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Nutritional deficiency in crisphead lettuce grown in hydroponics

Lauro L Petrazzini; Guilherme A Souza; Cléber L Rodas; Eduardo B Emrich; Janice G Carvalho*; Rovilson J Souza

UFLA, Depto. Ciências do Solo, C. Postal 3037, 37200-000 Lavras-MG; lauropetrazzini@hotmail.com; amaralufla@gmail.com; cleberrodas@yahoo.com.br; janicegc@ufla.br; rovilson@ufla.br; *in memorian

ABSTRACT

The identification of nutrient deficiency symptoms in lettuce helps both producers and technical staff to keep the plant nutritional balance in their producing areas. The objective of this study was to evaluate production and describe and record the visual symptoms caused by the isolated or combined shortage of K, Ca, B and Zn in crisphead lettuce grown in hydroponics. The experimental design was completely randomized blocks with four replications and eight treatments, representing the single (K, Ca, B, Zn) and combined (Ca and B, K and Zn, B and Zn) omission of nutrients, with a control treatment containing a complete nutrient solution. We used the crisphead lettuce cultivar Rider Plus. Under Ca shortage, plant growth was reduced and chlorosis appeared in the borders of young leaves. K shortage was the most detrimental to production of shoot fresh and dry matter and root dry matter. Where B was absent, plant growth was limited, the apical dominance was lost and leaves became wrinkled. Plants without Zn showed mild chlorosis in the blade of young leaves, elongation and bending of petioles and reduction in root density. The combined omission of Ca and B slowed down plant growth and induced necrosis at the borders of young leaves, while the combined omission of K and Zn initially induced K deficiency symptoms with reduced growth. When B and Zn were simultaneously subtracted, plants first showed B deficiency symptoms: reduction in plant size as compared to the control treatment and death of the apical bud.

Keywords: *Lactuca sativa*, mineral nutrition, visual diagnosis.

RESUMO

Deficiências de nutrientes em alface americana cultivada em hidroponia

A identificação dos sintomas de deficiência de nutrientes na cultura da alface americana pode auxiliar produtores e técnicos a manter o equilíbrio nutricional das plantas em suas áreas de cultivo. O objetivo deste trabalho foi avaliar a produção de massa e descrever e registrar os sintomas visuais causados pela deficiência isolada ou combinada de K, Ca, B e Zn em alface americana cultivada em hidroponia. O delineamento experimental foi inteiramente casualizado com quatro repetições e oito tratamentos, compostos pelas omissões simples (K, Ca, B, Zn) e combinadas (Ca e B; K e Zn; B e Zn) de nutrientes e um tratamento controle, contendo todos os nutrientes. Foi utilizada a alface americana Rider Plus. Sob omissão de Ca, as plantas apresentam menor crescimento com clorose nas margens das folhas mais jovens. O K foi o nutriente que mais restringiu a produção de matéria fresca, matéria seca de parte aérea e matéria seca de raiz. Sem B, houve menor crescimento, perda da dominância apical e enrugamento das folhas. As plantas sem Zn apresentaram leve clorose no limbo das folhas novas, pecíolos alongados e curvos e menor densidade de raízes. A omissão conjunta de Ca e B proporcionou crescimento lento e necrose nas margens das folhas mais jovens. A omissão conjunta de K e Na induziu inicialmente sintomas de carência de K com redução do crescimento. A omissão conjunta de B e Zn induziu primeiramente sintomas de deficiência de B: as plantas tiveram seu porte reduzido quando comparadas ao tratamento completo e morte de gema apical.

Palavras-chave: *Lactuca sativa*, nutrição mineral, diagnose visual.

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Lettuce (*Lactuca sativa*) is part of the diet worldwide (Yuri *et al*., 2004). In Brazil, it is the most popular vegetable. Lettuce gained the preference of farmers due to its adaptability to various climatic conditions and low susceptibility to pests and diseases, in addition to enabling successive crops and having guaranteed market, which secures economic returns (Rezende *et al*., 2005). Lettuce is grown in open fields, greenhouses or hydroponics. The state of São Paulo alone commercialized 29,297 tons between January and July 2010 in CEAGESP, its largest wholesale market (Agrianual, 2011).

Among the several lettuce groups used in Brazil, the crisphead type has an escalating importance. It started to be grown in the country in the 1970s and since then its cultivation has been increasing along with the expansion of chains of snack bars, cafeterias and fast-foods, as well as with the intensification in demand, especially in summer, when the preference for salads steps up year after year. Currently, the crisphead type is estimated to represent 20% of the national lettuce market (Sala & Costa, 2008).

The cost of fertilizers contributes significantly to reduce crop profitability in Brazil (Caires *et al*., 2012). In lettuce producing areas, calcium, potassium, boron and zinc are the elements most frequently related to nutritional imbalance.

The objectives of this work were to evaluate the effects of shortage of K, Ca, Zn and B alone, and of the combined shortage of B and Ca, K and Zn, and B and Zn in yield, as well as observe and describe deficiency symptoms in lettuce grown in hydroponics.

MATERIAL AND METHODS

The experiment was carried out at the Department of Soil Sciences of the Federal University of Lavras, in Lavras, state of Minas Gerais, Brazil (21°14'S, 45°00'W, 910 m of altitude). We used the lettuce cultivar Plus Rider (Seminis), recommended for winter cropping, which produces heavy compact heads, is tolerant to tip-burn (calcium deficiency) and mildew (races 1, 2A, 2B, 3 and 4), has a growth cycle of 80 to 90 days and can be commercialized either *in natura* or processed.

We used the completely randomized design with four replications and eight treatments, as follows: (a) complete solution (Hoagland & Arnon, 1950); (b) complete solution minus calcium; (c) complete solution minus potassium; (d) a complete solution minus boron; (e) complete solution minus zinc; (f) complete solution minus calcium and boron; (g) complete solution minus potassium and zinc and; (h) complete solution minus boron and zinc.

Seeds germinated in commercial substrate (Plantmax®), in 288-cell trays. Thirty days after germination, we transferred the seedlings to two 17-L trays with Hoagland and Arnon solution at 20 and 50% ionic strength, for 15 days at each concentration. After the adaptation period, we applied the treatments (nutrient omission) for 60 days, up to the harvest, renewing the nutrient solutions every other week during the experimental period. Single and multiple deficiency symptoms were recorded.

At harvest, i.e. after 60 days under nutrient shortage, we separated plants in roots and shoots. We counted total and commercial number of leaves and assessed shoot fresh and dry mass and root volume and dry mass. For obtaining dry mass, we independently rinsed leaves and roots in distilled water and dried them in an oven with forced air circulation, at 60-70°C.

We submitted data to analysis of variance and compared means by the Skott & Knott test, 5% probability, using the software Sisvar (Ferreira, 2000).

RESULTS AND DISCUSSION

Both the isolate and the combined shortage of nutrients caused morphological changes in the lettuce plants. These changes were expressed as visual symptoms (Figure 1) and also as variations in number of leaves, shoot fresh and dry mass, and root dry mass (Table 1).

The omission of calcium reduced plant growth as compared to the control treatment and induced chlorosis in the borders of young leaves. As Ca deficiency progressed, chlorosis turned into necrotic spots also at leaf borders. This symptom, known as tip-burn, is a typical physiological disorder caused by inadequate supply of Ca (Beninni, 2003). Ca deficiency also inhibited the development of lettuce heads. At the end of the experiment, leaf edges were completely necrotic (Figure 1A). These findings corroborate the results obtained by Pacheco Silva *et al*. (2011) who, also working with lettuce, observed tip-burn and a rosette appearance, with young leaves becoming yellow and eventually burnt. In the root system, the omission of Ca caused necrosis of root tips, giving plants and roots a darker color. This agrees with Epstein & Bloom (2004), who mentioned that the symptoms of Ca deficiency appear in young leaves and meristematic regions. As the nutrient is not redistributed within deficient plants, growing points either become damaged or die. Consequently, root growth is severely affected, as demonstrated by the significant reduction of root dry mass observed in this treatment (Table 1).

The omission of K slowed down the growth pace in relation to the check treatment, as observed also with Ca. Old leaves showed mild chlorosis, more concentrated in the blade center, near the central veins (Figure 1B), which initially showed browning. As the deficiency became more severe, necrotic spots also appeared on the leaf blade. Leaf petioles showed necrosis along the edges. These symptoms are consistent with the findings of Mengel & Kirkby (1987) that K deficiency does not present prompt visible symptoms, causing first reduction in plant growth to then induce chlorosis and necrosis. The omission of K affected the development of the root system to a lesser extent, although causing severe color change

Table 1. Number of leaves (NL), shoot fresh (SFM) and dry (SDM) matter and root dry matter (RDM) of crisphead lettuce under single and multiple nutrient shortage [número de folhas (NL), produção de massa fresca (SFM) e seca (SDM) da parte aérea e massa seca de raiz (RDM) de plantas de alface americana submetidas a omissões simples e múltiplas de nutrientes]. Lavras, UFLA, 2009.

Treatment	NL	SFM (g)	SDM (g)	RDM (g)
Control (complete)	24.75 a	255.00 a	15.43 a	2.04 a
-K	8.75 d	41.75 c	0.41 e	0.74 c
-Ca	12.00 b	44.75 c	1.89 d	1.19 c
-B	7.75 d	55.00 c	4.25 c	1.33 c
-Zn	15.75 b	155.75 b	6.37 b	1.61 b
-Ca and B	8.00 d	35.75 c	0.38 e	0.74 c
-K and Zn	8.50 d	43.50 c	0.63 e	0.82 c
-B and Zn	10.00 d	49.75 c	3.76 c	1.29 c
General mean	11.94	85.16	4.22	1.19
CV (%)	11.89	13.27	20.79	17.20

Means followed by the same letter in the column do not differ significantly from each other, Scott & Knott test, $p>0.05$ (médias seguidas de mesma letra na coluna não diferem entre si pelo teste Scott & Knott, 5%).

Figure 1. Crisphead letucce plants submitted to the shortage of: (a) calcium; (b) potassium; (c) boron; (d) zinc in the left and with no nutriente omission (complete treatment) in the right; (e) calcium and boron; (f) potassium and zinc and; (g) boron and zinc [plantas de alface americana submetidas à omissão de nutrientes: (a) cálcio; (b) potássio; (c) boro; (d) zinco à esquerda e tratamento completo a direita; (e) cálcio e boro; (f) potássio e zinco e; (g) boro e zinco]. Lavras, UFLA, 2009.

and necrosis in roots.

As observed for other nutrients, B deficiency reduced plant growth. Nevertheless, initial symptoms were thickening and wrinkling of young leaves. As the deficiency went on, this wrinkling became more severe and leaf edges bent down. Boron deficiency led to the death of the apical bud (Figure 1C) and thus to loss of dominance, preventing the normal development and closing of the plant head. Furlani *et al*. (2001) described that this sort of malformation, as well as eventual necrosis, may result from the action of radicals that accumulate under boron shortage conditions. These radicals damage the membranes, which have a lipid nature. According to Mengel & Kirkby (1987), B deficiency is expressed primarily by abnormal or delayed development of growth points. Considering B relative immobility in plant tissues, it becomes easy to picture why B deficiency is characterized by growth disturbance in meristematic tissues. Under B omission, the first indications of shortage are difficulties in cell division and differentiation, and it occurs due to the key role B plays in the synthesis of nitrogenous bases (Malavolta, 2006). B shortage reduced root density, although roots became thicker. Root tips browning and necrosis were also observed. Marschner (1995) had already reported that B deficiency prevented root elongation, making roots thicker and shorter.

Zn deficiency also slowed plant growth in comparison to control plants (Figure 1D), in addition to induce chlorosis in the blade of young leaves, which also showed deeper veins. Petioles were more elongated and curved than usual and the root system was visibly less dense when compared to the complete treatment.

Plants under simultaneous shortage of Ca and B (Figure 1D) also showed slower growth in relation to the control, along with several morphological abnormalities in leaves. At first, the youngest leaves showed chlorosis in the borders (typical of Ca deficiency), which evolved to necrosis with the progress of the shortage. B deficiency led to the early death of apical buds and leaf thickening. Root tips also showed necrosis and hence interruption of root growth. Following, roots became thicker and several lateral roots appeared, which were equally thick. Nevertheless, the volume of the root systems under stress was smaller than to those of control plants.

Where K and Zn were omitted simultaneously we needed to harvest the plants 15 days after starting the treatment to prevent them from dying, as it happened also when K was omitted alone. In the combined omission of K and Zn, K deficiency symptoms (Figure 1F) appeared first: old leaves showed mild chlorosis, concentrated in the blade center, next to and along the central veins. As the deficiency progressed, leaf veins assumed an oily aspect that evolved to necrosis. As observed aboveground, root growth was severely affected by K and Zn shortage. Root density decreased and roots changed in color in relation to control plants, eventually showing necrosis.

Plants grown in nutrient solution in the simultaneous absence of B and Zn showed B deficiency symptoms. Plant height was reduced compared to control and the apical bud died (Figure 1G); older leaves got thicker in comparison to younger leaves; younger leaves bent down and initiated chlorosis, and; roots were thicker, though the root system volume was smaller.

The most severe drops in shoot (leaves + stem) dry matter production were observed in the absence of K either alone or in combination, and when Ca and B were simultaneously omitted (Table 1). Compared to control plants, shoot dry mass fell 96% when K and Zn were absent, 97% when only K was suppressed, and 97.53% in the treatment without Ca and B. Ca alone caused a reduction of 87.75% in shoot dry weight, while B deficiency resulted in 72.45% drop. All these values differed significantly from that observed in the minus Zn treatment, 58.71% reduction in shoot dry matter in relation to control plants.

Treatments severely affected root dry matter as well. The combined omissions of (1) Ca and B and (2) B and Zn and the single omission of B caused significant reductions in root dry weight, respectively 40.5, 35.5 and 33.5% compared to the control, and did not significantly differ to each other (Table 1). Ca exclusion also hindered root development, reducing root dry mass by 41% compared to control. Ca effect on roots is due to the formation of polyploid nuclei that hamper cell division resulting in root browning and eventually death (Malavolta *et al*., 1997). B also has a noticeable influence on root development (Marschner, 1995). We observed that B deficiency prevented cell elongation causing roots to become shorter and thicker, with a 49% drop in root dry matter in comparison to the control. Zn omission, although also limiting root dry matter, caused a mild reduction, 19.5% in relation to control plants.

The shortage of any of the studied nutrients induced symptoms which were promptly perceptible in plants and also variations in the characteristics evaluated. Nevertheless, K deficiency resulted in the most drastic symptoms in crisphead lettuce. K deficiency was the most severe regarding both shoot fresh and dry matter, as well as root dry matter when compared to the control treatment.

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REFERENCES

AGRIANUAL 2011: A*nuário da Agricultura Brasileira*. São Paulo: FNP Consultoria e Agroinformativo. 135 p.

BENINNI ERY; TAKAHASHI HW; NEVES CSVJ. 2003. Calcium management in hydroponic lettuce. *Horticultura Brasileira*: 21: 605-610.

CAIRES EF; JORIS HAW; CHURKA S; FILHO RZ. 2012. Performance of maize landrace under no-till as affected by the organic and mineral fertilizers. *Brazilian Archives of Biology and Technology*: 55: 221-230.

EPSTEIN E; BLOOM A. 2004. *Mineral nutrition of plants*. Sunderland: Sinauear Associates. 403p.

FERREIRA DF. 2000. *SisVar: Sistema de análise de variância para dados balanceados. Versão 4.0*. Lavras: DEX/UFLA.

FURLANI AMC; TANAKA RT; TARALLO M; VERDIAL MF; MASCARENHAS HAA. 2001. Exigência a boro em cultivares de soja. *Revista Brasileira de Ciência do Solo* 25: 929-937.

HOAGLAND DR; ARNON DI. 1950. *The water culture method for growing plants without soil.* England: California Agricultural Experiment Station, 31p.

MALAVOLTA E. 2006. *Manual de nutrição mineral de plantas*. São Paulo: Ceres. 638p.

MALAVOLTA E; VITTI GC; OLIVEIRA SA. 1997. *Avaliação do estado nutricional das plantas: princípios e aplicações*. 2. ed. Piracicaba: POTAFOS. 319 p.

MARSCHNER H. 1995. *Mineral nutrition of higher plants*. 2. ed. London: Academic Press. 889p.

MENGEL K; KIRKBY EA. 1987. *Principles of plant nutrition*. 4. ed. Bern: International Potash Institute. 687p.

PACHECO SILVA ML; RODRIGUES MA; BIANCO MS; CECÍLIO FILHO AB; GAION LA. 2011. Caracterização de sintomas visuais de deficiências de macronutrientes em alface. *Horticultura Brasileira (suplementos)*: 29: 3714-3721.

REZENDE BLA; CECÍLIO FILHO AB; MARTINS MIEG; COSTA CC; FELTRIM AL. 2005. Viabilidade econômica das culturas de pimentão, repolho, alface, rabanete e rúcula em cultivo consorciado, na primavera-verão, Jaboticabal, estado de São Paulo. *Informações Econômicas*: 35: 22-37.

SALA FC; COSTA CP. 2008. 'Gloriosa': cultivar de alface americana tropicalizada. *Horticultura Brasileira*: 26: 4009-410.

YURI JE; RESENDE GM; MOTA JH; SOUZA RJ; RODRIGUES JÚNIOR JC. 2004. Comportamento de cultivares e linhagens de alface americana em Santana da Vargem (MG), nas condições de inverno. *Horticultura Brasileira:* 22: 322-325.