ACTA HYDROLOGICA SLOVACA

Ročník 19, č. 1, 2018, 157 – 161

APPLICATION OF DRIP IRRIGATION AND EC MEASUREMENTS FOR PRECISION FARMING IN VEGETABLE FARMS - PRIMARY RESULTS

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Water and nitrogen are considered as the main limiting factors for growing vegetables in Bulgaria. Appropriate drip irrigation and fertigation are effective methods for enhancing water and nutrient use efficiency in vegetable farming that can reduce the risk of nutrient leaching. Soil electrical conductivity (EC) is acknowledged as an easily measured but reliable indicator for nutrient distribution in soil that influences crop productivity. The aim of presented study was to examine the applicability of EC measurement as a rapid indicator for optimization of fertigation parameters and crop positioning to the irrigation line. The investigations were conducted on alluvial sandy to loamy soils having coarse texture, low humus content and slightly acidic pH. One-year experiment with zucchini using drip irrigation and tree fertilizer treatments was carried out. Soil samples were taken to assess spatial distributions of EC the down profile. In addition, soil water content, salt content and EC were monitored using ProCheck Decagon devices. The results showed that the soluble salts (nitrate) distributions in the soil were readily evaluated by the EC measurements. During fertigation, dissolved salts moved laterally and vertically. Accordingly, the EC measurements also differed apparently up to 40 cm from irrigation line. As a result, the conducted experiments allowed corrections of the applied irrigation and the fertilizer rates, and the location of irrigation lines to the vegetable plants. Finally, the application modern measuring techniques in the field was essential to advance the irrigated vegetable farming.

KEY WORDS: drip irrigation, soil electrical conductivity, vegetable farming

APLIKÁCIA KVAPKOVEJ ZÁVLAHY A EK MERANIA PRE PRESNÉ POĽNOHOSPODÁRSTVO NA ZELENINOVÝCH FARMÁCH – ZÁKLADNÉ VÝSLEDKY. Voda a dusík sa považujú za hlavné obmedzujúce faktory pre pestovanie zeleniny v Bulharsku. Vhodná kvapková závlaha a fertigácia sú účinné metódy na zvýšenie účinnosti vody a výživy v zeleninárstve, ktoré môžu znížiť riziko vylúhovania živín. Elektrická vodivosť v pôde (EK) je považovaná za ľahko merateľný, ale spoľahlivý ukazovateľ rozloženia živín v pôde, ktorý ovplyvňuje produktivitu plodín. Cieľom predloženej štúdie bolo preskúmať uplatniteľnosť merania EK ako rýchleho indikátora na optimalizáciu fertigačných parametrov a polohy plodín k zavlažovaniu. Výskum bol vykonaný na aluviálnych pieskoch až hlinitých pôdach s hrubou textúrou, nízkym obsahom humusu a mierne kyslým pH. Bol uskutočnený jednoročný experiment s cuketou pomocou kvapkovej závlahy a ošetrenia stromovými hnojivami. Na posúdenie priestorových rozdelení elektrickej vodivosti v pôde na dolnom profile boli odobraté vzorky pôdy. Okrem toho bol monitorovaný obsah vody v pôde, obsah soli a EK s použitím zariadení ProCheck Decagon. Výsledky ukázali, že rozdelenia rozpustných solí (dusičnanov) v pôde boli ľahko vyhodnotené pomocou meraní EK. Počas fertigácie sa rozpustené soli pohybovali bočne a vertikálne. Preto sa merania EK tiež zrejme líšili až do 40 cm od zavlažovacej línie. Výsledkom bolo, že vykonané experimenty umožnili korekciu aplikovaného zavlažovania a rýchlosti hnojenia, a umiestnenie zavlažovacích potrubí k zeleninovým plantom. Nakoniec, aplikácia moderných meracích techník v teréne je nevyhnutná pre pokrok v zavlažovaní zeleniny.

KĽÚČOVÉ SLOVÁ: kvapková závlaha, pôdna elektrická vodivosť, pestovanie zeleniny

Introduction

Water and nitrogen are considered as the main limiting factors for growing vegetables in Bulgaria. The way they are used is one of the factors strongly influencing their effectiveness (Mohammad, 2004 a,b, Atanasova, Mitova, Dimitrov, Stancheva, 2007, Shaban et al., 2014).Improving the effectiveness of these factors is the main goal of the precision vegetable farming (Tzenova & Mitova, 2010). Appropriate drip irrigation can reduce nitrogen leaching in depth. Fertigation is an effective method for nitrogen application because it can control the time and amount of fertilizer used. Besides being a measuring unit for the nutritional value given to the plant, Electrical conductivity (EC) is a climate controlling mechanism. Plants should start their development at low EC, and then EC must grow as quickly as possible to meet the nutritional needs of the plant, also increase the internal osmotic value to create stronger plants.

Climate change due to global warming has a serious impact on water resources, affecting groundwater and surface water. Minimising the use of water in vegetable production, while preserving yield and production quality, has become an important issue in the last decade. A very important point in assessing the quality of fertigation in vegetable crops is the use of soil electrical conductivity. Electrical conductivity (EC) is a measure of the ability of materials to conduct electrical current and is expressed usually in milli Siemens per centimeter (mS/cm) or in deci Siemens per meter (dS/m). Richards (1954) defines four classes of soil salinization. Another more comprehensive study on soil salinity is given by Rhoades and Lovejoy (1990), where beans are presented as a salt sensitive culture. It can be grown on soils with an electrical conductivity of less than 2 dS/m. In opposite, barley is a tolerant crop and can be grown on soils with electrical conductivity up to 16 dS/m.

Soil electrical conductivity depends on many factors such as soil water content, soil texture and particle size distribution. The electrical conductivity of the sand is low, of the silt is medium and of the clay is high. The EC also depends on other parameters of soil fertility. Soils with average electrical conductivity are the most fertile ones. In dry soils, EC is low, and in the case of more humid soils the electrical conductivity is high. Cationic Capacity (CEC) is related to soil fertility, porosity and salinity. Increasing fertilizer and organic matter fertility also increases to certain limits. Soils having higher porosity, show also high CEC values. Poor soils have low porosity. The excess of soluble salts in the soil is readily measured by conductivity measurement.

The aim of presented study was to examine the applicability of EC measurement as a rapid indicator for optimization of fertigation parameters and crop positioning to the irrigation line.

Material and methods

The investigations were conducted on alluvial sandy soils. The predominant fraction was fine sand - 23.3%, the percentage of large particles such as gravel was 37.2%, the soil humus content is low. The soil is non-carbonate and slightly acidic. The average annual temperature was 10.6°C, while the average annual precipitation was 581.8 mm, reaching its peak at the end of spring and early summer (stringmeteo.com, 2010).

Experiment with zucchini using drip irrigation was carried out on plots with 60 m^2 size. The experiment consisted of the following treatments: 1. Control; 2. Manure; 3. Compost. On the second and third treatments the organic fertilizers were applied at following rates: Manure 44 t/ha; Compost 21 t/ha. Compost and manure are with equal rate of 340 kg of nitrogen per hectare. Such quantity is permitted for two years by the EU Nitrates Directive. On 30m^2 of each plot, the nitrogen mineral fertilizer was applied by fertigation with a rate of 240 kg of nitrogen per hectare. Samples were taken at soil depths of 0-30 cm; 30-60 cm and 60-90 cm. On the same samples, measurements of EC were made directly on fields. ProCheck sensors (Decagon Devices, Inc.) were used for measuring soil water content, soil electrical conductivity and soil salt content.

Results and discussion

The changes of the wetting front down the soil profile is presented on Figure 1. Red-orange colour indicates the changes of the water content. In the middle of the figure there is also seen the interflow of moisture from neighbouring irrigation lines. The movement of nitrates correlates strongly with that of the water. The content of highly soluble nitrate salts is a base for increase of the electrical conductivity in soil - EC. Directly under the drip irrigation line, the soil water content varies at different depths from 0.205 cm^3/cm^3 at 30-50 cm depth to 0.235 cm^3/cm^3 at 0-30 cm and below 60 cm depth. Nitrates were leached under 60 cm depth under the drip irrigation line (Figure 1). The highest EC was observed at 40 to 60 cm depth and at 20 cm apart to the irrigation line owing to the leaching of nitrates down the soil profile (Figure 2). Dissolved salts (nitrates) moved down soil profile with the water front and the highest EC was observed in the places with the lowest water contents. In the areas with the highest soil water content, the EC was about 0.20 dS/m, while in dryer soils areas the EC reached 0.35 dS/m and more. It was an evident that the soil water content correlates negatively with the soil electrical conductivity. This information was important for the positioning of plants and the irrigation lines in order to provide an optimal access of the roots to the water and nutrients available in the soil.

EC under the irrigation lines at 0-30, 30-60 and 60-90 cm soil depths was compared between the three treatments – with and without using mineral nitrogen fertilization (Figure 3). In all treatments, the mineral nitrogen from fertilizer was leached down to the second or third soil sampling layer.

High electrical conductivity measurements were also observed near the irrigation line merging the lateral movement of dissolved salts (nitrates) (Figures 4 and 5).

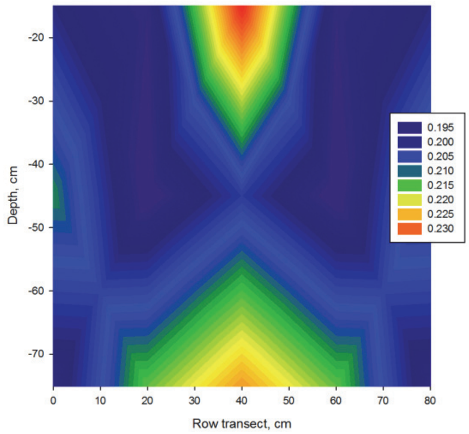

Fig. 1. Spatial distribution of the volumetric soil water content (cm³/cm³)after irrigation (measurements using ProCheck devices).
Obr. 1. Priestorová distribúcia objemového množstva vody v pôde (cm³.cm⁻³) po zavlažovaní (merania pomocou zariadení ProCheck).

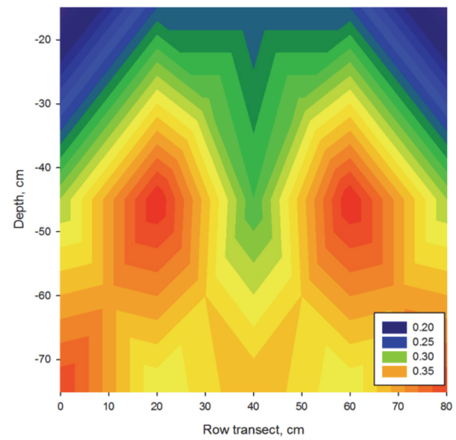

Fig. 2. Spatial distribution of the Electrical conductivity (dS/m) in the treatment with mineral fertilisers.
Obr. 2. Priestorová distribúcia elektrickej vodivosti (dS.m^{-1}) pri ošetrovaní minerálnymi hnojivami

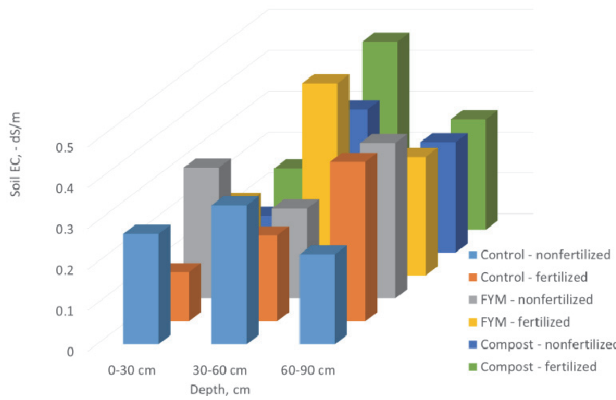

Fig. 3. Soil EC measurements at different soil depths for the three experimental treatments.
Obr. 3. Merania EK pri rôznych hĺbkach pôdy pre tri experimentálne úpravy.

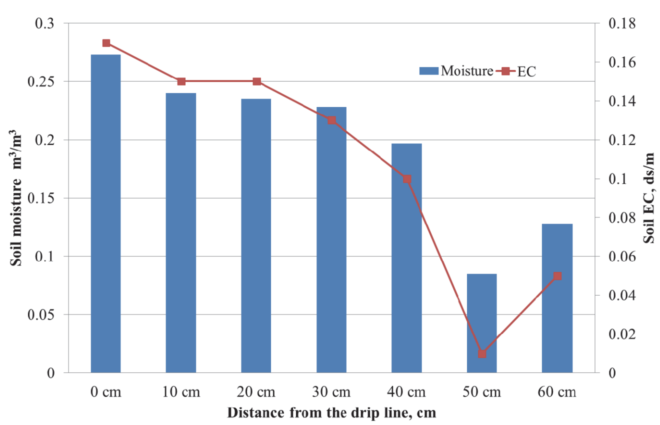

Fig. 4. Spatial distribution of the water and salts contents at different distances to the drip irrigation line (0-30 cm) - measurements with Decagon devices.
Obr. 4. Priestorová distribúcia obsahu vody a solís pri rôznych vzdialenostiach od kvapkovje závlahy (0 – 30 cm) – meranie pomocou zariadení Decagon.

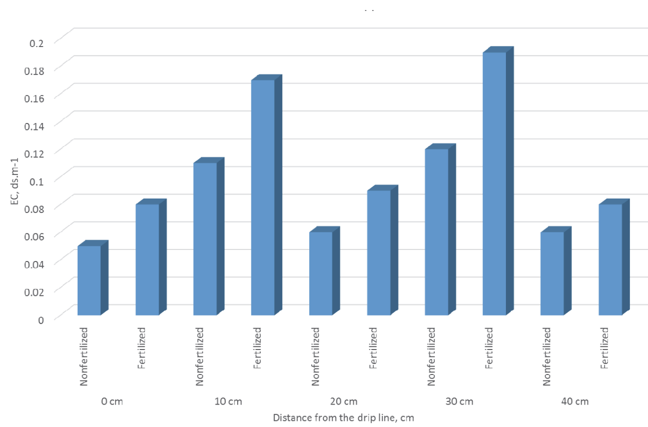

Fig. 5. Electrical Conductivity of the soil after fertilization - treatment with farmyard manure.
Obr. 5. Elektrická vodivosť pôdy po fertilizácii – úprava s kravským hnojom.

Immediately after the irrigation with fertilization, a decrease in the soil water content was observed with a distance to the irrigation line. In both the EC and the salt content measurements, a lateral drift up to 40 cm from irrigation line was observed. This was also the trend in the soil electrical conductivity measurements with the ProCheck, indicating that a direct measurement of the lateral and vertical distribution of fertilizers in the soil is easily obtainable.
Our studies have shown that the application of modern measuring instruments in the field is requirement for farmers engaged in irrigated agriculture.
In the electrical conductivity observations, elevated values were observed after ammonium nitrate fertilization for mineral fertilizer treatments (Figure 5). The spatial changes in the electrical conductivity measurements were observed to be: low under the irrigation line (0 cm), higher at 30 cm distance to the irrigation line and moderate at 40 cm distance. These distributions also corresponded to the distributions of the irrigation water down the soil profile and in a distance to the vegetable crop. At 30 cm distance to the irrigation line, the soil water content usually decreased. Field measurements showed that the best crop location regarding the fertigation was at 20 cm distance to the irrigation line, where the optimal ratio between water and nutrients content was observed.
Consequently, the conducted studies allowed corrections of:
- The irrigation rates;
- The fertilizer rates;
- The location of irrigation lines and the plants.

Thus, the irrigation lines can be arranged according to the plants so that their roots develop in the soil areas with the highest plant available soil water content and the optimum concentration of nutrients.

Conclusion

1. Most of the fertilizers moved along with the wetting front of drip irrigation;
2. The distribution of soil electrical conductivity depended on the movement of irrigation water and dissolved salts in the soil.
3. Planting and irrigation lines disposition should allow the plants being located at location with the optimal soil water and nutrient contents (i.e. highest electrical conductivity).

Acknowledgement

The project "Leaching of the Nitrates in the Soil in the Conditions of Fertigation in Mineral and Organic Fertilisers Application", subject to Contract No. 20/2016 is supported by the Programme for Scientific Research in the University of Forestry, Sofia, Bulgaria

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Voda a dusík sa považujú za hlavné obmedzujúce faktory pre pestovanie zeleniny v Bulharsku. Účinnými metódami na zvýšenie účinnosti vody a výživy v zeleninárstve sú vhodná kvapková závlaha a upravená fertigácia, ktoré môžu znížiť riziko straty živín pomocou lúhovania. Pôdna elektrická vodivosť (EK) je ľahko merateľným, ale spoľahlivým ukazovateľom distribúcie živín v pôde, ktorý významne ovplyvňuje produktivitu plodín.

Cieľom predloženej štúdie bolo preskúmať uplatniteľnosť merania EK ako rýchleho indikátora na optimalizáciu fertigačných parametrov a polohy plodín k zavlažovaniu. Výskum bol vykonaný na aluviálnych piesočnatých pôdach až hlinených pôdach s hrubou textúrou, nízkym obsahom humusu a mierne kyslým pH. Bol uskutočnený jednoročný experiment s cuketou pomocou kvapkovej závlahy a ošetrenia stromovými hnojivami. Experimentálne pole pozostávalo z niekoľkých častí s veľkosťou 60 m^2, ktoré boli upravené nasledovne: 1. kontrola; 2. hnoj; 3. kompost. Pri druhej a tretej úprave sa organické hnojivá aplikovali v nasledujúcich dávkach: hnoj 44 $t.ha^{-1}$; kompost 21 $t.ha^{-1}$. Kompost a hnoj sa aplikovali v rovnakej miere na 340 kg dusíka na hektár, čo zodpovedá množstvám povoleným smernicou EÚ o dusičnanoch. Na 30 m^2 každého pozemku bolo dusíkaté minerálne hnojivo aplikované fertigáciou v množstve 240 kg dusíka na hektár. Vzorky pôdy sa pravidelne odoberali v hĺbkach 0 – 30 cm, 30 – 60 cm a 60 – 90 cm. Na meranie obsahu vody, elektrickej vodivosti a obsahu soli v pôde sa použili snímače ProCheck (Decagon Devices, Inc.), a tak nepriamo hodnotili priestorové rozloženie živín v profile.

Výsledky ukázali, že pohyb dusičnanov veľmi súvisí s pohybom vody, pretože rozpustené soli (dusičnany) sa premiestňujú zospodu do zemného profilu. Priamo pod kvapkovým zavlažovacím potrubím sa obsah vody v pôde pohyboval od 0,235 $cm^3.cm^{-3}$ v hornej 30 cm vrstve na 0,205 $cm^3.cm^{-3}$ pri hĺbke 30 až 50 cm a opäť sa zvýšil pod hĺbkou pôdy 60 cm. Navyše sa zistilo, že lúhovanie dusičnanov sa nachádza tesne pod kvapkovým zavlažovacím potrubím. Najvyššie hodnoty EK sa namerali v hĺbke 40 až 60 cm a 20 cm od zavlažovacieho potrubia, čo naznačuje pohyb dusičnanov v pôdnom profile.

Okrem toho boli merania EK najvyššie na miestach pôdy s najnižším obsahom vody a naopak. Napríklad v oblastiach s vlhkými pôdami bolo EK asi 0,20 $dS.m^{-1}$, zatiaľ čo v oblastiach vysušených pôd dosiahlo EK 0,35 $dS.m^{-1}$ a viac. Preto nameraný obsah vody v pôde negatívne koreluje s elektrickou vodivosťou pôdy. Tieto informácie boli dôležité kvôli tomu, aby sa správne umiestnili zavlažovacie potrubia k rastlinám a aby sa zabezpečil optimálny prístup koreňov k dostupnej vode a živinám v pôde.

Výsledkom bolo, že vykonaná štúdia umožnila korekciu a úpravu použitého zavlažovacieho programu, miery hnojenia a umiestnenia zavlažovacích potrubí k rastlinám. A napokon, používanie modernej meracej techniky v tejto oblasti je nevyhnutné pre pokrok v zavlažovaní zeleniny.

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