

Irrigation and Fertilization Control Trial Using Two Different Drip Irrigation Systems (AutoAgronom and Conventional Drip) in Greenhouse Cucumber Production in Israel

Sretenka Srdić¹, Ivana Koleška¹, Dijana Mihajlović¹, Nabeel Gnayem²

¹ Faculty of Agriculture, University of Banja Luka, Republic of Srpska, BiH

² Fine Seeds R&D filed center, Israel

Abstract

Since agriculture is the highest consumer of water, there are many trials to improve water use efficiency especially in arid countries. Thus, in the world are developed many irrigation techniques that could decrease water use. In this paper is analyzed new irrigation technique (AutoAgronom) used in greenhouse cucumber (two varieties Rocky and Champion) production in order to improve water use in Israel. AutoAgronom is tested against conventional system where drip irrigation was used. AutoAgronom (AA) system follows pH, Electrical conductivity, oxygen level and nitrates on which basis irrigation was done. Obtained results strongly recommend use of AA system in vegetable production. In variety Champion irrigated by AA system (9.167 kg/m²) obtained yield was 20% higher in comparison with the same variety under conventional drip irrigation. Quantity of irrigation water, as well as fertilizers using AutoAgronom system are saved up to 9.7%, while phosphoric acid is saved up to 8.3%.

Key words: AutoAgronom, cucumber, irrigation, nitrates, greenhouse

Introduction

Nowadays agriculture sector is the biggest consumer of water. More than 70% of global withdrawals is engaged in irrigated agriculture, while in some countries more than 90% of water is used for irrigation (Kulkarni, 2011). According to FAO (Food and Agriculture Organization) about 40% of world food is from irrigated agriculture (FAO, 2002). In California on 2003 field crops consumed 63% of the total water, and returning back only 17% of revenue (Cooley et al., 2008), while vegetables consumed 19% of applied irrigation and giving contribution of 39%.

Since Israel has semi-arid climate and lack of available water, scientists have developed a new irrigation system called AutoAgronom. This system is based on systematic and continuous monitoring of irrigation and fertilization processes giving an optimal nourishing to the plants. Optimal fertigation has been done through permanent monitoring of key parameters that are oxygen, soil pH, Electrical conductivity (EC) and nitrates. According to the level of these parameters, decision regarding irrigation requirement could be done precisely. AutoAgronom system is mainly used in drip irrigation of vegetables production, while some experiments show AutoAgronom applicability in field crop and even in orchards. Regarding new techniques that use computerized systems, many of them were developed, but they are not based on following parameters that AutoAgronom system follows. The AutoAgronom system is far more than all other techniques in water and fertilizers saving. This confirms experiments conducted in Israel where water and fertilizer savings could be up to 50% and in the same time yield is increased in range 15-40%.

AutoAgronom system allows control of oxygen and nitrates in the soil as well as pH and EC. It has shown in experiments that cucumber grown under low oxygen level in the root zone had lower development of leaves as well root mass. This experiment indicate that frequent refreshment of nutrient solution increase oxygen volume in the root zone, so it could be as an indicator together with other parameters to improve water and fertilizer management (Holtman et al., 2005). Irrigation scheduling is based on measured data of pH, EC, soil water content and matrix potential. New moisture sensors that measure water content and EC in soil could predict the frequency and volume of irrigation (Pardossi et al., 2009; Dukes et al., 2010). Good results of soil moisture sensors in irrigation management has been documented by many researchers (Munoz-Carpena et al., 2008; Zotarelli et al., 2009). Many countries developed sensors that could be

useful tool to estimate proper irrigation schedule that will give the best results of yield and water saving (France, Israel, Texas USA, The Netherlands) (Pardossi & Incocci, 2011). Despite of developing different sensors for irrigation scheduling, in most developing countries, farmers are irrigating according to their experience. Decreasing water content affect plants growth where water is lost through transpiration causing a loss in turgor. As a defense against water loss, transpiration decreases (Akinici & Lösel, 2012).

The aim of this experiment is to compare AutoAgronom system with conventional irrigation and to test its influence of yield and plant development of cucumber grown in greenhouse in Israel climate conditions combined with saving water and fertilizers.

Material and Methods

The experiment has been conducted in Israel in 2014 at Fine seeds research and development center farm, in Baqa El Garbiya (costal area between Haifa and Tel-Aviv). The trial was conducted in two plastic houses, both with dimensions of 48 m x 9 m giving an area of 430 m². The plastic house is Tunnel shape with maximum height of 4.7 m. The cover material of plastic houses was thermal 120 micron thickness polyethylene. The soil was clay with 48% saturation percentage (SP%) and field capacity reached when tensiometers scale show 130 mbars. Two different drip irrigation systems were used, conventional (C) and AutoAgronom (AA). Two varieties of cucumber (Champion as beit Alpha mini cucumber and Rocky as Baby cucumber) were tested under the two systems. The seedlings are planted in soil without raising beds. In both irrigation systems seedling are planted in double row with 40 cm distance between rows and 40 cm between plants in a row giving plantation density of 2.5 plants/m². In experiment each variety was planted in 5 rows as 5 replicates that includes 560 plants for each plastic house. In conventional system two pipelines in two rows are applied. Drippers were on distance of 20 cm with discharge of 1 l/h giving irrigation depth of 5 mm. The Auto AutoAgronom (AA) greenhouse had one lateral pipe per two rows with discharge of 0.6 l/h giving 2.5 mm irrigation depth. Seedlings were planted in both experiments (C and AA) on 08.02.2014. Plants were grown as vertical high support (2m height) with one main stem where all side branches were pruned to have 1-2 internodes.

Harvest started on 28.03.2014 and ended on 26.05.2014 as total 25 harvests, 1-3 harvest a week. Yield of 5 replication of each variety from

each treatment greenhouse was followed separately on each harvest date to calculate the production of fruits as kg/m². The AA system had sensors for measurement of dissolved nitrates, oxygen in soil, pH and EC, as well as tensiometer placed on 5 cm depth and soil temperature thermometer. All sensors else than tensiometer were located in double layer plastic pot buried in 20 cm depth and filled with the soil. The pot is shown in Picture 1.



Fig 1. Pot with sensors
Saksija sa senzorima

Lower layer of pot collects drained soil water and provide all sensors to measure once every 5 minutes and transmit readings to controller that pass them by cellular modem to PC computer that has the software for irrigation/fertilization program. The program used obtained 30 mbars of average soil reading of tensiometer (5 cm depth) showing maximum 35 and minimum 25 mbars reading. Oxygen reading range was 5-8 ppm, nitraterange was of50-70 ppm, EC range 1-1.5 dS/m and pH range 5.5-6.5. The software controlled the irrigation of 15 liters on each pulse that operated by the controller during 24 hours a day as average of 70-100 times a day. Fertilization of AA is done with irrigation head control that includes 2 mother solution barrels (500 liters each), one include dissolved solid fertilizer 17:10:27 (Nitrogen 17%, 10% P₂O₅, 17% of Potassium) and another has microelements diluted (Fe 1000 ppm, Mn 500 ppm, Zn 250 ppm, Mo 250 ppm, Cu 250 ppm) as 25 kg into 100 liters of tap water.

This solution was injected into irrigation water by TEFEN fertilizers pump in rate of 1-1.5 l/h as the controller ordered. There are online EC and pH on head control to determine the EC and pH in irrigation water. The pH

was controlled by injecting 1-2 liters of 10% solution of phosphoric acid from acid mother solution barrel. Control greenhouse was equipped with separate irrigation and fertilization head control and not sharing with AA, and had 2 mother solutions of 17:10:27 and phosphoric acid as same dilution rates. The injection in pipeline is done by TEFEN pump as 2 l/m³. The timing and the quantity of irrigation were done manually and determined by electronic tensiometers reading placed on 20 and 40 cm depth. This electronic tensiometers are produced by Mottes company system that is capable to broadcasts data by SIM card to web site. This system could be programmed to send sms (text message) and e-mail that are used to determine the timing of irrigation (above 220 mbars on 20 cm depth tensiometer = double than field capacity). The quantity of irrigation water is determined by allowing water to deplete up to 40 mbars (40 cm depth tensiometer). As general we followed the Mottes system in control greenhouse and irrigated once every 2-4 days with 5-10 mm. Fertilizer application was done continuously with every irrigation. In this treatment field kits were used for measuring EC, pH, Cl and Nitrate. Fertilizer and water counters are used to count liters applied in each treatment and for calculation of saved quantities in each treatment.

Soil analysis in laboratory was done once a month including fertility factors (N, P, K, pH, EC, Mg, Ca, Cl, Na, SAR, SP). Statistical analysis of the results has been done using Tukey model of two factors analysis when $p < 0.05$.

Results and Discussion

Average soil parameters based on analysis of three soil sampling is done on three different dates and are shown in table 1. The highest results of analyzed parameters (Table 1) in the soil solution are obtained in the control. The reason for that is lying in a fact that in AA system irrigation has been done with smaller amount of water but more frequently that cause better leaching and less accumulation of salinity represented by Na and Cl.

Accordingly, nutrients concentration in the water that is used for irrigation in AA system was lower than in the control water irrigation. In both plastic houses maximum and minimum daily temperature were measured on which basis is done average monthly temperature for growing season in both treatments and it is shown in the (Table 2).

Tab. 1. Average soil parameters

Prosječni parametri zemljišta

Treatment <i>Tretman</i>	EC	pH	Cl ppm	Na ppm	Mg ppm	Ca ppm	N- NO ₃ ppm	P ppm	K ppm
AA	1.05	7.2	150	72	74	103	104	53	75
Control <i>Kontrola</i>	1.08	7.5	251	85	82	125	172	62	82

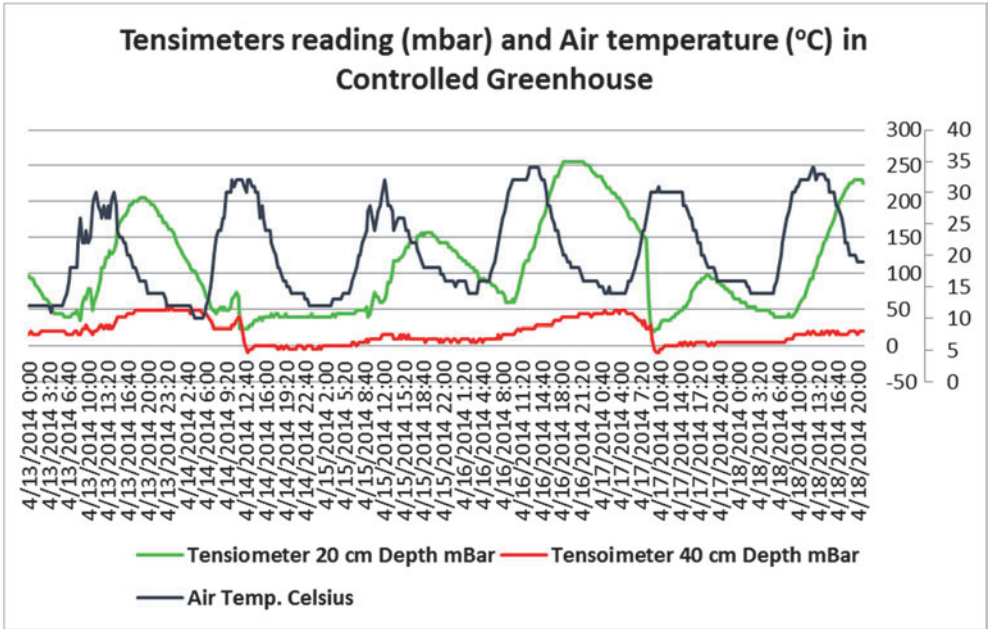
Tab. 2. Average monthly maximum and minimum temperature in plastic houses

Prosječna mjesečna maksimalna i minimalna temperatura u plastenicima

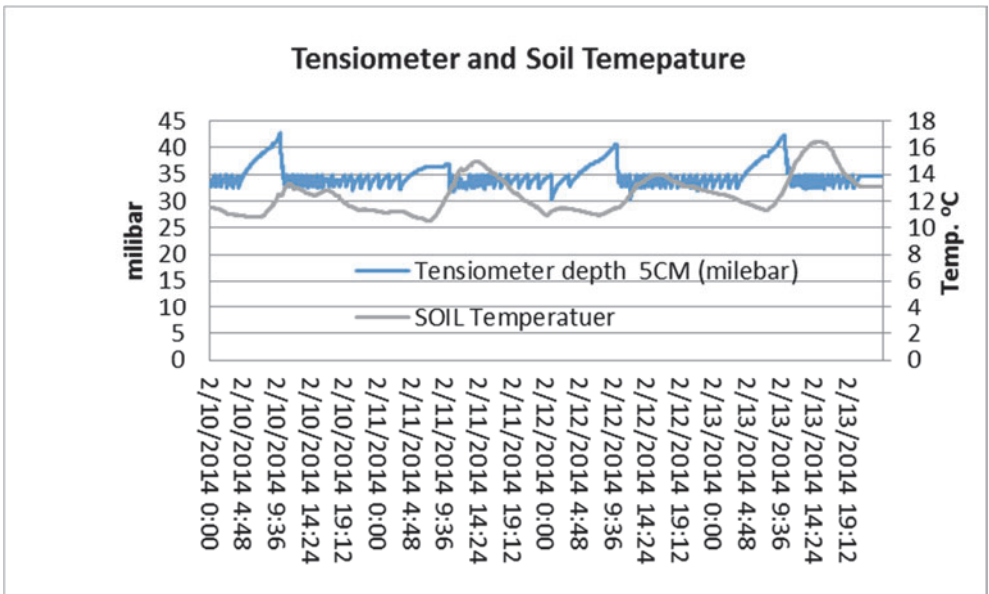
Parameter <i>Parametar</i>	February <i>februar</i>	March <i>mart</i>	April <i>april</i>	May <i>maj</i>
max temp.°C	22	27	29	34
min temp.°C	6	10	12	15

Temperature in plastic houses is gradually increased approaching to final harvest in May. Since cucumber require temperature 22-25° C that is optimal for growth, higher temperature was regulated by ventilation of plastic houses. Tensiometers reading in different soil depths versus air temperature in C treatment is shown in the Graph 1. In this figure we can see the range of temperature during the day and night that is affecting significantly the range of tensiometers reading for both depths, 20 and 40 cm. This graph is showing readings between 13-18 of April in order to show the difference during that period in tensiometers readings. Irrigation frequency was determined by tensiometer placed on 20 cm depth and when the reading was above 200 mbars irrigation was done. Quantity of irrigation was determined by the tensiometer placed on 40 cm depth by ensuring the dropping of reading up to 40 mbars. Thus irrigation was applied with 100 m³/ha every 3 days which is determined by tensiometer on the 20 cm depth. In the Figure 2. is represented tensiometer reading versus soil temperature under AA treatment.

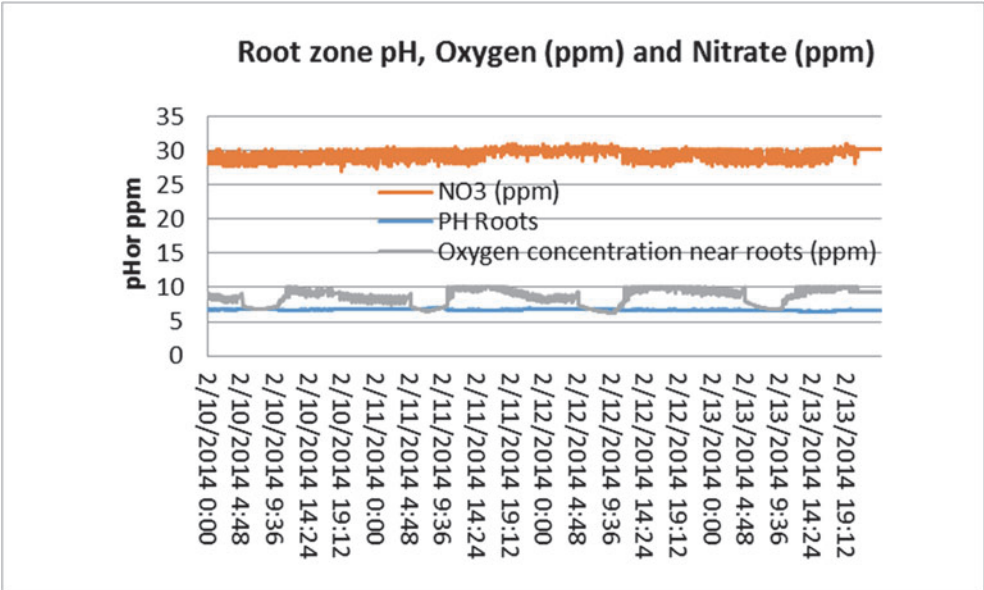
This figure describes the range of tensiometers placed on 5 cm depth in soil. The tensiometer reading is kept above 30 mbars by irrigation frequency done once every 30 minutes. In the Figure 3. pH, Oxygen and Nitrate concentration in the root zone under AA system are presented.



Graph 1. Tensimeters readings versus air temperature in C treatment
Tenzimetarsko čitanje u odnosu na temperaturu vazduha u tretmanu C

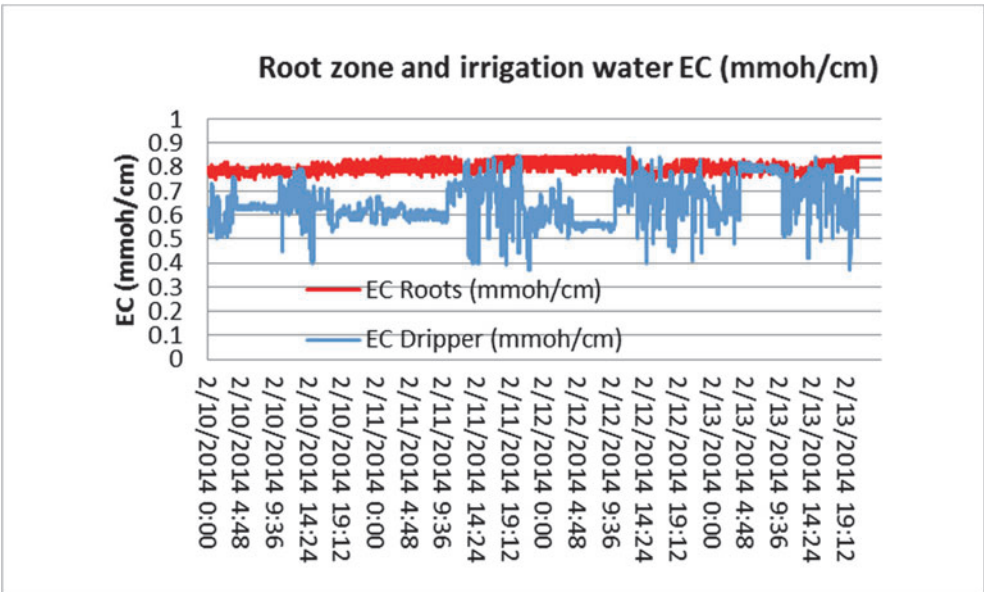


Graph 2. Tensimeters readings versus soil temperature in AA treatment
Tenzimetri čitanja odnosa temperature zemljišta u AA sistemu



Graph. 3. Tensiometers readings of pH, oxygen and nitrate in the root zone under AA system

Tenziometarsko čitanje pH, kiseonika i nitrata u zoni korijena pod AA sistemu



Graph 4. Tensiometers readings of soil and irrigation water EC in AA system

Tenziometri čitanja zemljišta i vode za navodnjavanje EC u AA sistemu

As could be seen from the Graph. 3. pH of the soil in the root zone was kept about 6.7, while nitrates were about 30 ppm and oxygen about 8 ppm. Soil and drip water electrical conductivity (EC) under AA system is represented in the Figure 4.

Electrical conductivity of the soil root zone is kept about 0.8 dS/m and EC of irrigation water in range 0.4-0.8 dS/m. In Picture 2. has shown tensiometers broadcasting under C system. On the left side is tensiometer placed on the 20 cm depth while on the right side is tensiometer placed on 40 cm depth. The white box above is SIM card of cellular transmission.



Fig 2. Tensiometers broadcasting in C system
Emitovanje tenziometara u C sistemu

Total yields of cucumber and yields per month by variety and treatment are shown in Table 3.

In the Table 3. it could be seen that there is significant difference among treatments and varieties. In total Rocky AA yield was significantly higher for 0.887 kg/m² that is 21.9% more than in control. There was obtained significant difference in yield between Champion AA and Champion C, where Champion AA had higher yield for 1.525 kg/m² what is about 20 % greater yield. It could be noticeable that in May there was no significant difference between Rocky AA and Champion C.

Using AA irrigation system water and fertilizers could be saved. In the Table 4. are shown results of water, fertilizers and phosphoric acid savings during experiment. In total its obtained about 10% savings of mentioned parameters with an addition of yield increment about 20%.

Tab. 3. Yield by months and in total (kg/m²)

Prinos po mjesecima i ukupni prinos (kg/m²)

Variety and Treatment <i>Varijetet i tretman</i>	Total yield <i>Ukupan prinos(kg/m²)</i>	April yield <i>Prinos u aprilu (kg/m²)</i>	May yield <i>Prinos u maju(kg/m²)</i>
Rocky AA	4.932C	1.293C	3.639AB
Champion AA	9.167A*	4.589A*	4.579A*
Rocky Control	4.045D	0.942D	3.102B
Champion Control	7.642B	3.179B	4.463AB

A, B, C, D -Significant difference between treatments at level $p < 0.05$

A, B, C, D - Značajna razlika između tretmana na nivou $p < 0.05$

Tab. 4. Irrigation water and fertilizers applied during growing period in both treatments

Količina vode za navodnjavanje i đubriva primijenjeni tokom vegetacije u oba tretmana

Parameters <i>Parametri</i>	Growing period <i>Period rasta</i>		February <i>Februar</i>		March <i>Mart</i>		April <i>April</i>		May <i>Maj</i>	
	AA	C	AA	C	AA	C	AA	C	AA	C
Irrigation water quantity <i>Količina vode za navodnjavanje (l/m²)</i>	210.0	232.5	40.0	42.5	33.5	37.5	51.8	57.5	85.0	95.0
Fertilizers <i>Đubriva 17:10:27+ME (kg/m²)</i>	52.5	58.1	10.0	10.6	8.3	9.4	12.9	14.4	21.3	23.8
Phosphoric acid 82% <i>Fosforna kiselina 82% (cc/m²)</i>	1.1	1.2	0.2	0.2	0.2	0.2	0.3	0.3	0.4	0.5

In Table 4. is presented applied amounts of irrigation water, fertilizers and phosphoric acid where could be seen that the less water is used in AA system in cucumber production. In that way for whole growing period is saved 22.5 l/m² of water in comparison to control that is 9.7%.

Regarding fertilizers savings, in AA system is consumed about 9.6% less fertilizers, that represent 5.6 kg/m². Phosphoric acid is saved in about 8.3%.

Conclusion

In this experiment AutoAgronom irrigation system was tested against controlled drip irrigation in cucumber production. Two varieties of cucumber were used, Rocky and Champion. Obtained results show advantage of AutoAgronom system in yield production, in fertilizers saving as well as in phosphoric acid savings. Among varieties, the highest yield increment is obtained in Champion AA (9.167 kg/m²), which is 20% significantly higher than the yield obtained in control irrigation system (7.642 kg/m²). Regarding variety Rocky, in AA system is obtained 21.9% significantly higher yield. Quantity of irrigation water, as well as fertilizers used in AutoAgronom system are saved up to 9.7%, while phosphoric acid is saved up to 8.3%.

These results highly support AutoAgronom system in vegetables production in regions that are scarce with fresh water such as Mediterranean semi arid region.

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Kontrola navodnjavanja i fertilizacije u plasteničkoj proizvodnji krastavca u Izraelu pri upotrebi dva različita sistema navodnjavanja "kap po kap" (AutoAgronom i konvencionalno navodnjavanje)

Sretenka Srdić¹, Ivana Koleška¹, Dijana Mihajlović¹, Nabeel Gnayem²

¹Poljoprivredni fakultet, Univerzitet u Banjoj Luci, Republika Srpska, BiH

²Fine Seeds R&D filed center, Izrael

Sažetak

Kako je poljoprivreda jedan od najvećih potrošača vode, postoje brojni ogledi kako bi se poboljšala efikasnost upotrebe vode u navodnjavanju, naročito u aridnim regionima. U svetu su razvijene brojne tehnike navodnjavanja kojima se može smanjiti potrošnja vode. U ovom radu je analizirana nova tehnika navodnjavanja (AutoAgronom) u proizvodnji krastavca (dva varijeteta Rocky i Champion) kako bi se poboljšala efikasnost upotrebe vode u Izraelu. AutoAgronom je testiran u odnosu na konvencionalno navodnjavanje, odnosno navodnjavanje kap po kap. AutoAgronom (AA) sistemom se prati pH, električni konduktivitet (EC), nivo kiseonika i nitrati, gde se na ovim merenjima bazira frekvencija navodnjavanja. Dobijeni rezultati preporučuju upotrebu AA sistema u proizvodnji povrća. U proizvodnji varijeteta Champion u sistemu AA, dobijen je 20% veći prinos (9 163 kg/m²) nego kod istog varijeteta navodnjavanog konvencionalno. Upotrebom AA sistema količina vode za navodnjavanje kao i hraniva su smanjeni za oko 9,7%, dok je količina fosforne kiseline smanjena za 8,3%.

Ključne riječi: AutoAgronom, krastavac, navodnjavanje, nitrati, platenik

Sretenka Srdić
E-mail address: sretenka25@yahoo.com

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