died as well, leaving the plant with a bushy appearance. Results showed that chervil grew faster and developed the disorder symptoms faster than parsley.

ROZWÓJ OBJAWÓW NIEDOBORU WAPNIA U TRYBULI (*Anthriscus cerefolium* (L.) Hoffm.) I PIETRUSZKI KĘDZIERZAWEJ (*Petroselinum crispum* (Mill.) Nym. convar. *crispum*)

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Słowa kluczowe: trybula, pietruszka, niedobór wapnia, zaburzenia fizjologiczne, wapń, roztwór składników pokarmowych

Streszczenie

Wykonano badania mające na celu zaobserwowanie rozwoju i opisanie objawów uszkodzenia tkanek liści trybuli i pietruszki wskutek niedoboru wapnia. Rośliny trybuli dokarmiane roztworem z kompletną dawką składników pokarmowych wykazywały fizjologiczne symptomy niedoboru wapnia w normalnych warunkach szklarniowych, podczas gdy objawy niedoboru wapnia u pietruszki obserwowano jedynie w warunkach bardzo niskiego poziomu wapnia.

W pracy podano szczegółową charakterystykę zgorzeli u trybuli oraz objawów niedoboru wapnia u pietruszki. U trybuli charakterystyczne symptomy niedoboru wapnia były widoczne na młodych liściach. Najpierw zgorzel obejmowała wierzchołek liścia, a w kolejnych etapach rozwoju rośliny zamierał cały liść. Do typowych objawów niedoboru wapnia u pietruszki należały losowo rozmieszczone na starszych liściach chlorotyczne plamy, deformacja porażonych liści jak również ogólna chloroza i zamieranie stożków wzrostu. Porażone rośliny tworzyły więcej liści bocznych aby zrekompensować stratę liści głównych, które również często zamierały. Rośliny tworzyły charakterystyczny krzaczasty pokrój.

Wyniki niniejszej pracy dowodzą, że u trybuli objawy niedoboru wapnia rozwijają się szybciej niż u pietruszki.

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