Analysis of the electric conductivity and pH behaviors in recycled drainage solution of rose cv. Charlotte plants grown in substrate

Análisis del comportamiento de la conductividad eléctrica y el pH en el drenaje reciclado en rosa cv. Charlotte cultivada en sustrato

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ABSTRACT

In open soilless cropping systems contamination from nutrient lixiviation is generated making it necessary to design closed or semi-closed systems, which require the determination of the maximum saline levels in recycling solutions. In this study, the electric conductivity (EC) and pH behaviors were analyzed in drainage solution intended for recycling in the crop; in addition, parameters were used to estimate nutrient availability for the plants in a substrate based cropping system. This research project was carried out under greenhouse conditions in the municipality of Mosquera (Colombia). Rose cv. Charlotte grafted on 'Natal briar' stocks were used, sown in pots arranged on elevated beds, 15 m in length. This project was carried out using a split-plot design with sub-plots (with the substrate as the main plot and the recycling as the sub-plot), three kinds of substrate and three recycling percentages (0, 50, and 100%), for a total of 27 experimental units. Substrate mixtures based on burned rice husk and coconut fiber were used. Recycling during one harvest cycle of the roses did not show EC and pH values above those that are considered to have a negative impact on production; however, an increasing behavior in the EC and pH values was observed. Likewise, no significant differences between the 50 and 100% recycling were observed, which means 100% recycling can be used, optimizing nutrient use and water conservation.

Key words: soilless cropping, closed systems, nutrient recycling, organic substrates, cutting flowers.

RESUMEN

En los sistemas de cultivo sin suelo abiertos se genera contaminación procedente de la lixiviación de nutrientes, por lo que es necesario plantear sistemas cerrados o semicerrados que exigen determinar los niveles salinos máximos de las soluciones recirculantes. En el presente trabajo se analizó el comportamiento de conductividad eléctrica (CE) y pH en el drenaje a reciclar en el cultivo, como parámetros estimadores de la disponibilidad de nutrientes para las plantas en un sistema de cultivo en sustrato. La investigación se llevó a cabo en condiciones de invernadero en el municipio de Mosquera (Colombia). Se utilizaron plantas de rosa cv. Charlotte injertadas sobre 'Natal briar', sembradas en materas dispuestas en camas suspendidas de 15 m de longitud. La investigación estuvo enmarcada en un diseño de parcelas con subparcelas, teniendo como parcela principal el sustrato y subparcela la recirculación: tres tipos de sustrato y tres porcentajes de recirculación (0, 50 y 100%), para un total de 27 unidades experimentales. Se utilizaron mezclas de sustratos a base de cascarilla de arroz quemada y fibra de coco. La recirculación durante un ciclo de cosecha de rosa no alcanzó valores de CE y pH superiores a los que se estiman tienen un efecto negativo sobre la producción; sin embargo, se observó un comportamiento ascendente en los valores de CE y pH, así mismo entre el 50 y 100% de recirculación no se evidenciaron diferencias significativas, lo que permite mantener un 100% de recirculación optimizando el uso de nutrientes y el ahorro de agua.

Palabras clave: cultivo sin suelo, sistemas cerrados, reciclaje de nutrientes, sustratos orgánicos, flor de corte.

Introduction

Soilless cropping has seen significant expansion due to the advantages it offers in controlling and optimizing the conditions surrounding roots. However, this cropping system, especially in open systems with solution loss, generates contamination due to nutrient lixiviation. In order to maintain acceptable salinity levels in the root media, an open cropping system with substrate requires drainage at over 20% of the applied fertigation (Lorenzo *et al*., 1993). The contribution generated by these leachates to the system shows contamination sources of 2,500 kg ha^{-1} just in the case of nitrates (Caballero and Cid, 2002). Closed systems are those in which the drained solution is again incorporated, totally or partially, as a supply for the fertigation of the same crop (Urrestarazu and Salas, 2004).

In general, water losses in traditional soil based crops and soilless open crop systems are produced by both drainage and evapotranspiration, while the only water loss of

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quantitative importance in systems with recirculating nutrition solution is due to evapotranspiration (Esmeral *et al*., 2011).

The disposal of part of the drained saline solution becomes as a middle point between open and closed systems. The criteria for total or partial renovation are diverse but it can be carried out when the EC reaches a limit value that is acceptable for correct plant development or when any individual component of an undesirable salt exceeds its limit, which makes it toxic (Urrestarazu and Salas, 2004).

The concentration of salts in irrigation water constitutes the main limitation of recycling. Prior desalination implies the dumping of waste in addition to the economic cost and even then contamination still persists and water loss is still similar. Current strategies for reducing underused water and fertilizer quantities include the collection and reuse of recycled drainage water in closed or semi-closed systems, which reduces the applied quantities of irrigation water and optimizes application of fertilizers (Lorence and Heinrich, 2003).

In this system, it has to be considered that an increase in substrate salinity reduces the growth rate of stems (Lorence and Heinrich, 2003), which has a direct effect on quality because longer stems result in higher market prices. It is necessary to maintain pH around 5.5 - 5.8 and sodium in proportion to the ratio of the total cation content, as well as chloride in proportion to the ratio of the total anion content. Altland and Buamscha (2008) found that phosphorus uptake was not diminished by a pH between 4.8 and 9.2, but they considered that elements such as calcium, boron, iron and aluminum were affected by the increase in pH. This requires increasing nutrient levels in the solution as the concentration of undesirable ions (sodium and chloride) present in the irrigation water increases, as well as supplying the necessary ammonium for maintaining a stable pH in the root environment.

Under adequate environmental conditions (T < 30°C and RH > 60%) roses cv. Jaguar can tolerate up to 15 mmol L^{-1} of chlorides and slightly higher sodium levels without sustaining a substantial decrease in productivity as long as the solution has a pH between 5.5 and 6.0, a good calcium level (2.5 µmol L^{-1}) and adequate proportions of the remaining anions and cations. This is why it is necessary to discard the recycling solution when its chloride or sodium content is 15 µmol L^{-1}, which would imply an EC of 3.5 dS m^{-1} under experimental conditions (Caballero and Cid, 2002).

EC is an estimating parameter for the total concentration of salts and has to be maintained during the cropping cycle (Carrasco *et al.,* 2007). Depending on the species and EC of the water used to prepare the solution, the required range for adequate crop growth is between 1.5 and 3.0 dS m^{-1} (Carrasco and Izquierdo, 1996). Urrestarazu and Salas (2004) recommend taking into account ions such as nitrates and potassium, which come out of balance during the recycling process.

The objective of this study was to analyze the electrical conductivity and pH behaviors in drainage water solution that was recycled from a rose crop cv. Charlotte grown in substrate, taking into account the changes during the cropping cycle due to recycling of leachates.

Materials and methods

This research project was carried out under greenhouse conditions in the municipality of Mosquera, Colombia, which is located at 74.2° W and 4.7° N, at 2,556 m a.s.l., with 80% relative humidity and an average annual precipitation of 645 mm and temperature of 14.7°C. This zone is located in the middle-high basin area of the Bogota River with the characteristics of a Low Montane Dry Forest life zone (LMdf).

Rose plants of variety Charlotte grafted on 'Natal briar' stocks were used, sown in 8 L capacity pots on 12 m^2 elevated beds (15 x 0.8 m) with a plant separation of 0.16 m between plants, for an approximate density of 7 plants/m^2 in the greenhouse.

The trial was composed of nine treatments, where plants were grown in substrates and subjected to three recycling percentages, as shown on Tab. 1.

Fertigation and recycling system

A drip irrigation system with self-compensated drippers spaced at 30 cm, four outlets (two per pot) and flow volume of 0.7 L min^{-1} was used. A reservoir, house with filtration and fertilizer injection system (venturi type injectors), solenoid valves and irrigation controller were available, which guaranteed an automatized fertigation system.

The fertilizers used during the research project were provided by a company with the following formula (mg L^{-1}): N, 113.3; P, 10.0; K, 42.9; Ca; 73.3; Mg 30.8; S, 23.5; Mn, 0.66; Zn, 0.33; Cu 0.33; Fe, 2; B, 0.33; and Mo, 0.06. EC of 1.81 and pH of 5.83.

TABLE 1. Assessed treatments in roses plants cv. Charlotte grown in substrates based on rice husk and coconut fiber with recycling of drainage water solution.

Treatment	Substrate	Recycling (%)
35BRH-0R	35% burned rice husk plus 65% coconut fiber	0
35BRH-50R		50
35BRH-100R		100
65BRH-0R	65% burned rice husk plus 35% coconut fiber	0
65BRH-50R		50
65BRH-100R		100
100BRH-0R	100% burned rice husk	0
100BRH-50R		50
100BRH-100R		100

The recycling system consisted of three parts (Fig. 1). The first one consisted of the beds in the field, which were built elevated from the ground with a double container and plastic gutters in the lower part in order to collect and lead drainage water solution to the measuring containers located in front of each bed. The second part consisted of a series of pipes, which by means of gravity, led the drainage water solution from each bed of the crop to the recycling house. The system design considered the lead of the drainages of the three repetitions of each and every one of the treatments that recycled 50 and 100% to a tank in the recycling house for a total of six tanks in this area. The drainage from the treatments with 0% recycling was led by gravity to an open well that was also located in the recirculating house, after which it was pumped out of the trial area. The third part was located in the recirculating house and was the automatized phase, which was equipped with specialized hardware and software, as described by Cuervo *et al.* (2011).

Measured variables

Every day, between 7:00 and 8:00 AM, the drainage volume of each experimental unit (corresponding to the day before) was measured and samples were collected for determining EC and pH.

Global radiation, *PAR* and temperature were also measured using a HOBO meteorological station located in the crop field. Temperature data was recorded every 30 min, giving a total of 48 measurements per day, which were averaged out to obtain the mean daily temperature.

Experimental design

This study was carried out using a split-plot design with sub-plots, three substrate mixtures, and three recirculating percentages, each one with three repetitions for a total of nine treatments and 27 experimental units. The experimental unit consisted of one 12 m^2 bed. The data analysis was carried out using the SAS® v9.1 statistical package (SAS Institute, Cary, NC). Pearson's correlation coefficient was determined for the information analysis, considering the values with over 15% correlation as significant, with significance under $P \leq 0.05$. A correlation analysis was carried out in a general way and by grouping the data by the phenological development stage of the flowering stems (Cáceres and Nieto, 2003).

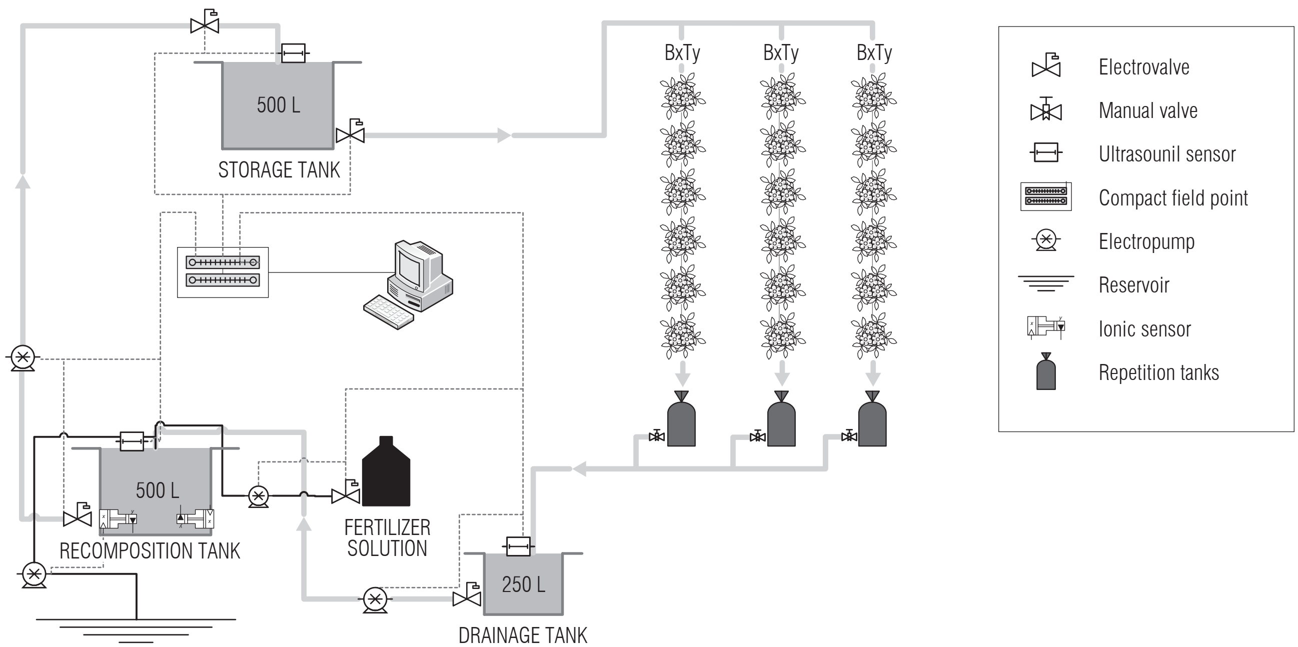

FIGURE 1. Schematic representation of the automatic drainage recirculating system for one treatment with three repetitions. * B = Block, x = Repetition (1, 2 and 3), T = Treatment, and y = 1, 2,...9.

Results and discussion

EC and pH behaviors by substrate and recycling percentage

Figure 2 shows the mean EC and pH behavior per week for the treatments corresponding to substrate 35BRH. As expected, the highest EC values during the crop production peak were found in the treatments with 50 and 100% recycling (Fig. 2A). Meanwhile, the highest values were reached with 100% recycling starting at the pea size stage. On the other hand, the highest pH values were reached with 50% recycling (Fig. 2B).

Unlike the previous substrate, the highest EC values in the 65BRH substrate were reached with 50% recycling (Fig. 3A). However, in both mixtures, the values did not exceed 2.8 dS m^{-1}, which does not imply negative effects on crop production. Similar to substrate 35BRH, the lowest values were registered in the treatment with 0% recycling and at the primordium and rice size stages (Fig. 3B). It can also be observed that this variable, with 50 and 100% recycling, showed a similar behavior during the cropping cycle.

Figure 4 shows the behavior of the mean EC and pH per week for the treatments with 0, 50 and 100% recycling for substrate 100BRH. Similar to the observations in the 35BRH substrate, the highest EC value during the crop production peak was found in the 100BRH-100R treatment and the lowest one in the 100BRH-0R treatment (Fig. 4A). The highest mean EC value did not exceed 3.5 dS m^{-1}, but in some field measurements and on specific days values close to 3.8 dS m^{-1} were registered in the beds located at the margins of the crop, under high luminosity and temperature conditions, and, as a result, during days with low drainage.

The obtained EC values in the drainage water of the substrates do not seem to have negative effects on the production, because, as Carrasco and Izquierdo (1996) stated, the EC range required for an adequate crop growth lies between 1.5 and 3.0 dS m^{-1}, depending on the species and EC of the water used to prepare the solution. On the other hand, Caballero and Cid (2002) stated that it is necessary to discard the recycling solution when its chloride or sodium content is 15 μmol L^{-1}, values that imply an EC of 3.5 dS m^{-1} under experimental conditions.

Figure 4B shows the weekly behavior of the mean pH. Similar to the EC, the highest pH value during the crop production peak was observed in the 100BRH-100R treatment and the lowest one in the 100BRH-0R treatment, while the 100BRH-50R treatment showed an intermediate behavior. The three recycling percentages maintained similar trends during the cropping cycle in the three assessed substrates and registered the lowest values between the primordium and rice size stages.

Analysis of EC and pH by substrate and recycling percentage

Table 2A shows the statistical analysis carried out for the substrates without taking into account the recycling percentages. The EC did not show significant differences in any of the analyzed phenological stages, while the pH

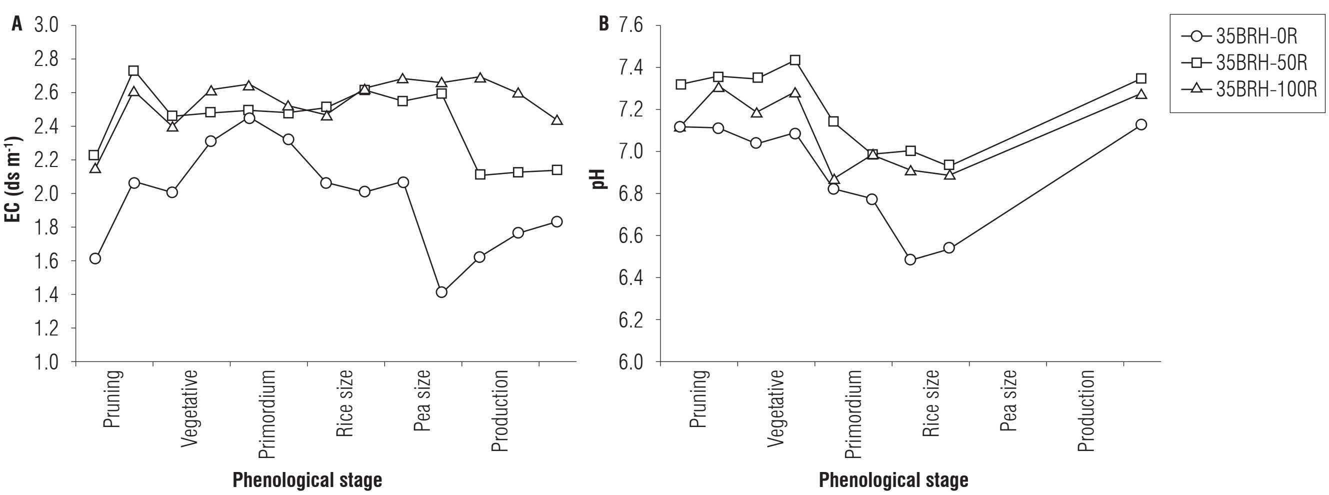

FIGURE 2. Behavior of mean EC (A) and pH (B) in drainage water solution measured at different phenological stages of flowering stems in rose cv. Charlotte grown in the 35BRH substrate, using three drainage recycling percentages. 35BRH-0R = 35% burned rice husk, 65% coconut fiber, with 0% recycling; 35BRH-50R = 35% burned rice husk, 65% coconut fiber, with 50% recycling; 35BRH-100R = 35% burned rice husk, 65% coconut fiber, with 100% recycling.

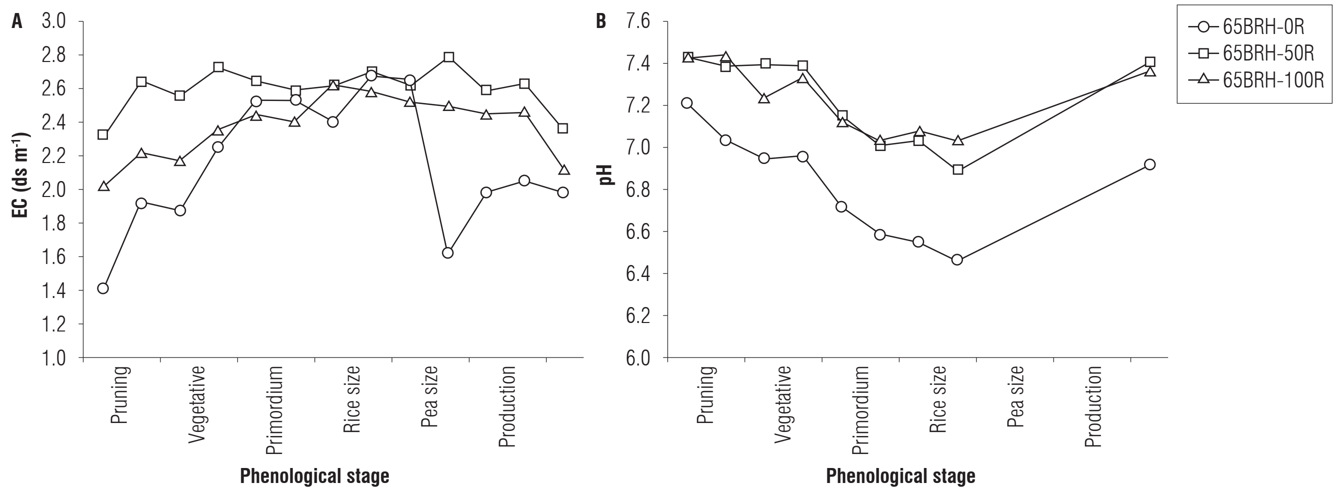

FIGURE 3. Behavior of mean EC (A) and pH (B) in drainage water solution measured at different phenological stages of flowering stems in rose cv. Charlotte grown in the 65BRH substrate, using three recycling percentages for drainage. 65BRH-0R = 65% burned rice husk, 35% coconut fiber with 0% recycling; 65BRH-50R = 65% burned rice husk, 35% coconut fiber with 50% recycling; 65BRH-100R = 65% burned rice husk, 35% coconut fiber, with 100% recycling.

values showed significant differences in the initial and final vegetative stages as well as the pea size stage and during production, showing lower values in the 100BRH substrate in these four stages. As a result, the pH values tended to be lower in the 100BRH treatment, as compared with the other substrates.

The statistical analysis of EC and pH carried out for the recycling percentages without taking into account the substrate showed significant differences in the different phenological stages (Tab. 2B). For both variables, the 0% treatment showed lower values than with 50 and 100% recycling, while no significant differences were encountered in EC or pH between these two recycling percentages.

Relationship between EC and pH and climatic variables

In order to relate climate variables with evapotranspiration and the behavior of the chemical variables of the drainage water, a correlation analysis between pH, EC, temperature, global radiation (GR) and photosynthetically active radiation (*PAR*) was carried out.

From the statistical comparisons and correlations between climatic variables, correlations of 78 and 82% were found respectively between temperature and GR and *PAR*. Therefore, only temperature was used for the statistical analysis with the remaining variables in order to avoid bias in the statistical model.

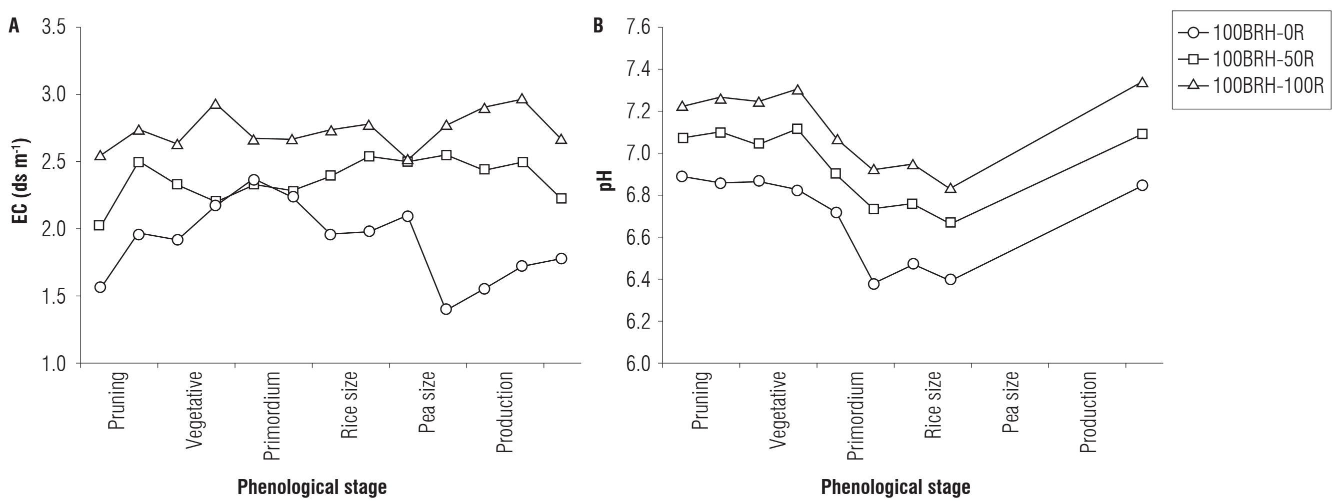

FIGURE 4. Behavior of the mean EC (A) and pH (B) in drainage water solution measured at different phenological stages of flowering stems in rose cv. Charlotte grown in the 100BRH substrate, using three recycling percentages for drainage. 100BRH-0R = 100% burned rice husk with 0% recycling; 100BRH-50R = 100% burned rice husk with 50% recycling; 100BRH-100R = 100% burned rice husk with 100% recycling.

Table 3 shows the results from the general and grouped analysis by the phenological stages. For the general analysis of correlations involving mean and maximum temperatures, drainage volume and evapotranspiration showed a significant positive correlation, EC showed a positive and significant correlation with mean temperature, while the correlation with pH was negative and significant. In the analysis by phenological stage, the EC showed a positive correlation with maximum temperature at vegetative stage 4. The highest correlation values between evapotranspiration and maximum temperature were established when they were grouped by phenological stage.

TABLE 2. Mean EC and pH values of drainage water solution measured at different phenological development stages of flowering stems of rose cv. Charlotte grown in three types of substrate, using different drainage recycling percentages. Analysis by substrate without considering the recycling percentage in A, by for recycling percentage without considering the substrate in B.

A. Analysis by substrate						
Phenological Stage	**EC**			**pH**		
	35BRH	**65BRH**	**100BRH**	**35BRH**	**65BRH**	**100BRH**
Pruning	1.99 a	1.92 a	2.05 a	7.18 a	7.36 a	7.06 a
Vegetative 1	2.47 a	2.25 a	2.40 a	7.26 a	7.29 a	7.08 b
Vegetative 2	2.29 a	2.20 a	2.30 a	7.18 a	7.19 a	7.05 a
Vegetative 3	2.47 a	2.44 a	2.44 a	7.26 a	7.23 a	7.08 a
Vegetative 4	2.53 a	2.54 a	2.47 a	6.94 a	7.00 a	6.90 b
Primordium	2.44 a	2.50 a	2.41 a	6.91 a	6.88 a	6.68 a
Rice size	2.35 a	2.54 a	2.38 a	6.79 a	6.89 a	6.73 a
Pea size	2.42 a	2.65 a	2.45 a	6.78 a	6.80 a	6.63 b
Chickpea size	2.44 a	2.60 a	2.38 a	-	-	-
Breaking of color	2.22 a	2.30 a	2.25 a	-	-	-
Production	2.14 a	2.15 a	2.23 a	7.24 a	7.23 a	7.10 b

B. Analysis by recycling percentage						
Phenological stage	**EC**			**pH**		
	0%	**50%**	**100%**	**0%**	**50%**	**100%**
Pruning	1.53 a	2.19 b	2.24 b	7.07 a	7.27 b	7.25 b
Vegetative 1	1.98 a	2.62 b	2.52 b	7.00 a	7.28 b	7.34 b
Vegetative 2	1.94 a	1.94 a	2.40 a	6.95 a	7.26 b	7.22 b
Vegetative 3	2.25 a	2.47 a	2.63 a	6.96 a	7.31 a	7.31 a
Vegetative 4	2.45 a	2.50 a	2.59 a	6.75 a	7.07 b	7.02 b
Primordium	2.37 a	2.45 b	2.53 b	6.58 a	6.91 b	6.98 b
Rice size	2.15 a	2.51 b	2.61 b	6.50 a	6.93 b	6.98 b
Pea size	2.22 a	2.62 b	2.67 b	6.46 a	6.83 b	6.92 b
Chickpea size	2.28 a	2.56 b	2.57 b	-	-	-
Breaking of color	1.48 a	2.65 b	2.65 b	-	-	-
Production	1.87 a	2.25 a	2.41 a	6.96 a	7.28 b	7.33 b

Means followed by the same letter in a row do not show significant statistical differences for Tukey's test ($P \leq 0.05$).

TABLE 3. General correlation coefficient and correlation coefficient by group at different phenological stages between maximum and mean temperatures and the variables: drainage volume (DV), evapotranspiration (ET), EC and pH. Cycle of rose cv. Charlotte grown in substrates during the period from March to June 2009.

		Maximum temperature				**Mean temperature**			
		DV	**ET**	**EC**	**pH**	**DV**	**ET**	**EC**	**pH**
General		0.40261*	0.30459*	0.02852	-0.03988	0.56937*	0.22430*	0.14507*	-0.21287*
Phenological stage	Vegetative 1	0.69059*	0.11562	0.15460	0.00644	0.69430*	0.16417	0.27205*	0.07958
	Vegetative 2	0.68418*	0.06468	0.06332	0.08531	-0.85147	0.06468	0.01106	0.25423
	Vegetative 3	-0.54356	0.47710	0.09495	0.03155	0.54951*	0.60288*	0.04452	0.08954
	Vegetative 4	-0.07154	0.62385*	0.36915*	0.00134	0.18339*	0.62709*	0.25568*	-0.0558
	Primordium	0.27660*	0.66040*	0.01607	-0.06675	0.44844*	0.46632*	0.12954	0.04362
	Rice size	0.22912*	0.58764*	0.06019	-0.02371	0.32313*	0.36195*	0.10679	0.05328
	Pea size	0.25732*	0.12996	0.04187	-0.01543	-0.09307	0.24817	0.08588	0.01543
	Chickpea size	0.35548*	0.26425*	0.19451	-	-0.41105	-0.41508	0.02106	-
	Breaking of color	0.16895*	0.17140	0.12294	-	0.19503*	0.14524	0.12755	-
	Production	0.38187*	0.00270	0.04521	-0.03406	0.36398*	0.20273*	0.19149*	-0.05694

* Significant differences ($P \leq 0.05$).

Similarly, no significant differences were found at the initial vegetative stages between maximum temperature and water consumption by evapotranspiration, which means that water consumption during this cropping stage has a direct relationship with maximum temperature and that other parameters (mean temperature, solar radiation and water retention curves of the substrates) influence water consumption by the crop.

However, Fig. 5 shows how water consumption in the three substrates (Fig. 5A, B and C) how water consumption increased starting at the primordium and rice size stages as a

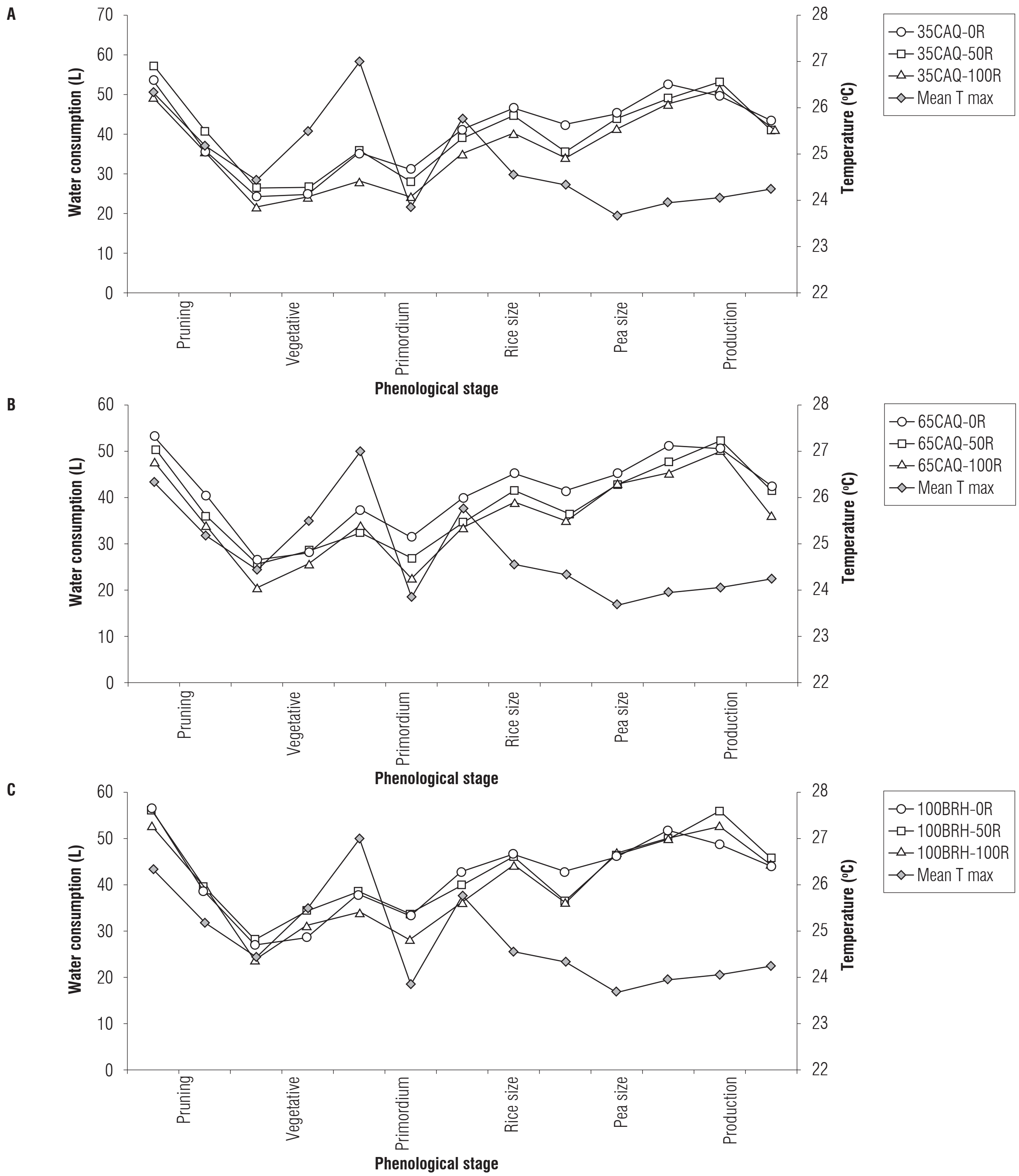

FIGURE 5. Water consumption by evapotranspiration and mean maximum temperatures in rose cv. Charlotte in substrates with 100% burned rice husk (100BRH) (A), 35% burned rice husk: 65% coconut fiber (35BRH) (B), and 65% burned rice husk: 35% coconut fiber (65BRH) (C), with 0, 50 and 100% recycling.

result of the intensification of the crop growth rate, which is the reason why there is a higher water demand until the production stage, where it started to decay as harvesting of flowering stems and removal of part of the crop foliage began. It should be noted that the mean maximum temperature did not show variations above 4ºC during the cropping cycle.

The mean temperature showed a direct relationship with evapotranspired water consumption by the crop, as shown in Fig. 6. For the vegetative stages, regressions with positive slopes (Fig. 6A and B) can be observed. However, for the chickpea and production stages (Fig. 6C and 6D), the slopes of the regressions were less accentuated, even showing a negative tendency at harvest (Fig. 6D). Particularly, the r^2 values during the vegetative stages were 0.3033 and 0.3032, respectively. From the regression equation of these two vegetative stages, it is possible to infer that for each temperature increase of 1ºC, water consumption by evapotranspiration increased by 7L (Fig. 6B). During the final stages of the reproductive phase, the regression curves showed that water consumption was less dependent on temperature (Fig. 6C and 6D). The values of the drainage volumes varied. This can be explained by the fact that leaf area no longer increases and has even a tendency to decrease as a result of senescence or work performed on the crop. As a result, the transpiration area would assimilate such behavior by stabilizing the water demand of the crop.

Discussion

In this research project, no significant differences were found in the productivity and quality parameters of the harvested stems (longevity and flower opening) in the different treatments (data not shown). This is supported by Savvas *et al.* (2008), who found that the entire drainage solution can be recycled without risking the exhaustion of essential nutrients in the root zone.

The highest EC values were reached in the treatments with recycling due to the fact that ions accumulate in the system as recycling is carried out and the solution becomes concentrated. This increase in EC could be explained by the results of Carmassi *et al.* (2006), who reported that a progressive

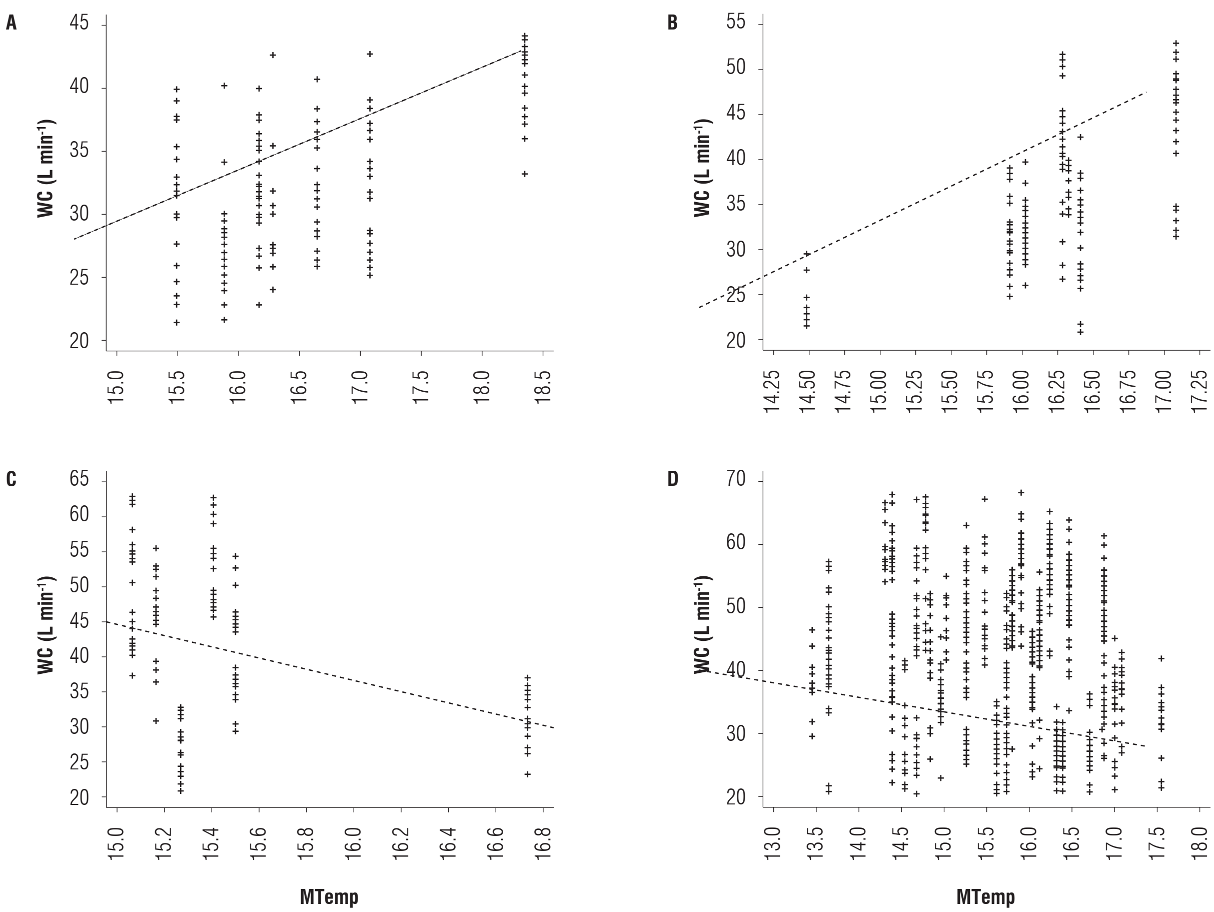

FIGURE 6. Behavior of water consumption by evapotranspiration as a function of mean temperature in the phenological stages of vegetative 3 (A), vegetative 4 (B), chickpea size (C) and production (D).

increase in the EC of recycled water is associated with an accompanying increase in sodium concentration and also, possibly due to Ca^{2+} and Mg^{2+}. The EC values did not exceed 3.5 dS m^{-1}, which would not affect the productivity and quality of flowering stems, since, according to Raviv and Blom (2001), the foliage of Sonia cv. plants grown on rock wool was not affected by an increase in the solution EC from 1.8 to 3.8 dS m^{-1}. On the other hand, Urban *et al.* (1994) did not find water stress on leaves of 'Sonia' plants subjected to fertigation for more than two months with an EC of 3.8 dS m^{-1}. Similarly, Cabrera (2001) did not find effects on stem growth with an EC near 2.9 dS m^{-1}. Raviv and Blom (2001) also stated that EC values under 3.8 dS m^{-1} in a rose crop grown in a well aerated substrate do not have effects on osmoregulation. However, Lorence and Heinrich (2003) stated that an increase in the substrate EC has an impact on stem growth, which makes it necessary not only to perform a water analysis but also to constantly monitor the substrate.

Furthermore, the pH values did not exceed 7.5 during the cropping cycle in none of the assessed treatments and the normal pH range for the water was from 6.5 to 6.8. High pH values are often caused by bicarbonate (HCO_3) and carbonate (CO_3) concentrations, a phenomenon known as alkalinity (Bauder *et al.,* 1997). The high carbonates form complexes with calcium and magnesium complexes generating carbonates and bicarbonates, which leave sodium ion as the dominant ion in the solution. This, associated with high sodium levels which are a product of recycling, can result in water deficit and, considering that rose crops under greenhouse conditions have continuous, year-round production, the new shoots and young leaves would be exposed to water stress (Raviv and Blom, 2001). This kind of stress causes loss in cell turgidity and reduces the leaf expansion rate (Jones, 1992), which in turn leads to a reduction in the leaf area available for carrying out photosynthesis and to losses in productivity (Kool and Lenssen, 1997). A reduction in photosynthesis is also connected to a decrease in a plant's capacity to make osmotic and turgidity adjustments as a reaction to water stress (Auge *et al.*, 1990).

Possibly, the lower pH values observed in the three substrates with the three recycling percentages between the primordium and rice size stages were a result of an active increase in nutrient absorption (NO_3^-, $H_2PO_4^-$), so the rhizosphere became acidified by the liberation of hydrons (Taiz and Zeiger, 1998). This is the reason why it is necessary to be especially careful with elements such as phosphorus because, at pH values such as these, its solubility in the substrate increases and thus its lixiviation (Ansorena, 1994).

Conclusions

Recycling during a harvest cycle in roses does not result in EC and pH values above those that are considered to have a negative impact on production. However, an increase in EC and pH values was observed, which implies an increase in the concentration of salts in the substrate, which in the long term could possibly result an impact on production.

The analysis of the EC and pH between the 50 and 100% recycling did not show significant differences in any of the phenological stages that where assessed during the cropping cycle, which means 100% recycling can be used, optimizing nutrient use and savings in water consumption.

Without considering recycling, the 100BRH treatment showed the lowest pH and, without considering the substrate, the 0% recycling treatment showed the lowest pH.

Without considering recycling and substrate, the treatments with 100BRH and 0% recycling showed the lowest pH values.

The mean maximum temperatures and daily means showed a direct correlation with water consumption in the crop grown in substrate because, as the temperature increased, the water consumption by phonological stage also showed an increase.

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