Recirculation in Strawberry and Blackberry Soilless Crops: Drain Water Disinfection Systems

M. Torres[1], M. Rodríguez[1], J. Sánchez[1], R. Muñoz[1]

[1]ADESVA - Agrifood Technological Center, Parque Empresarial La Gravera, Avda. Dehesa del Piorno, 1 (21440) Lepe-Huelva

e-mail: mtorres@citadesva.com

INTRODUCTION

Agriculture intensification is generating environmental problems such as surface and ground water pollution and accumulation of chemicals in soil. The range of used nutrients lost to deeper soil layers is 20 to 50% in Europe, being the use of resources still very inefficient. RESFOOD is a project funded under the 7th Framework Program (Fp7), aiming to reuse drainage water in "soilless" cultivation and study the feasibility of two disinfection systems. Trials located in Huelva have been conducted for two seasons at experiential farm of ADESVA. In the first season (2013/2014), the influence of four systems were analyzed in **strawberry soilless crop: NR** (no recirculation), **RND** (recirculation-no disinfected), **RDO** (recirculation disinfected by ozone) and **RDOI** (recirculation disinfected by oxygen ionized). In 2014-15 the trial developed by ADESVA is repeated in order to validate the results and it is carried out a trial in **blackberry soilless crop** in commercial farm. Two different irrigation strategies were applied: drippers of 1 l/h y 0.5 l/h, analyzing also the influence of two systems: **RDH$_2$O$_2$** (recirculation disinfected by oxygen peroxide) y **RDO** (recirculation disinfected by ozone). The results will be obtained in July 2015. Description of disinfection systems:

Ionized oxygen: The charge in the oxygen molecules found in the air produces oxygen ions with positive and negative charges. The oxygen ions thus charged have the property of interchanging rapidly with other oxidizing components found in the air (which may be organic or inorganic substances). Due to the high potential degree of oxidation of charged oxygen ions, the membranes of bacteria, viruses etc. are ruptured and effectively eliminated. The charged oxygen ions react with monocellular organisms. In contrast, they do not have any effect on multicellular, organisms (people, animals).

Ozone is one of the most reactive substances known. It immediately liberates its third oxygen atom to any organic compound and converts back to stable oxygen. The organic compound is oxidized. It destroys on con tact all known bacteria, viruses, spores, yeasts, moulds, microscopic fungi and biofilms (attacking microbial membranes). Oxidation leaves no harmful residues, only oxygen, anddoes not contaminate.

MATERIAL AND METHODS

The tested variety of strawberry was Candonga (season 2013-2014) and Splendor (season 2014-15). Planting density was 96,000 plants/ha. Substrate was coconut Fiber. In the case of blackberry, the tested variety was Loch Tay. Planting density was 3.000 plants/ha and the substrate was coconut fiber with perlite. The size of the elemental plot is 25 plants and the experimental design of randomized complete block with three replications. The climate data were monitoring along two cycles, through a meteorological station located near of experimental plot. In the case of strawberry crop, pH and electrical conductivity control station was used to control irrigation and drainage which was installed in the "No Recirculation" trial.

Furthermore, Irrigations and drainages volumes were monitored along the season. Moreover, another probe was inserted in the substrate sack with the capacity to measure its EC, temperature and humidity. In the case of blackberry crop, a humidity, temperature and conductivity probe was set up in each kind of dripper. It also was monitored the volume of irrigation and drainage.

For both crops, It was calculated fertilizer unities (kg/ha) and water consumption (m3/ha), evaluating the irrigation and drainage evolution. Furthermore, yield and quality of fruit was studied measuring the following parameters: early production, first and second category production, total production, vigour, average weight, firmness and °Brix. Pathogens analyses were also carried out in periodic samples in ADESVA´s experimental plot and commercial farm. In strawberry crop (season 2013-14), 2 samplings of water (in the last month of the season), 4 samplings of fertilizer solution (from the fertilizer tanks of each thesis), 2 samplings of non-disinfected drainage (from the drainage obtained after an irrigation at the ends of the crop lines) and 2 samplings of disinfected drainage (from drainage after being recirculated and disinfected by both disinfection systems installed, ozone and oxygen ionized)

The following pathogens were analysed: Aerobic mesophilic bacteria, Coliforms (MPN/100 ml), E. coli (MPN/100 ml), Salmonella, Moulds (CFU/ml), Yeasts (CFU/ml) and Pseudomonas spp. (CFU/ml). In the case of the "recirculation with no disinfection" system, the drainages, once pumped, were introduced directly into the fertilizer solution tank (RND), where they were mixed with clean water and with the fertilizer ingredients (from the mother solution tanks) to finally produce the designed nutritive solution (which was corrected for each new irrigation). In the "recirculation with disinfection by ionized oxygen and by ozone" theses, the drainages were previously conducted to another tank (drainage tank) where they were disinfected, and subsequently introduced into the fertilizer tank (RDIO and RDO) to follow the same procedure already mentioned before. The data were subjected to statistical analysis of variance (ANOVA), or Kruskall-Wallis or Mood´s median (medians separation P<0.05). It was used statistical software, MINITAB.

RESULTS

Tape irrigation (l/h and l.m.)	Early production (t.ha^{-1})	1st category (t.ha^{-1})	2nd category (t.ha^{-1})	Total production (t.ha^{-1})	Fruit average weight (g/fruit)	Vigour of the plant (cm)	% 2nd category
RDOI	22.78 a	47.36 a	7.53 a	54.89 a	18.51 a	21.64 a	13.72
NR	17.15 b	42.23 a	6.91 a	49.14 a	19.59 a	21.29 a	14.06
RND	17.27 b	40.24 a	6.94 a	47.18 a	17.69 a	23.94 a	14.71
RDO	18.71 b	45.90 a	8.09 a	53.99 a	20.40 a	21.16 a	14.98

Fig. 1 Parameters associated to strawberry crop production

Fig. 4
a Datalogger
b Control station
c Control kit (2 per station).

Cultivation system	Total m3/ha	Production(kg/ha)	Water footprint (l/kg)
NR	4900	49136 a	99
RND	2540	47180 a	53
RDIO	2585	54891 a	47
RDO	2578	53990 a	47

Fig. 2 Parameters associated to strawberry fruit quality

Month	Irrigation (litres)	Drainage (litres))	Drainage (%)
December	216.4	105.2	48.61
January	167.2	44.0	26.32
February	291.6	108.8	37.31
March	540.8	196.4	36.32
April	682.4	179.2	26.26
May	1914.4	767.6	40.1

Fig.3 Average monthly data for irrigation and drainage volume

Tape irrigation (l/h and l.m.)	Total sugar (ºBrix)	Firmness (g.cm^{-2})
RDIO	8.5 a	528.80 a
NR	8.9 a	544.04 a
RND	8.6 a	564.87 a
RDO	8.3 a	575.53 a

Fig. 5 Water consumption and water Footprint in strawberry

Note: Different letters mains significant statistical differences. ANOVA (P< 0.05)

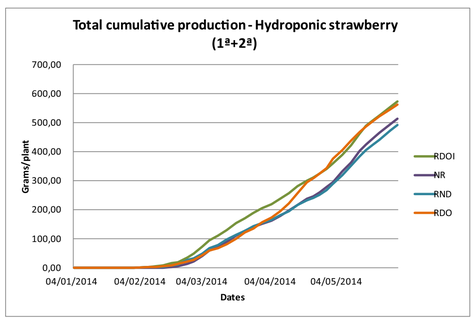

Fig. 6 Temporal evolution of total production over the course of the season

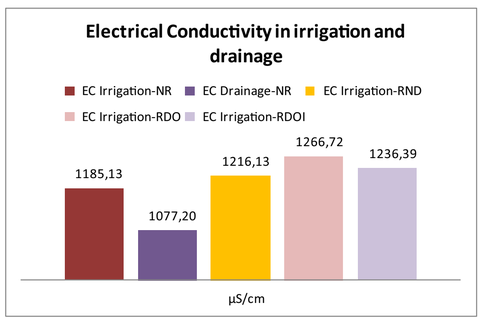

Fig. 7 Electrical Conductivity in irrigation water and drainage

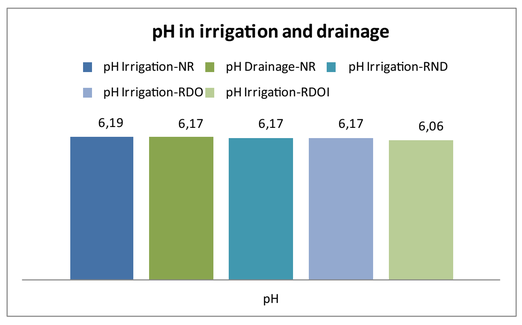

Fig. 8 pH of irrigation water and drainage

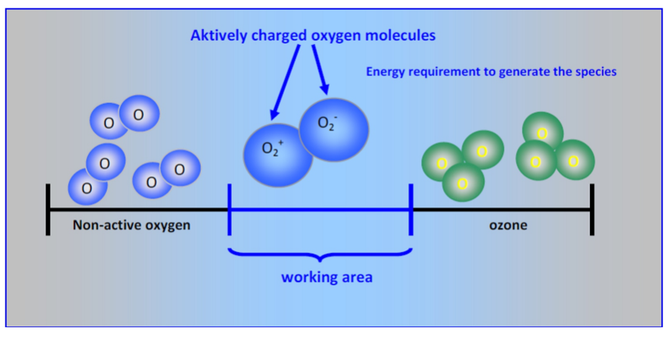

Fig. 9 Working area for natural oxidation

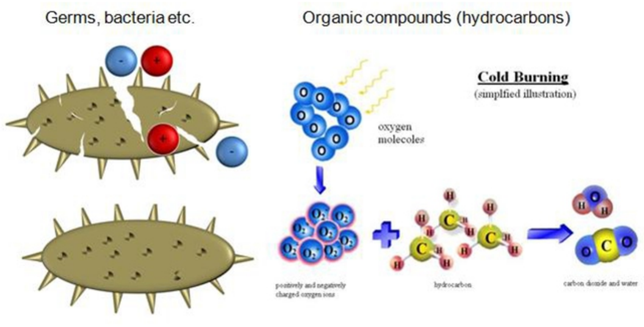

Fig. 10 Reaction: characteristics of the charged oxygen ions

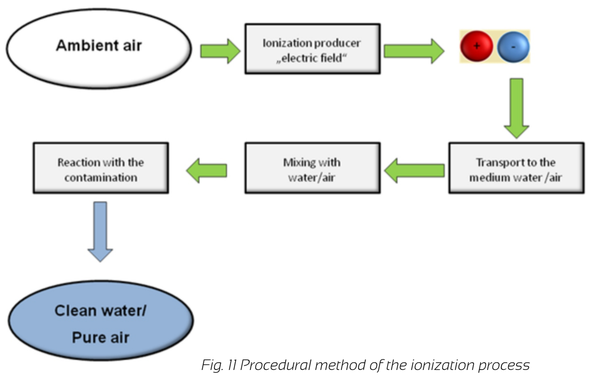

Fig. 11 Procedural method of the ionization process

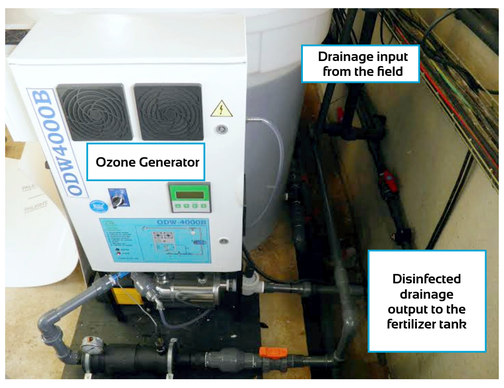

Fig. 12 Ozone system

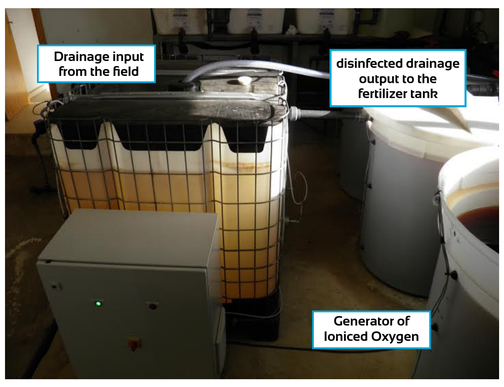

Fig. 13 Ionized oxygen system

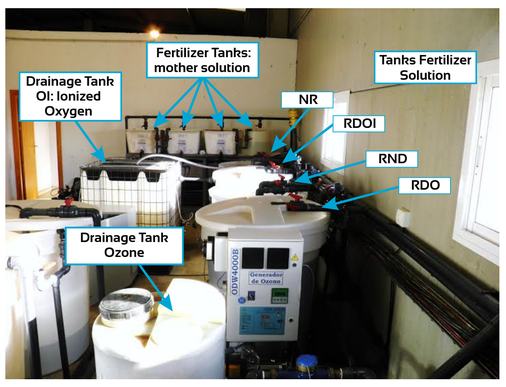

Fig.14 Irrigation house

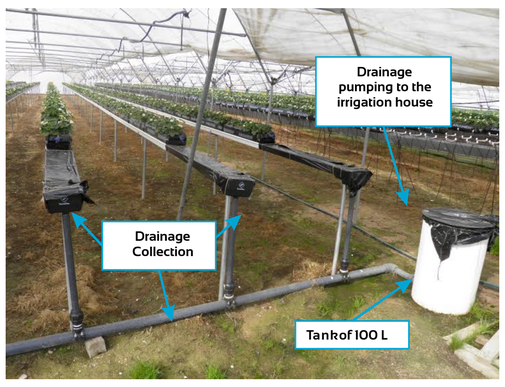

Fig. 15 Drainage collection tank

DISCUSSION AND CONCLUSION

RESFOOD project development in Huelva (Spain), used a total of 4 soilless cultivation systems: no recirculation, recirculation without disinfection, recirculation with disinfection by means of ionized oxygen and recirculation with disinfection through ozone - in real field conditions - with the goal of finding the most suitable and profitable solution for crop performance.

In the present trial there was an efficient management of resources in the cultivation of strawberries by means of the use of climatic data, tools which have made it possible to obtain information on the humidity and dynamics of the water in the substrate and percentage of drainages after irrigations and data obtained from the analysis of macronutrients and micronutrients in the fertilizing solution, drainages, substrate and leaf, as well as from the analysis of pathogens. The average percentage of drainage reached over the course of the whole strawberry season was 36%. These values are within those recommended in soilless cultivation, thus avoiding the reconcentration of salts in the substrate which could upset the normal functioning of the cultivation.

From analysis of the parameters of vigour of the plants, early production, 1st category production, 2nd category production, total production, average weight, °Brix and firmness of the fruit, it was concluded that the only significant statistical differences, at a confidence level of 95%, between the four systems are in early production, the greatest being in recirculation with disinfection by ionized oxygen.

For the rest of the parameters, whether associated with production or with quality, the plants showed similar agronomic behavior in all four systems studied. The concentrations of nutrients in the fertilizing solutions were lower than designed, which had a negative effect on crop yield, so that this was lower than expected in all four soilless cultivation systems.

In the recirculation systems a manganese deficiency appeared in the leaves and Cl- and Na+ ions reconcentrated in the drainages, but in this season it was not necessary to do "purges" (emptying part of the contents of the fertilizer tanks) in any of the three recirculation systems, as there were no recorded atypical electrical conductivity or pH values which might represent a risk to the normal functioning of the strawberry plants.

In general no differences were observed in the microorganism count in the drainages before and after the disinfection system, leading to the deduction that both the ozone and the ionized oxygen treatments were not sufficiently effective under the conditions of this study due to the low intensity in the treatment of both systems maintained over the course of the trial, as well as, in the case of the ozone machine, the short exposure time of the drainage to the O3.

Neither were there important appreciable differences between the disinfection systems and the other two systems: "no recirculation" and "recirculation without disinfection". It should be borne in mind that from April onwards, in the systems where there was no disinfection system installed and due to the drip feed clogging problems which appeared in them, hydrogen peroxide was added at 50%, at a maintenance dosage, which might also have had an effect on the pathogens.

The three recirculation systems (recirculation with no disinfection, recirculation with disinfection by ionized oxygen and recirculation with disinfection by ozone) consumed approximately half the water of the non-recirculating system. The electrical consumption of each of the disinfection systems recorded indicates that the ozone system consumed approximately 80% less energy while obtaining very similar results both in pathogen control and in fruit yield and quality, except in "early production", which was significantly superior with ionized oxygen. It was carried out an adjustment to the both disinfection system installed by ADESVA in season 2014-15 (ozone and ionized oxygen) to achieve the completed elimination of pathogens.