Soil chemical attributes in beet cultivation under different fertigation and salinity managements

Atributos químicos do solo em cultivo de beterraba sob diferentes manejos de fertirrigação e salinidade

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Abstract

Aiming to monitor and simulate the effect of the excess of soil salts in a protected environment, the experiment was carried out in a greenhouse located at the Department of Rural Engineering of the Universidade Estadual Paulista, Faculty of Agronomic Sciences, Campus of Botucatu - SP, from October 2011 to January 2012. The treatments consisted of the combination of two factors: initial soil salinity with 5 levels of electrical conductivity (S1 = 1.0; S2 = 3.0; S3 = 6.0; S4 = 9.0; S5 = 12.0 dS m⁻¹) and two fertigation managements (M1 = traditional; and M2 = with control of the ionic concentration of the soil solution) in beet (Beta vulgaris L) cultivation. The design was a randomized complete block with 4 replications, organized in a 5 x 2 factorial scheme, totaling 40 experimental plots. During the cultivation cycle, the EC, K and pH were monitored in the soil solution. At the end of the cycle, soil analysis and the spatial distribution of EC in the soil profile were performed. The highest levels of soil salinity occurred in the deeper layers of the soil profile, being evidenced in the traditional fertigation management due to the high EC values observed in this treatment. With the help of porous cup extractors, it was possible to monitor the concentration of fertilizers applied via fertigation and to maintain the concentration at pre-established levels throughout the cultivation.

Additional keywords: electrical conductivity; porous cup extractors; soil solution.

Resumo

Visando monitorar e simular o efeito do excesso de sais no solo em ambiente protegido, foi realizado um experimento em casa de vegetação, localizada no Departamento de Engenharia Rural da Universidade Estadual Paulista, Faculdade de Ciências Agronômicas, Campus de Botucatu – SP, no período de abril a junho de 2012. Os tratamentos foram formados da combinação de dois fatores: salinidade inicial do solo com 5 níveis de condutividade elétrica (S1 = 1.0; S2 = 3.0; S3 = 6.0; S4 = 9.0; S5 = 12.0 dS m⁻¹) e dois manejos de fertirrigação (M1 = tradicional e M2 = com controle da concentração iônica da solução do solo) em cultivo de beterraba (Beta vulgaris L). O delineamento adotado foi o de blocos casualizados completos, com 4 repetições, organizados em esquema fatorial 5 x 2, totalizando 40 parcelas experimentais. Durante o ciclo de cultivo, foram monitoradas a CE, K e pH na solução do solo. Ao final do ciclo, foram realizadas análise do solo e a distribuição espacial da CE no perfil do solo. Os maiores níveis de salinidade do solo ocorreram nas camadas mais profundas do perfil do solo, sendo evidenciados no manejo tradicional da fertirrigação, devido aos altos valores de CE observados neste tratamento. Foi possível, com o auxílio dos extratores de cápsulas porosas, monitorar a concentração dos fertilizantes aplicados via fertirrigação e manter a concentração nos níveis preestabelecidos durante todo o cultivo.

Palavras-chave adicionais: condutividade elétrica; extratores de cápsulas porosas; solução do solo.

Introduction

Protected cultivation is one of the options for high-yielding agriculture, in addition to providing efficient control of pests, diseases and climatic adversities. However, unlike field cultivation, in which climatic actions such as rainfall events promote leaching of salts, agricultural greenhouse soils behave similarly to semi-arid regions, due to the protection against rainfall and the frequent evaporation. With this, there is accumulation of salts due to excessive fertilization during several crop cycles, thus salinizing the soils of these areas (Medeiros et al., 2010), which causes losses in the productivity of commercial crops that show sensitivity to high salinity (Eloi et al., 2011; Medeiros et
Among the techniques to increase the efficiency of fertilizers in a protected environment, fertigation is the most used (Silva, 2014). Notwithstanding, fertigation management is usually done through the application of pre-established amounts of fertilizers, without any monitoring of the nutritional status of the plant during the growing season (Silva et al., 2015b), which have caused problems regarding soil salinity and symptoms of toxicity in plants, leading to the discouragement of their use by producers (Silva et al., 2000). For this reason and because it is a technique that requires rapid and precise changes in the amount of nutrients applied, it is important to know the state of the soil through successive monitoring during the growing cycle, to promote the necessary adjustments for obtaining higher yields (Souza et al., 2012), avoiding the lack or excess of fertilizers in the soil.

Among the known methods to estimate the concentration of salts in the soil solution, the electrical conductivity is the most practical. Notwithstanding, the quantification of the electrical conductivity of the saturation extract is the most evidenced in the literature (Richards, 1954) and, therefore, is considered as standard method. However, for being a time-consuming and destructive method of measurement, several authors highlight soil solution extractors as an alternative for measuring the electrical conductivity (EC) of the soil solution (Eloi et al., 2011; Souza et al., 2013), since it is conveniently easy to use and represents what is happening in the soil-plant interaction where such a method can be adopted to control the soil solution in a protected environment (Silva, 2014).

Hence, the objective of this work was to present the evolution of soil salinity and other soil chemical attributes, using two fertigation managements and porous cup extractors to monitor the ionic concentration of the soil solution as a control of salinization in beet crop.

**Material and methods**

The work was carried out in a greenhouse located at the Department of Rural Engineering of the Universidade Estadual Paulista, Faculty of Agronomic Sciences, Campus of Botucatu – SP, from October 2011 to January 2012. The municipality is in the midwest of the state of São Paulo, at 830 m altitude, 22º57’South latitude and 48º31’West longitude. The soil material used was removed from the 0-30 cm surface layer and was characterized as Red-Yellow Latosol (Embrapa, 2013). It was dried, ground and previously sieved in a 4-mm mesh sieve. Granulometric and physical analyses of the soil were performed (Table 1) in the Department of Soil Sciences of UNESP/FCA, classifying it as clayey.

Before the experiment was carried out, soil fertility analysis was performed to correct the pH of the soil (Table 2) by liming with dolomitic limestone (RPTN = 84%), increasing the base saturation to 80%, as recommended by Trani et al. (1998).

<table>
<thead>
<tr>
<th>Table 1 - Granulometry and physical parameters of the soil.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Granulometry</strong></td>
</tr>
<tr>
<td>Sand (g kg⁻¹)</td>
</tr>
<tr>
<td>395.5</td>
</tr>
<tr>
<td>PD - particle density; SD - soil density; P - porosity; MCC - moisture content of container; MPWP - moisture at the permanent wilting point.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2 - Chemical properties set before the artificial soil salinization.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pH</strong></td>
</tr>
<tr>
<td>CaCl₂</td>
</tr>
<tr>
<td>5.1</td>
</tr>
<tr>
<td>EC - Electrical conductivity; OM - organic matter; P - Phosphorus; K - Potassium; Ca – Calcium; Mg – Magnesium; H⁺Al – potential acidity; SB - sun of bases; CEC – cationic exchange capacity; V - saturation by bases.</td>
</tr>
</tbody>
</table>

The first stage of the experiment was conducted after the soil was accommodated in 14-liter pots with a 2-cm envelope layer (synthetic blanket + gravel) at the base, where the artificial salinization of the soil was carried out, raising the soil moisture to its maximum retention capacity, with application of solutions with known concentrations, corresponding to electrical conductivity values of (1.0, 3.0, 6.0, 9.0, 12.0 dS m⁻¹), determined by the artificial salinization curve (Figure 1).

The proportion of salts, as well as of the types of salts applied, were based on Furlani (1998) fertilization recommendations for nutrient solutions in vegetables, and the amounts of salts added were estimated according to methodology proposed by Richards (1954):

\[ Q_s = EC_{se} \times 640 \times Vs \]  

Where: \( Q_s \) is the amount of salts applied (mg pot⁻¹), etc.
ECse is the electrical conductivity required in the soil saturation extract (dS m⁻¹) and Vs is the volume of water present in the saturated soil (L pot⁻¹).

After the artificial salinization of the soil, new soil chemical analyses were carried out aiming at the recognition of the soil (Table 3) to identify its current state in each treatment before the proposed fertigation management.

![Figure 1 - Curve of artificial soil salinization.](image)

### Table 3 - Chemical properties of soil determined after salinization.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>EC (dS m⁻¹)</th>
<th>pH</th>
<th>OM (g dm⁻³)</th>
<th>P (mg dm⁻³)</th>
<th>K (mmol c⁻¹ dm⁻³)</th>
<th>Ca (mmol c⁻¹ dm⁻³)</th>
<th>Mg (mmol c⁻¹ dm⁻³)</th>
<th>H⁺Al (mmol c⁻¹ dm⁻³)</th>
<th>SB</th>
<th>CEC</th>
<th>V (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₁</td>
<td>0.53</td>
<td>5.5</td>
<td>25.3</td>
<td>22.6</td>
<td>1.5</td>
<td>44.0</td>
<td>13.8</td>
<td>25.6</td>
<td>59.3</td>
<td>84.9</td>
<td>70.0</td>
</tr>
<tr>
<td>S₂</td>
<td>3.40</td>
<td>5.5</td>
<td>24.0</td>
<td>80.0</td>
<td>6.0</td>
<td>47.0</td>
<td>15.0</td>
<td>24.0</td>
<td>68.0</td>
<td>91.0</td>
<td>74.0</td>
</tr>
<tr>
<td>S₆</td>
<td>6.34</td>
<td>5.4</td>
<td>21.8</td>
<td>104.6</td>
<td>7.6</td>
<td>49.9</td>
<td>14.7</td>
<td>26.6</td>
<td>72.2</td>
<td>98.7</td>
<td>73.1</td>
</tr>
<tr>
<td>S₉</td>
<td>9.22</td>
<td>5.5</td>
<td>22.8</td>
<td>132.6</td>
<td>6.9</td>
<td>55.9</td>
<td>14.9</td>
<td>26.6</td>
<td>77.7</td>
<td>104.4</td>
<td>74.5</td>
</tr>
<tr>
<td>S₁₂</td>
<td>12.30</td>
<td>5.5</td>
<td>21.9</td>
<td>154.0</td>
<td>16.5</td>
<td>71.0</td>
<td>19.3</td>
<td>25.6</td>
<td>106.8</td>
<td>132.4</td>
<td>80.6</td>
</tr>
</tbody>
</table>

**EC** - Electrical conductivity; **OM** - organic matter; **P** - Phosphorus; **K** - Potassium; **Ca** - Calcium; **Mg** - Magnesium; **H⁺Al** - potential acidity; **SB** - sun of bases; **CEC** - cationic exchange capacity; **V** - saturation by bases.

The cultivation of beet (*Beta vulgaris* L.), cultivar Early Wonder, was implanted after artificial salinization, using a drip irrigation system with self-compensating emitters, through a flow rate of 2.5 L h⁻¹, with 95% distribution uniformity. Each line had a record for the control of the fertigation management performed by Venturi injectors.

The treatments were formed from the combination of two factors: initial soil salinity with 5 levels of electrical conductivity (S₁ = 1.0; S₂ = 3.0; S₆ = 6.0; S₉ = 9.0; S₁₂ = 12.0 dS m⁻¹) and two fertigation managements (M₁ = traditional; and M₂ = with control of the ionic concentration of the soil solution). The design was a randomized complete block with four replications and the factors were arranged in a 5 x 2 factorial scheme, totaling 40 experimental plots.

During the cultivation, the types of fertilizers used for the fertigation management were: potassium nitrate, potassium chloride and monoammonium phosphate, based on the applications of total fertilizer for the beet crop according to Trani et al. (1998): 120 kg ha⁻¹ N; 360 kg ha⁻¹ P₂O₅ and 210 kg ha⁻¹ K₂O. Fertilizer application was carried out via irrigation water, with different management for treatments M₁ and M₂. For treatment M₁, the recommendations proposed by Trani et al. (1998) were used, considering the crop uptake determined by Grangeiro et al. (2007) in the frequency of daily fertigation. For treatment M₂, fertigation events were only performed after the concentration of the electrical conductivity of the soil solution was below that established in the initial salinity treatments. When the EC was 20% above the values established, there were no more fertigation events until the EC was reduced again.

The electrical conductivity of the soil solution was measured one day after the end of each fertigation event, using the soil solution extraction via porous cups containing 20 mL syringes, in which the soil was subjected to a vacuum, reducing firstly the air from inside the extractors with the aid of a vacuum pump, creating an internal suction of approximately 80 kPa. The vacuum application to the extractors occurred 12 h after the fertigation, at which time the soil moisture was verified by means of tensiometry through a puncture tensiometer. The porous cup extractors and the tensiometers were installed in each plot, located opposite one another, to a depth of 20 cm from the soil surface and 10 cm away from the plant.

The values of electrical conductivity and potassium were measured in the soil solution during the crop cycle, being corrected with the moisture values obtained by the standard method, i.e., in the
saturation extract of the saturated paste, according to Equation (2). The pH values were also monitored throughout the growing cycle.

\[ EC_s = \frac{EC_{ex} \cdot M_a}{M_s} \]  

(2)

Where: \( EC_s \) is the electrical conductivity estimated from the electrical conductivity of the soil solution obtained with porous cup extractors, being corrected for the moisture of the saturated paste (dS m\(^{-1}\)), \( EC_{ex} \) is the electrical conductivity obtained by the porous cup extractor (dS m\(^{-1}\)); \( M_a \) is the soil moisture measured at the moment of withdrawal of the soil solution by the porous cup (g g\(^{-1}\)) and \( M_s \) is the soil moisture in the saturated paste (g g\(^{-1}\)).

Irrigation management was carried out by reading the average tension in each treatment, through the tensiometers installed in each plot. When the tensions were observed, the corresponding moisture was calculated according to Carvalho & Oliveira (2012), from the soil water retention curve (Figure 2).

![Figure 2 - Water retention curve in the soil used for irrigation management.](image)

Having the moisture values, including that one corresponding to the container capacity, and still considering the soil volume in the pot, the reposition volume was calculated using Equation 3 (Carvalho and Oliveira, 2012). To apply the irrigation water to the pots, the net irrigation depth (I \( \text{NET} \)) was transformed into volume (L plant\(^{-1}\)) by multiplying I \( \text{NET} \) by the pot area (0.062 m\(^2\)).

\[ \text{I \( \text{NET} \)} = \left( \frac{M_{cc} - M_{actual}}{10} \right) \cdot ds \cdot Z \]  

(3)

Where: I \( \text{NET} \) is the net irrigation depth (mm), \( M_{cc} \) is the moisture in the container capacity (% in weight), \( M_{actual} \) is the actual moisture (% in weight), \( ds \) is the bulk density of the soil (g cm\(^{-3}\)), \( Z \) is the depth of the radicular system (cm).

At the end of the cycle, at 50 days after transplanting, soil samples were collected for chemical analysis (Raij et al., 2001), aiming to present the evolution of the salts according to the electrical conductivity of the soil solution in the different fertigation management studies. The soil salinity cross-sectional profile for both fertigation managements was determined by withdrawing soil samples at each 5 cm of pot depth in layers 5, 10, 15, 20 and 25 cm deep; the electrical conductivity was measured through the paste saturation extract at each depth. Having the data, the software Surfer® (Golden software, 2010) was used for spatialization thereof along the profile of the pots for the 5 treatments of electrical conductivity in the different fertigation treatments.

The variables were submitted to analysis of variance and, later, to regression analysis, where linear and 2nd degree polynomial models were tested. The regression equations were chosen based on the significance of the regression coefficients, at 1 and 5% of probability, by the F test and based on the highest value of the coefficient of determination (\( R^2 \)). For the qualitative factors, Tukey test was performed at 5% probability.

Results and discussions

Irrigation management

Figure 3 shows the soil water tensions measured throughout the growing cycle for the different fertigation managements studied. It is observed that the period between 13 and 40 days after transplanting (DAT) presented the highest values of tension observed during cultivation, thus representing the time of greater water consumption by the plants. Silva et al. (2015a), in studies on different soil water tensions, observed that the lowest yields for the beet crop were obtained at tensions of 55 and 65 kPa, but in none of the fertigation treatments studied these values were obtained, only at 26 DAT there were values above 40 kPa in \( M_a \) (Figure 3B).
The irrigation depths for soil salinity levels and fertigation management are presented in Figure 4. For the traditional management of fertigation (Figure 4A), the largest depths were applied for the treatment with EC of 3 dS m$^{-1}$ (15.6 L plant$^{-1}$). In the controlled management (Figure 4B), the highest irrigation depths (15.48 L plant$^{-1}$) were obtained for the treatment with EC of 1 dS m$^{-1}$. There was a reduction in water application for treatments with higher EC values (S$_6$ to S$_{12}$); possibly, the increase of the total potential in the soil, due to the contribution of the osmotic potential, caused the reduction of water consumption by the plants (Nobre et al., 2014).

Monitoring of the electrical conductivity, potassium and pH in the soil solution

Figure 5 shows the regression model adopted for the electrical conductivity values measured in the saturation extract and estimated from the electrical conductivity of the soil solution. The correlation of the values presented a coefficient of determination (R$^2$) of 0.92, thus demonstrating that the results can be considered satisfactory, considering that the determination of soil moisture was carried out using tensiometers, which implies indirect measurement, of less accuracy, as stated by Silva et al. (2000).

The electrical conductivity (EC) values of the soil solution, extracted through ceramic porous cups installed at 20 cm depth, for the different types of fertigation management during the beet crop cycle, are presented in Figure 6. It can be observed that the traditional management (Figure 6A) showed a decrease in the electrical conductivity of the soil solution from 8 to 22 days after transplanting (DAT), probably due to the higher nutritional requirement of the plant in this period. At 29 DAT, there is a growing increase of EC until the end of the crop cycle.

In the controlled management (Figure 6B), the soil solution remained constant from 8 to 29 DAT for the saline treatments S$_1$, S$_3$, S$_6$, while for the higher saline levels (S$_9$ and S$_{12}$), there was an oscillation, with values decreasing from 8 DAT up to 22 DAT, and
increasing from 29 DAT until the end of the growing cycle. According to Grangeiro et al. (2007), in experiments carried out with the cultivar Early Wonder, the greatest nutrient demand required by the crop occurred between 30 and 50 days after sowing for most of the nutrients studied. Such period differs from those presented in the experiment, possibly due to the effect of saline stress on plants.

Figure 5 - Correlations between the electrical conductivity values measured in the saturation extract and estimated from the soil solutions obtained with porous cup extractor.

The concentrations of potassium in the soil solution for the soil salinity levels in the traditional and controlled fertigation managements are observed in Figure 7. A similar behavior was observed between the EC and K levels in the soil solution at certain moments of the cultivation period, but the control management kept K concentrations constant throughout much of the production cycle. According to Silva et al. (2000), the determination of K by the soil solution is very efficient to control the availability of this nutrient to the crop, being thus a useful tool for the control of K throughout the crop cycle.

Figure 8 shows the pH values in the soil solution in the fertigation treatments studied. There was no variation of pH between the treatments, being maintained between 5.5 and 6.5 and in some occasions rising to 7.0. According to Filgueira (2003), the beet crop is highly demanding on soil acidity, achieving better production values in the pH range from 6.0 to 6.8, values close to those observed in this experiment except for the analyses performed at 22, 29, 43 and 50 DAT.
Soil chemical analysis

According to the analysis of variance (Table 4), at 5% probability level, there were significant differences for the soil salinity factor for all studied variables except for pH and H+Al. The fertigation management factor had a significant influence on the response variables OM, K, Mg and Na. For the interaction of factors, the variables EC, K, Ca and Mg were significantly influenced (p<0.05). It is observed that there were differences between the fertigation treatments studied for the variables OM, K, Mg and Na. M1 presented the highest concentrations among these variables, except for Mg; thus, the hypothesis that management M1 provided higher amounts of nutrients may be acceptable.

Medeiros et al. (2012) and Eloi et al. (2011), studying the effect of excess fertilizers on tomato crop production, did not observe differences in the fertigation managements studied; possibly the low values of electrical conductivity of these studies contributed to such observations, where the control via extractors can be considered, therefore, more efficient. Nonetheless, it is evident that the application of fertilizers (Souza et al., 2012) or residues (Bonini et al., 2014) alter the chemical attributes and can contribute in a way to cause damage, when in excess, or benefits, when well managed, to plants.

The soil electrical conductivity at the end of the production cycle was adjusted for both fertigation managements by the linear model, with an increase of 1.26 (M1) and 0.98 (M2) dS m⁻¹ for each unit increase of the ECs. For the variable K, there was an increase of 0.68 (M1) and 0.52 (M2) mmol c dm⁻³ for each unit increase of the ECs, showing that the largest fertilizer concentrations were applied in the traditional fertigation management. Notwithstanding, the variable Mg presented higher concentrations of applied nutrients in M2, where the linear adjustment showed an increase of 0.31 (M1) and 0.35 (M2) for each unit increase of the ECs (Table 5).
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2011), caused by the high concentrations of fertilizers
(Oliveira et al., 2015; Silva et al., 2013b; Eloi et al.,
productive and qualitative parameters of cr
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adjustment (Table 5). In the literature, studies involving
influence on the soil electrical conductivity, with linear
management.

Table 5 - Statistical analysis of soil chemical parameters after the production cycle, according to different levels of salinity and fertigation management.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Regression equations</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC</td>
<td>$\hat{y}(M_1) = 2.178 + 1.2685^{**}x$</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td>$\hat{y}(M_2) = 2.800 + 0.9836^{**}x$</td>
<td>0.85</td>
</tr>
<tr>
<td>K</td>
<td>$\hat{y}(M_1) = 14.999 + 0.681^{**}x$</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>$\hat{y}(M_2) = 11.981 + 0.526^{x}$</td>
<td>0.91</td>
</tr>
<tr>
<td>Ca</td>
<td>$\hat{y}(M_1) = 49.905 + 1.665^{x}$</td>
<td>0.65</td>
</tr>
<tr>
<td>Mg</td>
<td>$\hat{y}(M_1) = 5.905 + 0.311^{x}$</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>$\hat{y}(M_2) = 8.009 + 0.35^{x}$</td>
<td>0.55</td>
</tr>
<tr>
<td>SB</td>
<td>$\hat{y}(M_1) = 70.601 + 2.677^{x}$</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>$\hat{y}(M_2) = 75.945 + 2.137^{x}$</td>
<td>0.82</td>
</tr>
<tr>
<td>CEC</td>
<td>$\hat{y}(M_1) = 108.18 + 2.744^{x}$</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>$\hat{y}(M_2) = 113.84 + 2.078^{x}$</td>
<td>0.80</td>
</tr>
<tr>
<td>Na</td>
<td>$\hat{y}(M_1) = 0.541 + 0.023^{x}$</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>$\hat{y}(M_2) = Ns$</td>
<td>-</td>
</tr>
</tbody>
</table>

Parameters such as SB and CEC also had an
fluence on the soil electrical conductivity, with linear
adjustment (Table 5). In the literature, studies involving
fertigation managements have shown reductions in the
productive and qualitative parameters of crops
(Oliveira et al., 2015; Silva et al., 2013b; Eloi et al.,
2011), caused by the high concentrations of fertilizers
applied, as observed in the present experiment, with
damage to the plants in any of the studied
managements (Silva et al., 2015b), depending,
obviously, on the tolerance of the cultivated crop.

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**Distribution of salts in the soils**

In experiments in pots, according to Silva et al.
(2000), the interference caused by the walls of the
recipient in the distribution of water and salts may
result in a situation that favors the increase or reduction of the concentration of salts in the root region, and may interfere in the tolerance of the crop. As shown in Figure 9, soil salinity showed unequal spatial distribution, in cross section, for S; in the traditional (Figure 9A) and control managements (Figure 9B).

Figure 9 - Spatial distribution of electrical conductivity in the pots at different levels of salinity and initial management of fertigation studied.
For the spatial distribution of the electrical conductivity for $S_4$, the highest values were found in the region near the soil surface and under the dripper, decreasing with depth, with the formation of well-defined isolines for both fertigation managements (Figure 9C and 9D).

For the spatial distribution of $S_6$ treatments, the highest EC values were found in the deepest layers of the pot, with EC between 6 and 6.5 dS m$^{-1}$ for the traditional management (Figure 9 E) and 5.5 to 7.5 dS m$^{-1}$ for the control management (Figure 9F). For $S_6$, the lowest values were observed near the root system of the crop, possibly due to the nutrient absorption by the plant, with EC values from 3 to 5.5 dS m$^{-1}$. The highest values were around 7.0 to 9.5 dS m$^{-1}$ for the traditional management (Figure 9G) and 8 to 11.5 dS m$^{-1}$ for the control management (Figure 9H) in the layers from 15 to 20 cm, respectively.

For the spatial distribution of treatment $S_{12}$, values of 5.5 to 8.0 dS m$^{-1}$ were observed for the surface layers of the pot and near the root system of the plant. From the depth of 10 cm there was an increase in salinity at the largest depths of the pot. In the traditional management (Figure 9i), the highest EC values found were from 9 to 14 dS m$^{-1}$ and for the control management (Figure 9j), the values ranged from 9 to 12 dS m$^{-1}$, found between layers 15 and 20 cm deep.

Similar values were observed by Dias et al. (2005) in studies with salinity and melon cultivation, where the authors observed that the treatments with the highest amount of salts had higher EC values in the deeper layers of the soil.

**Conclusions**

The highest levels of soil salinity occur in the deeper layers of the soil profile and are evidenced in the traditional management of fertigation due to the high EC values observed in this treatment.

With the aid of soil solution extractors, it is possible to monitor the concentration of fertilizers applied via fertigation and to maintain the concentration at pre-established levels throughout the cultivation.

**References**


