Full Length Research Paper

Growth, nutrient accumulation and nutritional efficiency of sunn hemp in function of nutrient omission

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The inadequate supply of nutrients in sunn hemp comprises nutritional requirements and efficiency, causing a decrease in the growth and inducing specific nutritional disorders. For this reason this research sought to evaluate the effect of N, P, K, Ca and Mg restriction on nutrient accumulation, nutritional efficiency, plant growth and characterize the visual symptoms of nutrient deficiency in crotalaria. The experiment was conducted in a greenhouse in pots with constantly aerated nutrient solution. The experimental design was completely randomized with six treatments, corresponding to the complete nutrient solution (all nutrients) and omission of N, P, K, Ca and Mg individually, with three repetitions. The plant species used was sunn hemp juncea. When the particular nutrient deficiency symptom was defined, collection of the corresponding treatment plants was carried out to evaluate the stem diameter, leaf area, dry matter production of the root, shoot and entire plant, accumulation of N, P, K, Ca and Mg in the root, shoot and entire plant, efficiency of absorption and utilization of the nutrients studied and characterization of the visual deficiency symptoms of nutrients during the experimental period. The restriction of N, P, K, Ca and Mg in the cultivation of sunn hemp caused a reduction in plant growth and characteristic visual symptoms of nutritional deficiency of the respective nutrient. Deficiency of N and Mg caused greatest losses in growth of sunn hemp in relation to the other macronutrients due to lower capacity of the plant to use these nutrients in the production of dry matter when grown in the restrictive environment.

Key words: sunn hemp juncea, nutrient restrictions, nutritional disorder, macronutrients.

INTRODUCTION

sunn hemp juncea is highlighted among species of the legume family utilized for green manure, especially due to its high biomass production capacity and supply of N to subsequent crops, contributing to the productivity of crops grown in rotation or succession (Cho et al., 2015). Thus, assessment of the nutritional status becomes necessary in the culture given the importance of biomass production (Lima et al., 2010), where visual analysis is a

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very important diagnostic tool for assessing the nutritional status of plants (Berry, 2015).

Knowledge of the plant nutritional status allows for diagnosis and interpretation of the methods in which plants respond to fertilization (Berry, 2015); this technique is of interest to researchers, technicians and producers from around the world, since it has no cost, is faster than laboratory methods and can be used for field conditions (Berry, 2015; Fontes, 2011).

Therefore, correct use of this technique can avoid the inadequate supply of nutrients which leads to nutritional deficiency in plants with morphological changes that may cause restrictions to plant growth and dry matter production (Souza et al., 2015). An example of this is P deficiency in C. juncea, which induced reductions in the stem diameter and dry matter in relation to treatment with application of P (Dourado et al., 2001).

There is a clear lack of research on the nutrition of crotalaria, where studies are necessary to evaluate crop response in relation to omission of nutrients and losses in nutrient acquisition, dry matter conversion and nutritional disorders considering nutrient accumulation.

Knowledge of the order of nutritional deficiency limitation which depends on a genetic factor is important for proper nutrient management and meeting the culture demands. For a better understanding of this fact it has been hypothesized that nutritional deficiency of N, P, K, Ca and Mg in sunn hemp can differentiate the extent of dry matter loss due to differences in the optimization of nutrient use efficiency by the plant.

In this sense, it was sought to evaluate the effect of N, P, K, Ca and Mg restriction on nutrient accumulation, nutritional efficiency, growth of plants and visual symptoms characteristic of nutrient deficiency in crotalaria.

**MATERIALS AND METHODS**

The experiment was conducted in a greenhouse at the Universidade Estadual Paulista Julio de Mesquita Filho - Jaboatobal Campus, Brazil during the period from August to October of 2013.

The experimental design was completely randomized with six treatments, corresponding to the complete nutrient solution (all nutrients) and individual omission of N, P, K, Ca and Mg, with three repetitions.

After emergence, the plants of C. juncea were transplanted in pots containing 8 dm³ of the nutrient solution of Hoagland and Arnon (1950). The plants were subjected to a one week adaptation period, receiving a nutrient solution diluted to 50% of the usual concentration, and the solution without dilution starting on the second week of cultivation until the end of the experiment.

The pH value of the nutrient solution was monitored daily and adjusted to 5.5 ± 0.5 using 0.1 N NaOH or HCl solutions when necessary. Deionized water was used to replace evaporated water. The nutrient solution was aerated continuously with the aid of an air compressor, and renewed weekly.

During the experimental period, descriptions of the visual symptoms of nutrient deficiency in the plants of each treatment were made daily as of the second week of cultivation with the 100% nutrient solution.

At the moment of appearance of nutrient deficiency symptoms, collection of plants of the corresponding treatment was performed, evaluating the diameter of the stem measured 2 cm from the stem base of each plant; leaf area was measured with the LI-3100 Area Meter® device. Roots and shoots were collected and the material was washed with deionized water and dried in a forced air circulation oven at 65°C until reaching constant weight, obtaining the dry matter production. The material was then ground in a Wiley mill to acquire the concentrations of N, P, K, Ca and Mg in the root, shoot and entire plant, according to the methodology described by Bataglia et al. (1983). Accumulation of these nutrients was calculated using data of dry matter production of the root, shoot and entire plant, as well as the concentration of these nutrients.

From the dry matter and nutrient content in the plant, nutritional indices were calculated: absorption efficiency = (total nutrient content in the plant)/ (root dry matter), as described by Swiader et al. (1994) and utilization efficiency = (total produced dry matter)/(total nutrient content in the plant), according to Siddiqi and Glass (1981).

Data were subjected to analysis of variance using the F-test at 5% probability. When significant they were compared by the Tukey test at 5% probability using the SISVAR software, version 5.3 BETA (Ferreira, 2011).

**RESULTS AND DISCUSSION**

**Nitrogen**

Omission of N in the nutrient solution was highlighted by a decrease in stem diameter, leaf area and dry matter when compared to the complete nutrient solution (Table 1). Reduction in plant growth was due to reduced N accumulation in the plant in comparison with the complete nutrient solution (Tables 2, 3 and 4) which resulted in reduced efficiency of absorption and utilization of N (Tables 5 and 6).

This effect of N omission in reducing plant growth is widely reported in literature (Almeida et al., 2015; Bianco et al., 2015; Flores et al., 2015). An example of this type of study was performed in legumes Valeri et al. (2014) verified a decrease in stem diameter and dry matter when compared to plants grown in a complete nutrient solution. Reduced growth is one of the main effects caused by N deficiency in plants. Nitrogen is the element that plants need in greatest quantities, because it is makes up amino acids, amides, proteins and nucleic acids, so its deficiency rapidly inhibits plant growth (Marschner, 2012). Because the omission of N decreased nutrient absorption, it induced the appearance of characteristic symptoms of N deficiency. These symptoms were first observed in older leaves, with chlorosis followed by necrosis along the margins, reduced size, and premature leaf fall and senescence. Later, these symptoms were also observed in young leaves.

Chlorosis of the leaves can be explained by collapse of the chloroplasts caused by increased proteolysis, leading to a decrease in chlorophyll content and subsequent leaf yellowing (Viegas et al., 2014).

In this work the redistribution of N within the plant was
Phosphorus

It was verified that the omission of P decreased the stem diameter, leaf area and dry matter production of the root, shoot and whole plant (Table 1), caused by losses in the accumulation of this nutrient in the plant, that is, in absorption (Tables 2, 3 and 4) and absorption efficiency (Table 5). However, the omission of P promoted higher nutrient use efficiency compared to the complete nutrient solution (Table 6).

This increased P utilization efficiency with nutrient restriction in the nutrient solution is because of the low phosphorus content in the plant representing only 2% of the amount present in the plant of the complete treatment (Tables 2, 3 and 4), and given its known importance in the transfer of energy and organic synthesis in the plant, any increase in dry matter induces higher nutrient utilization efficiency.

The effect of P restriction on the plant was also reported by Dourado et al. (2001) in field cultivation of *C. juncea*, which showed that without P application there was reduced stem diameter and plant dry matter. Restriction to plant growth under deficiency of this nutrient also caused symptoms such as dark green color of older leaves progressing to necrosis and without the formation of side shoots, with reflection on the formation of a thin stalk and reduced flowering. A similar result was observed by Flores et al. (2015).

According to Coelho et al. (2011), the dark green color of leaves occurs due to a decrease in protein synthesis in the case that phosphorus is deficient, resulting in an increased quantity of sugars in the vegetative organs of the plant, thus favoring the synthesis of anthocyanin in leaves that produce the coloration. They also claimed evident, since the old leaves were the first to show symptoms. As reported by Faquin (2005), N is easily redistributed in plants via the phloem, in the form of amino acids. When the N supply in the medium is insufficient, N from the old leaves is mobilized to the organs and younger leaves.
Table 3. Nutrient accumulation in roots the sunn hemp in function of the omission of nutrients in the nutrient solution.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>N (mg per plant)</th>
<th>P (mg per plant)</th>
<th>K (mg per plant)</th>
<th>Ca (mg per plant)</th>
<th>Mg (mg per plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete solution</td>
<td>50.85^A</td>
<td>30.02^A</td>
<td>30.37^A</td>
<td>38.49^A</td>
<td>6.78^A</td>
</tr>
<tr>
<td>-N</td>
<td>5.49^D</td>
<td>7.50^B</td>
<td>3.40^C</td>
<td>2.60^B</td>
<td>1.44^B</td>
</tr>
<tr>
<td>-P</td>
<td>20.25^B</td>
<td>0.57^B</td>
<td>13.23^B</td>
<td>3.38^B</td>
<td>1.26^B</td>
</tr>
<tr>
<td>-K</td>
<td>11.66^DC</td>
<td>3.69^B</td>
<td>1.89^C</td>
<td>3.15^B</td>
<td>0.68^B</td>
</tr>
<tr>
<td>-Ca</td>
<td>16.45^CB</td>
<td>5.08^B</td>
<td>9.85^B</td>
<td>2.11^B</td>
<td>1.24^B</td>
</tr>
<tr>
<td>-Mg</td>
<td>8.12^D</td>
<td>2.39^B</td>
<td>5.55^C</td>
<td>2.22^B</td>
<td>0.20^B</td>
</tr>
<tr>
<td>F treatment</td>
<td>130.13**</td>
<td>270.03**</td>
<td>165.59**</td>
<td>1247.99**</td>
<td>623.79**</td>
</tr>
<tr>
<td>DMS</td>
<td>6.91</td>
<td>3.49</td>
<td>3.88</td>
<td>2.35</td>
<td>0.58</td>
</tr>
<tr>
<td>C.V.%</td>
<td>13.4</td>
<td>14.4</td>
<td>13.2</td>
<td>8.6</td>
<td>9.7</td>
</tr>
</tbody>
</table>

** Significant at 1% probability by the F-test. Means followed by the same letter in the column do not differ by the tukey test at 5% probability.

Table 4. Nutrient accumulation in whole plant the sunn hemp in function of the omission of nutrients in the nutrient solution.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>N (mg per plant)</th>
<th>P (mg per plant)</th>
<th>K (mg per plant)</th>
<th>Ca (mg per plant)</th>
<th>Mg (mg per plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete solution</td>
<td>397.10^A</td>
<td>101.16^A</td>
<td>524.08^A</td>
<td>222.51^A</td>
<td>60.90^A</td>
</tr>
<tr>
<td>-N</td>
<td>13.09^E</td>
<td>18.31^C</td>
<td>7.27^D</td>
<td>16.98^B</td>
<td>5.04^D</td>
</tr>
<tr>
<td>-P</td>
<td>119.44^D</td>
<td>2.44^B</td>
<td>52.51^C</td>
<td>43.41^C</td>
<td>11.48^D</td>
</tr>
<tr>
<td>-K</td>
<td>191.62^DC</td>
<td>38.79^B</td>
<td>15.53^DC</td>
<td>85.09^B</td>
<td>30.26^B</td>
</tr>
<tr>
<td>-Ca</td>
<td>238.75^B</td>
<td>44.53^B</td>
<td>162.63^B</td>
<td>16.73^D</td>
<td>18.87^C</td>
</tr>
<tr>
<td>-Mg</td>
<td>147.58^DC</td>
<td>24.40^C</td>
<td>33.57^DC</td>
<td>15.94^D</td>
<td>2.08^E</td>
</tr>
<tr>
<td>F treatment</td>
<td>93.74**</td>
<td>301.76**</td>
<td>451.86**</td>
<td>297.74**</td>
<td>240.97**</td>
</tr>
<tr>
<td>DMS</td>
<td>63.30</td>
<td>9.37</td>
<td>44.64</td>
<td>22.27</td>
<td>6.69</td>
</tr>
<tr>
<td>C.V.%</td>
<td>12.5</td>
<td>8.9</td>
<td>12.2</td>
<td>12.2</td>
<td>11.4</td>
</tr>
</tbody>
</table>

** Significant at 1% probability by the F-test. Means followed by the same letter in the column do not differ by the tukey test at 5% probability.

that plants with phosphorus deficiency present reduced growth because multiple processes are affected, including synthesis of proteins and nucleic acids, delayed flowering and growth, and dormant lateral buds.

Potassium

Restriction of K in the nutrient solution promoted a decrease in stem diameter and leaf area that induces less dry matter production of the root, shoot and entire plant (Table 1), which was also highlighted by Flores et al. (2015). This fact can be explained by the lower absorption or accumulation of this nutrient (Tables 2, 3 and 4) and low nutrient absorption efficiency of the plant (Table 5). However, the culture showed the highest utilization efficiency, that is, greater ability to convert absorbed K into dry matter compared to the control (Table 6), possibly a plant strategy to increase use of the nutrient in metabolism.

The effect of potassium on limiting plant growth is due to its role in protein synthesis and translocation of sugars, membrane permeability and the activity of various enzymes involved in the respiration and photosynthesis processes required for the opening and closing of stomata (Silva et al., 2015).

It was also observed that the K absorption efficiency was affected by the omission of N and high efficiency of Ca and Mg absorption when the plant has absorbed lower amounts of K, indicating antagonism (Table 5). According to Rosolem (2005), potassium is a strong competitor with other cations because of its absorption efficiency. When this ion is absent from the solution, absorption of other cations is increased, since there is a decrease in competition as a result of the lack of potassium.

In this context, the K deficiency symptoms were characterized by dark spots along the edges and tip of the old leaves and stem. According to Puga et al. (2010), this symptom may be attributed to the formation of soluble nitro gated putrescine compounds that accumulate in the plant, responsible for the necrotic spots
aparting in the nutrient deficient leaves. Smaller leaves were also observed following by reduction of shoot growth, thin stem and delayed flowering. Bianco et al. (2015) also reported reduced growth with K restriction in the nutrient solution.

**Calcium**

Calcium omission caused a reduction in plant development for all growth parameters studied (Table 1), which was also indicated by other authors (Flores et al., 2015; Bianco et al., 2015). The loss in plant development under Ca omission in the nutrient solution is due to the lower Ca accumulation in the dry matter of roots, shoots and the entire plant (Tables 2, 3 and 4) as well as lower nutrient absorption efficiency of the plant (Table 5); however the Ca deficiency resulted in more efficient use of the nutrient compared to the complete nutrient solution (Table 6).

In the absence of Ca in the nutrient solution deformation of the youngest leaves, shoots and the apical meristem was identified, and according to Taiz and Zeiger (2006) this may be attributed to the fact that Ca is essential to maintain cell wall membrane integrity. Furthermore, the greatest portion of Ca in the plant is found in the non-water-soluble forms, which in part explains the lack of redistribution in deficiency conditions and causes the appearance of symptoms in the younger parts (Viegas et al., 2014).

Necrosis was also observed with evolution of deficiency, resulting in death of the apical meristem, increase of lateral shoots, reduced growth and delayed flowering. Similar results were reported by other authors (Bianco et al., 2015; Silva et al., 2015). According to Marschner (2012), Ca deficiency may retard growth and cause the death of meristems.

**Magnesium**

Deficiency of Mg decreased the stem diameter, leaf area and dry matter production of the plant (Table 1), a fact also observed by Flores et al. (2015). Reduced plant
development under Mg deficiency in the nutrient solution was due to lower accumulation of this nutrient in dry matter of the root, shoot and entire plant (Table 2, 3 and 4), based on lower efficiency of nutrient absorption and utilization (Tables 5 and 6).

It was also noted that the Mg absorption efficiency was increased in plants grown under K deficiency (Table 5), where this occurs when K absorption is low and Mg absorption is thus facilitated (Malavolta, 2006).

The omission of Mg while decreasing Mg absorption induced visual symptoms that initiated with chlorosis interneval of the older leaves followed by evolved yellowing to necrosis and delayed flowering. Similar results were observed by Bianco et al. (2015).

This pattern of chlorosis occurs because chlorophyll in the vascular bundles remains unchanged for longer periods than chlorophyll in the cells between these bundles, and if the deficiency is severe, the leaves may become yellow or white, followed by necrosis (Taiz and Zeiger, 2009). This is summed with the fact that leaf chlorosis occurs due to reduced chlorophyll synthesis (Marschner, 2012) and rapid destruction of chloroplasts (Bianco et al., 2015).

Conclusions

The restriction of N, P, K, Ca and Mg in cultivation of sunn hemp caused reduced plant growth and visual symptoms characteristic of nutritional deficiency of the respective nutrient.

The N and Mg deficiency caused greatest loss in the growth of sunn hemp in relation to the other nutrients due to lower capacity of the plant to use these nutrients in the production of dry matter grown in a restrictive environment.

Conflict of Interests

The authors have not declared any conflict of interests.