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Comparison of two pressurized irrigation systems on lettuce seedlings production

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Abstract

Automatized irrigation systems under nursery conditions have become an essential tool to satisfy rationally the water needs for plants without forgetting the sustainability aspects. The present study aimed to evaluate two sprinkler irrigation systems under nursery conditions: one with fixed laterals (fixed system) and another with self-propelled laterals (mobile system) and study the effect of their use on the behavior of tree lettuce seedlings production. The experiment was conducted on a greenhouse with a polystyrene (PVC) plastic film coverture and laterals closed with 60% plastic screen. The statistical design used was a 2x3 completely randomized factorial with four replicates, and the results analyzed using the Tukey test. To compare the lettuce seedlings behavior under both irrigation systems it was evaluated the leaves number, seedling's height, root length and fresh and dry mass of the aerial and root part of the plant. The Christiansen uniformity coefficient (CUC) and the water distribution coefficient (WDC) for the fixed irrigation system were considered adequate and for the self-propelled laterals system (mobile system) they were considered excellent. The volume of water used with the fixed system was 109.12% higher than with the self-propelled system. The lettuce seedlings irrigated with the self-propelled system had a growth, production and a seedling quality statistically superior than when irrigated with the fixed system. Independent of the irrigation system used, the Elizabeth lettuce cultivar had a greater seedling behavior. According with the results obtained, it is recommended the use of the self-propelled irrigation system (mobile system) on the production of lettuce seedlings.

Keywords: Greenhouse, Sprinkler irrigation, *Lactuca sativa L,* automation.

Introduction

The lettuce (*Lactuca sativa L*.) is the horticultural plant most consumed in Brazil and the most commercialized in the world (Bozkurt et al., 2009). According to Freitas et al. (2013), the most important stage on the lettuce productive system is the production of good quality seedlings, because of this depend the final behavior of the plants in the definitive production environment.

The most utilized method for seedlings production on nurseries is the multicellular trays. The development of the seedlings in the trays depend of factors such as the measuring of the cells (depth), the substrate used, the nursery microclimate and the water availability for plants (Marques, et al., 2003; Oliveira et al., 1993).

The amount and frequency of the applied water to the plants on the trays must be adjusted adequately to fulfill the plant needs, mainly because any deviation in the water offer may implies in irregularities on their germination, plant development and diseases apparition (Bandeira et al., 2011; Santos and Pereira, 2004). Several methods to determine the water needs in nurseries can be used (Caceres et al., 2007). The most rapid and direct is through the direct water determination or indirectly by using especial instruments such as tensiometers, neutron probes, TDR and FDR capacitive probes, etc.

Presently, the most rational form to control the water application to plants in controlled environments is through the use of automation irrigation using water sensors. The automated irrigation systems permit to satisfy rationally the water needs for plants without forgetting the sustainability aspects. An adequate irrigation management (when, how and how much to irrigate) will ensure a good production and high quality products avoiding water deficits and excesses reducing this way the inadequate use of water resources and production costs (Romero et al., 2012). The use of capacitive sensors to control soil moisture in protected environments has been shown to be an advance in the automation of irrigation processes, as they practically do not require calibration and can be used according to their dimensions. Its application has been widely diffused in research related to irrigation because it is a non-destructive method (Cruz, et al., 2010).

The irrigation of plants, to satisfy their water needs, can be performed by several methods. In protected environments it can be done through the use of different systems such as sprinkler, micro sprinkler, nebulizers and trickling. This last one although its high efficiency, presents operation difficulties due to the high seedlings density in the nurseries. Thus, the sprinkler and micro sprinkler are the more utilized.

With these methods, water is sprinkled on the plants simulating a rain and can be fixed (fixed laterals) with manual displacement or mobile (autopropelled laterals) with automatic displacement (Mantovani, 2009).

The micro sprinkler, generally, is the most indicated due to the hand labor economy and the better control on water distribution (Thebaldi et al., 2016). The micro sprinkler system with auto propelled lateral lines allows adjusting precisely the irrigation water depth by controlling the line displacement.

The present work aims to evaluate under nursery conditions two pressurized micro sprinkler irrigation systems, a system with fixed lateral lines and a mobile system with auto propelled lateral lines and to study the effect of their use on the behavior of three lettuce cultivars.

Results and Discussion

Plant behavior evaluation

Independently of the irrigation system utilized, the number of leaves of the seedlings was significantly affected by the cultivar (Table 1). The Elizabeth cultivar produced the greatest number of leaves (mean of six leaves), followed by the Monica and Veneranda, with a mean of four leaves each, obviously these last ones no different each other. The leaf number obtained in the present study was adequate and thus, the seedlings were ready at the transplanting time. According to Nicoulaud et al. (1990), seedlings with more than 3 leaves are in conditions to be transplanted.

It was observed significant difference between the mean seedlings height with the irrigation systems utilized for all the lettuce cultivars, with means of 96 and 67 mm for the auto propelled lines and the fixed lateral lines irrigation systems, respectively (Table 2). These results agreed with those obtained by Franzin et al. (2005) who found seedling heights between 79 and 104 mm. A probably reason why the lettuce seedlings irrigated with the autopropelled system presented a higher height than the those irrigated with the fixed system is because the fixed system operated with a fixed irrigation frequency, producing periods with elevated and low substrate water contents. The autopropelled system, applying water according with the plant needs, defined by sensors installed in the plant subtract, offered a substrate water contents more uniform and adequate.

According to Nicoulaud et al. (1990), for transplanting, the seedlings must have heights between 80 and 100 mm, obtained only with the auto propelled lines. For the fixed lines irrigation system, the seedlings did not reach the required height needing to remain more time in the trays if they were to be transplanted. The Auto propelled irrigation system proportionated thus a better stand for transplantation than the fixed one. No statistical difference was found for the heights among cultures. No difference was found for the seedlings roots length when irrigated by any of the irrigation systems (Table 2), fact explained, perhaps, because the available space for root growth was limited by the tray cells volumes. The root length means found varied between 65 and 76 mm. The effect of the irrigation systems on the fresh phytomass of the aerial part of the seedlings was significant to the 5% significance (Table 3). The auto propelled lines irrigation system produced a mean phytomass of 1462 mg plant^{-1}, however, with the fixed system produced only a mean of 934 mg plant^{-1}. The fresh phytomass mean of the aerial part of the Elizabeth cultivar was1367 mg, significantly greater than the fresh phytomass found for the Monica and Veneranda cultivars, 1102 and 1126 mg, respectively, with no significant differences among these last two.

The fresh phytomass mean of the rooting part of the Veneranda cultivar was significantly affected by the irrigation system used (Table 3) obtaining a mean of 313 mg seedling^{-1} for the auto-propelled lines compared with the 226 mg for the fixed lines irrigation system. For the Elizabeth and Monica cultivars, the irrigation systems did not affect the root fresh phytomass.

It is observed on Table 4 significant effect of the irrigation systems on the dry phytomass of the aerial part of the Elizabeth and Veneranda cultivars, obtaining, 105 and 82 mg seedling^{-1}, respectively, with the auto propelled system and 80 and 68 mg seedling^{-1}, respectively, with the fixed lines system. These results corroborate those found by Franzin et al. (2005). The Monica cultivar aerial part dry phytomass was not affected by the irrigation system utilized.

Although the dry phytomass of the rooting part of the seedlings for the three cultivars, obtained when irrigated with the auto propelled irrigation system were higher than the one obtained with the fixed lines system, the difference was not significant. These results also corroborate those found by Franzin et al. (2005).

Uniformity and water distribution coefficients of the irrigation systems

The Christiansen uniformity and the distribution uniformity coefficients for the irrigation system with fixed lines were 78.31 and 64.39%, respectively, classified by Mantovani (2001), and by the Brazilian Association of Technical Norms (1998) as reasonable. According to Keller and Bliesner (1990) the Christiansen uniformity coefficient is inadequate when lower than 84%. For the auto propelled irrigation system the Christiansen uniformity coefficients varied between 89.85 and 90.90% being classified by Mantovani (2001) as excellent and adequate for this type of installation by Keller and Bliesner (1990). Fort this system, the distribution uniformity coefficients varied between 79.69 and 81.46% classified as adequate by Mantovani (2001).

Volume of water applied to the seedlings by the two irrigation system.

The volume of water applied daily by the fixed lines irrigation system, during the growth of lettuce seedlings, with two irrigations of 4.72 mm irrigation^{-1} each, was 70 L. For the whole period totalized 2,542.00 L. The auto propelled irrigation system applied a mean irrigation depth of 3.78 mm per turn (forth and back), corresponding to a volume of water of 37 L, and a total of 1,216.00 L for the whole period, with 33 irrigation events. Thus, the fixed lines irrigation applied a volume of water 109.12% greater than the mobile irrigation system. This big difference is because the fixed system is programmed to irrigate at defined intervals and irrigation volumes, without considering the environment conditions. Differently, the auto propelled irrigation system applied water only when the water content of the substrate reached the volumetric water content of

Table 1. Number of leaves of Elizabeth, Monica e Veneranda cultivar seedlings, for the auto propelled lines and fixed lateral lines irrigation systems.

Cultivars	Elizabeth	Mônica	Veneranda	Mean
Irrigation System	Mean Leaf number			
Auto propelled lines	6 a B	4 a A	4 a A	5 a
Fixed lateral lines	6 a B	4 a A	4 a A	5 a
Mean	6 B	4 A	4 A	
CV (%)	4.29			

Means followed by the same small letter in the columns and the same capital letter in the lines do not differ each other by the Tukey test at 5% significance.

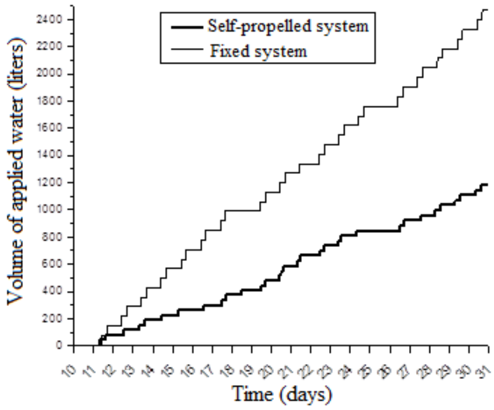

Fig 1. Water volumes applied by the two irrigation systems during the experimental period.

Table 2. Height of the seedling and root length for the Elizabeth, Monica and Veneranda cultivars with the auto propelled lines and fixed lines irrigation systems.

Cultivars	Elizabeth	Mônica	Veneranda	Méan
Irrigation System	Plant height (mm)			
Auto propelled lines	95 a A	98 a A	97 a A	96 a
Fixed lines	70 b A	67 b A	63 b A	67 b
Mean	82 A	83 A	80 A	
CV (%)	12.32			
Irrigation System	Root length (mm)			
Auto propelled lines	76 a A	69 a A	69 a A	71 a
Fixed lines	71 a A	65 a A	65 a A	67 a
Mean	73 A	67 A	67 A	
CV (%)	8.79			

Means followed by the same small letter in the columns and the same capital letter in the lines do not differ each other by the Tukey test at 5% significance.

Table 3. Fresh phytomass (mg) of the aerial and rooting part of the plant for the Elizabeth, Monica and Veneranda lettuce cultivars for the auto propelled and fixed lines irrigation systems.

Cultivars	Elizabeth	Mônica	Veneranda	Mean
System	Aerial part Fresh Phytomass (mg)			
Auto propelled lines	1688 a A	1309 a B	1390 a B	1462 a
Fixed lines	1046 b A	895 b A	862 b A	934 b
Mean	1367 A	1102 B	1126 B	
CV (%)	12.21			
System	Rooting part fresh phytomass (mg)			
Auto propelled lines	277 a A	256 a A	313 a A	282 a
Fixed lines	237 a A	207 a A	226 b A	223 b
Mean	257 A	232 A	269 A	
CV (%)	15.00			

Means followed by the same small letter in the columns and the same capital letter in the lines do not differ each other by the Tukey test at 5% significance.

Table 4. Dry mass (mg seedling^{-1}) of aerial and root part of the lettuce cultivars Elizabeth, Monica and Veneranda, for the auto propelled lines and fixed lines irrigation systems.

Cultivars	Elizabeth	Monica	Veneranda	Mean
Irrigation System	Dry phytomass of the aerial part of the seedling (mg)			
Auto propelled lines	105 a A	77 a B	82 a B	88 a
Fixed lines	80 b A	69 a A	68 b A	72 b
Mean	93 A	73 B	75 B	
CV (%)	10.57			
Irrigation System	Dry phytomass of the root part of the seedling (mg)			
Auto propelled lines	16 a A	15 a A	19 a A	17 a
Fixed lines	13 a A	13 a A	15 a A	14 a
Mean	15 A	14 A	17 A	
CV (%)	24.70			

Means followed by the same small letter in the columns and the same capital letter in the lines do not differ each other by the Tukey test at 5% significance.

29%. This water content corresponds to a water level easily available for the seedlings and completely adequate for its growth (De Boodt et al., 1972; Riviére et al., 1990). The water reduction when used the mobile system is similar to the 100% reduction found for Carpena (2003) when compared a mobile system with a conventional micro sprinkler.

Figure 1 show the accumulated water applied with both irrigation systems. It is observed that during the days 18, 21 and 25 of October there was not irrigation. On the 18^{th}, due to the lack of electric energy and on the 21^{th} and 25^{th} because the irrigations were suspended to allow foliar fertilization in the subsequent days of irrigation.

Materials and Methods

Location of the study

The study was conducted in a rural property at the Medianeira County, State of Paraná, Brazil (25º17'40", latitude south, 54º05'30", longitude west of Greenwich), 412 m above sea level. The experiment was installed in a greenhouse, 22.5 m length and 10.00 m width, steel structure covered with 150 µm thickness plastic polystyrene (PVC), treated for ultraviolet rays and laterals closed with a 60% protection and shading grid.

Climatic characteristics of the experimental site

The climatic information into the protected environment was monitored by a TYCON *Pro Weather* meteorological station programed to monitor wind velocity and direction, air temperature and relative humidity every 10s and save them every 5 min. The mean temperature in the environment during the experiment period was 24.71^{o}C, with minimum variations between 13.10 and 23.60^{o}C and the maximum between 25.80 and 38.10^{o}C. The mean relative humidity was 42.54%.

Irrigation Systems

In the present experiment it was used a fixed and a mobile irrigation system. The fixed irrigation system had fixed laterals and nine micro sprinklers, located at 1m above the trays with 1.10 x 1.10m spacing. The mobile system had auto propelled lateral lines with four micro sprinklers located at 1.0 m above the trays, spaced at 73.3 cm and traveling a linear distance of 2.20 m, allowing the irrigation of all trays. The emitters were the Hadar 7110 type, with a fixed diffusor and a nozzle orifice of 1.4 mm, the same model used in the fixed irrigation system.

Conduction of the experiment

The sowing was conducted in trays of 200 cells, filled with Caroline Soil subtract$^{@}$, composed by Sphagno Turf, expanded vermiculite, calcium dolomitic, agricultural plaster and NPK fertilizer, pH: 5.0 +/- 0.5, electrical conductivity of 0.7 +/- 0.3 mS cm $^{-1}$, density of 101 kg m^{-3}, without soil particle size specification. For each irrigation system were utilized 12 trays The sowing was conducted placing one peletized seed at the center of each cell to a 5 mm depth and submitted them during three days to a dark, fresh and non-irrigated environment. The three lettuce cultivars (Mônica SF31, Veneranda and Elizabeth) were selected because they have similar phenologic period (60 to 70 days) and they are commonly cultivated in the region.

Afterwards the trays were carried to the nursery and the irrigation systems installed. At this moment the irrigation was initiated.

The irrigation with the fixed lateral lines system was prefixed with two water application daily, at 10:00 and 16:30 h, each one of 4.72 mm with a water pump constant pressure of 0,14 MPa; this irrigation depth is the commonly used by the lettuce seedling producers of the region. The irrigation with the auto propelled system (mobile) was defined by water sensors installed in the plant subtract.

The irrigation started every time the volumetric soil water content of the subtract reached 29%. According to Riviére et al. (1990), this value corresponds to a mean water content when the soil water is easily available for plants and adequate for growing. At this moment, the needed and applied water depth was 3.78 mm, in a complete irrigation system cycle (forth and back) with a constant water pump pressure of 0.14 MPa. The sensor signals were sent to a "FieldLoger" register that monitored all the data and when it indicated lack of water in the subtract immediately was sent another signal to a Programed Logic Control that initiated de irrigation, limiting the water application to the time interval from 08:00 to 17:00h, following the recommendations of Wendling et al. (2002) who said that nocturnal irrigations can produce excess of water that stimulates diseases apparition. The utilized sensor was calibrated in the subtract itself, according with the technical specifications.

The irrigation water was derived from an artesian well located in the property and kept in a 320 L polyethylene box. The chemical analyses of this were done at the Food and Water Laboratory of the UTFPR in Medianeira. The electrical conductivity was 195 mScm^{-1} being classified as a C1S1, good quality water with low risks of salinization.

During the irrigations were registered the flow rate, the subtract water content, the air temperature, the relative humidity of the air and wind velocity. Air temperature and relative humidity were measured with sensors HMP35C and Temperature/RH Probe–*Campbell Scientific.* These parameters were registered every second and the mean value stored in a Field logger at each 60s.

Technical Evaluation of the irrigation systems

It was done by determining the Christiansen Uniformity Coefficient (CUC) and the Distribution Uniformity Coefficient (CUD) according to Bernardo et al. (2006).

Evaluation of Plant Behavior

At the end of the seedling formation (40 days) 15 seedlings were selected from each tray and the effect of treatments on the plant behavior evaluated by determining the leaves number, the height of the seedlings, the root length and the wet and dry phytomass of the aerial and rooting part of the plant. The dry phytomass was obtained by drying the vegetal material in an oven at 60 ^{o}C during 48 h until reaching a constant mass. The height and root length were measured with a millimeter graduated scale and the phytomass by using a precision balance with 0.01 mg of resolution.

Experimental Design

The statistical design used was a 2x3 completely randomized factorial, with four replicates. The treatments were two pressurized irrigation systems (a system with fixed laterals and a mobile with auto propelled lateral lines) and three lettuce cultivars (Mônica SF31, Veneranda and Elizabeth), totalizing 24 experimental parcels. Each parcel was constituted by a 200 cells polystyrene tray with 200 seedlings. The treatments were assigned to the parcels by a complete randomization using the methodology recommended by Banzatto and Kronka (2006). Four plants were assigned at random to each of the six treatment groups; treatments combinations were for fixed and mobile irrigation systems and the three lettuce cultivars. The obtained results were submitted to mean comparisons by using the Tukey test at 5% probability and processed by the SISVAR program (Ferreira, 2013).

Conclusions

The auto propelled lines irrigation system presented an irrigation performance greater than the one obtained with the fixed lines irrigation system, this according to the water application and distribution uniformity coefficients determined. To irrigate the lettuce seedlings, the auto propelled lines irrigation system used a lower volume of water than the fixed one. The lettuce irrigated with the auto propelled lines irrigation system had a greater seedling growth and production than when irrigated with the fixed one, originating, also, better quality seedlings. Independent of the irrigation system used, the Elizabeth lettuce cultivar had a greater seedling behavior.

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