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Lettuce production in a greenhouse with drip fertigation fractioning

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Abstract

This research presents results found for fertigation through drip on lettuce. Variety grown in a greenhouse. The respective treatments were: (F1), 100% of the nutritional demand required by the crop was provided at the time of planting; F2 in the treatment, 50% of fertilization occurred in the early planting and 50% complementary to the middle of the cycle, the expected timing of the harvest was 40 days after planting; F3 was fractionated treatment: being 1/3 of fertilizer at planting, 1/3 after 13 days and the last application after 26 days from the time of planting; F4 treatment followed the same reasoning, by dividing the application into 4 parts of 10 for 10 days. The design was completely randomized with three water potential levels in the soil and three replicates. It was found that the lowest water potential of the soil (P3) presented higher production of green mass for smaller numbers of fractioning of fertigation. On average, higher laminae resulted in lower green mass production.
Key words: *Fertigation, soil water potential, localized irrigation.*

Resumo

Produção da alface em casa de vegetação com o fracionamento da fertirrigação via gotejamento. Esta pesquisa apresenta resultados encontrados para fertirrigação via gotejamento na cultura da alface. Variedade cultivada em uma casa de vegetação. Os respectivos tratamentos foram: (F1), 100% da demanda nutricional requerida pela cultura foi fornecida no momento do plantio ; no tratamento F2, 50% da adubação se deu no início do plantio e os 50% complementares ao meio do ciclo da cultura, O período estimado da colheita foi de 40 dias após o plantio; o tratamento F3 foi fracionado: sendo 1/3 da adubação no plantio, 1/3 após 13 dias e a última aplicação após 26 dias a partir do momento do plantio; o tratamento F4 seguiu o mesmo raciocínio, fracionando a aplicação em 4 partes, de 10 em 10 dias. O delineamento foi inteiramente casualizado com três níveis de potencial de água no **solo** e três repetições. Constatou-se que o menor potencial de água no solo (P3) apresentou, maior produção de massa verde para menores números de fracionamento das fertirrigações. Em média, lâminas maiores de irrigação resultaram em menores produções de massa verde.
Palavras-chave: *Fertirrigação, potencial de água no solo, irrigação localizada.*

Introduction

The Lettuce (*Lactuca sativa* L.) is the most consumed leafy vegetable in Brazil source and has great economic importance in that country and globally. It is an herbaceous, delicate plant, with a short stem that holds leaves growing in a rosette pattern. Lettuce has a short growing cycle, large leaf area and shallow root system, requiring sandy-clayey soils rich in organic matter and with high concentrations of readily available nutrients (Silva et al. 2010).

According to Pagliarini et al. (2011), water is the most limiting of the necessary factors for plant growth in agricultural productivity because it is required in many metabolic processes that culminate in plant development. Plant nutrition is the second most limiting factor in the production of any crop. Nutritional requirements can be met by providing balanced doses of fertilizers directly to the soil or as topdressing, combined with the appropriate timing and method of application. Thus, monitoring both irrigation and soil fertility is key for the success of modern agriculture (Monteiro et al. 2007).

The current literature is quite sparse regarding the production of vegetable seedlings using fertigation as a nutrient delivery tool. This technique simulates the natural absorption of nutrients by the plant by delivering the nutrients in lesser, more frequent doses. Fertigation has been routinely used by farmers for protected crops and transplanted vegetables, but not in seedlings (Biscaro et al. 2011).

Biscaro et al. (2011), argue that fertigation is the most economical and efficient method of fertilizer application, especially when localized irrigation is used.

Fertigation has undergone intensive development and gained followers because of the ease of appalying nutrients synchronized with the pace of the absorption or accumulation of nutrients in each variety and at all stages of plant development (Zanini et al. 2007).

Fertigation ensures that fertilizers are applied directly to the region with a higher concentration of plant roots, allowing the fractionation of doses and increasing the efficiency of fertilization. Drip fertigation is more efficient in nutrient use than conventional fertilization, requiring 20 to 50% less fertilizer (Rozane et al. 2009).

Plants need water and nutrients at rates that vary significantly with the stage of crop development and the climatic conditions of the cultivation environment. As a result, the rate of absorption of the many nutrients within the nutrient solution may not match the rate of water absorption. (Steidle Neto et al. 2010).

In an evaluation of the effects of different irrigation depths and split fertilizer on coffee growth. Vilella and Faria (2003), found that fractionating fertilization influenced the length of primary branches. Splitting fertilization across nine applications showed the best results.

To contribute to the understanding of fertigation and fill a gap still little explored by researchers in this area, this study examines the advantage in the production of irrigated crops of the application of fertilizer through irrigation water in doses fractionated along the crop cycle.

Material and Methods

This experiment was conducted in a greenhouse located in the experimental area of the Department of Rural Engineering from São Paulo State University (Universida de Estadual Paulista- UNESP), Botucatu Campus, São Paulo, from June 10 to July 20, 2009. The altitude is 786m and the latitude is 22°51’03” S, and the longitude is 48°25’37” W. According to the Köeppen classification, the regional climate is Cfa,i.e., rainy temperate, characterized by the existence of four or six consecutive months with a mean air temperature greater than 10 ºC. The mean air temperatures in the warmest and coldest months are 22.8 °C and 16.7 °C, respectively. The mean annual air temperature is 20.6 ºC, and the mean maximum and minimum air temperatures are 23.5 and 17.4 ºC, respectively. The total average rainfall is 1518.8 mm, with means of 229.5 mm for the wettest month and 37.5 for the driest month. The mean annual evapotranspiration is 692 mm.

The experiment was conducted in a tall tunnel greenhouse, 15 m in length and 7.5 m in width, with heights at the center and sides of 3.0 and 1.7 m, respectively. The structure is formed by arched galvanized pipes. The cover is a 150-μm thick transparent polyethylene film. The sides are screened with 30% shade cloth to intercept insects and animals. The greenhouse is positioned in the north/south direction, perpendicular to the path of the sun.

The physical and chemical soil characteristics were determined for deformed samples according to the method of the Department of Soils, School of Agronomic Sciences (Faculdade de Ciências Agronômicas - FCA) of the UNESP and are displayed in Tables 1, 2 and 3.

Table 1. Results of soil chemical analysis. OM – organic matter content; P-resin – resin extractable phosphorus; SB – sum of bases; CEC – cation exchange capacity; %V – base saturation.

pH	OM	P-resin	H+Al	K	Ca	Mg	SB	CEC	%V
CaCl2	g/dm^3	mg/dm^3	---------------------------mmol$_c$/dm^3--------------------------						
6.3	28	228	15	1.3	98	22	121	135	89

Boron	Copper	Iron	Manganese	Zinc
---mg/dm^3---				
0.26	6.5	23	15.6	8.4

In the F1 fertigation treatment, 100% fertilizers occurred at planting. In the F2 treatment, 50% of the fertilization occurred at planting and the other half in the middle of the crop cycle, with harvest planned 40 days after planting. F3 was a fractionated treatment: 1/3 of fertilization occurred at planting, 1/3 after 13 days and the last third 26 after days planting. The F4 treatment was fractionated into four parts at 10-day intervals. Consequently, at the end of the crop cycle, the four-fertigation treatments had received the same amount of fertilizer.

Table 2. Results of soil particle size analysis.

Sand	Clay	Silt
	------------------------------g/kg------------------------------	
510	370	120

*The classification of Solo as the textural triangle is: Sandy Clay.

Table 3. Values of soil water content ($g.g^{-1}$) and matric potential (kPa).

Ψm (-kPa)	a% (g^1g^{-1})
10	0.2910
30	0.2239
50	0.2116
100	0.2033
500	0.1859
1500	0.1686

Table 4 shows the four-fertigation treatments and their dosages throughout the 40 days of the crop cycle. For the F1 treatment, each dripper, supplying a group of 4 lettuce plants, applied 0.4 g, 10 g and 1 g of urea, super simple phosphate and potassium chloride, respectively, on the first day of planting. For the F4 treatment, each dripper applied the same total dosage as the F1 treatment, but divided into four portions that were delivered 1, 10, 20 and 30 days after planting at a dosage of 0.1, 2.5 and 0.25 grams of urea, purified MAP and potassium chloride, respectively.

Table 4. Dates and dosages of fertigation performed (g/plant).

Treatments	F1	F2	F3	F4
Day of fertigation and dosage (N;P;K)	1and (0.4; 10; 1)	1and (0.2; 5; 0.5) 20 and(0.2; 5; 0.5)	1and (0.13; 3.3; 0.33) 13and (0.13; 3.3; 0.33) 26and (0.13; 3.3; 0.33)	1and (0.1; 2.5; 0.25) 10and (0.1; 2.5; 0.25) 20and(0.1; 2.5; 0.25) 30and(0.1; 2.5; 0.25)

For indication of when to irrigate, three tensiometers, one for each soil water potential treatment,were installed at a depth of 12 cm. Field capacity was considered to be a potential of -10 kPa, and the minimum potentials for the three soil water potential treatments were -20, -30 and -40 kPa. These potentials were named P1, P2 and P3, respectively. Irrigation was performed to return these potentials to field capacity (-10 kPa).

The irrigation system comprised Manari hose drippers manufactured by Petroisa Irrigações Ltda. Nine 19.2 m-long lateral lines were used for irrigation, with three alternating lateral lines for each irrigation treatments and three replicates. Each lateral line included all four fertigation treatments. The emitters were spaced 0.6 m apart, and the spacing between lines was 0.62 m (Fig. 1). Each lateral line had 32 drippers, totaling 288 points of discharge. The mean discharge was 1.33 Lh^{-1} at a pressure of 70 kPa. To maintain the working pressure, a 70-kPa pressure regulator was used at the connection between the main and the lateral lines. A uniformity test was performed following ABNT (1986) to check the uniformity of the distribution. The irrigation system operated for 7 consecutive days prior to planting the lettuce eto standardize the chemical characteristics of the soil and remove possible traces of fertilizer that had accumulated along the planting lines. Thus, the flow of the drippers leached chemical elements from the soil on the sides and below the planting areas, thereby minimizing the effects of the spatial variability of the chemical properties of the soil in question.

Figure 1. Lettuce-planting scheme.

Curly lettuce was planted on the ground along the irrigation system without raised beds, with the same spacing as the drippers and the lateral lines of the irrigation system. Groups of four lettuce plants were planted 15 cm equidistant from each other around each dripper, totaling 128 lettuce plants per line and 1152 plants in total. Thirty-nine days after planting, all treatments were irrigated to field capacity, and the plants were harvested on the following day. The mass of the lettuce obtained corresponds to the fresh mass and was correlated with the irrigation applied and with the fertigation treatments. The green mass of the four lettuce plants around each dripper was divided by four to obtain the mean green mass per dripper.

Inside the greenhouse, a Class A tank was installed to monitor the local evapotranspiration, with measurements recorded every three days at 9:00 am (Fig. 2). Baseline evapotranspiration was determined using the Class A tank coefficient for bare soil in the equation. The internal temperature and maximum and minimum relative humidity were recorded daily with a maximum and minimum digital thermo-hygrometer (Figs. 3 and 4).

The experiment was conducted in a randomized block design, with four fertigationt reatments and three soil water potentials with three replications. For statistical analysis, Tukey’s tests were used at 5% probability.

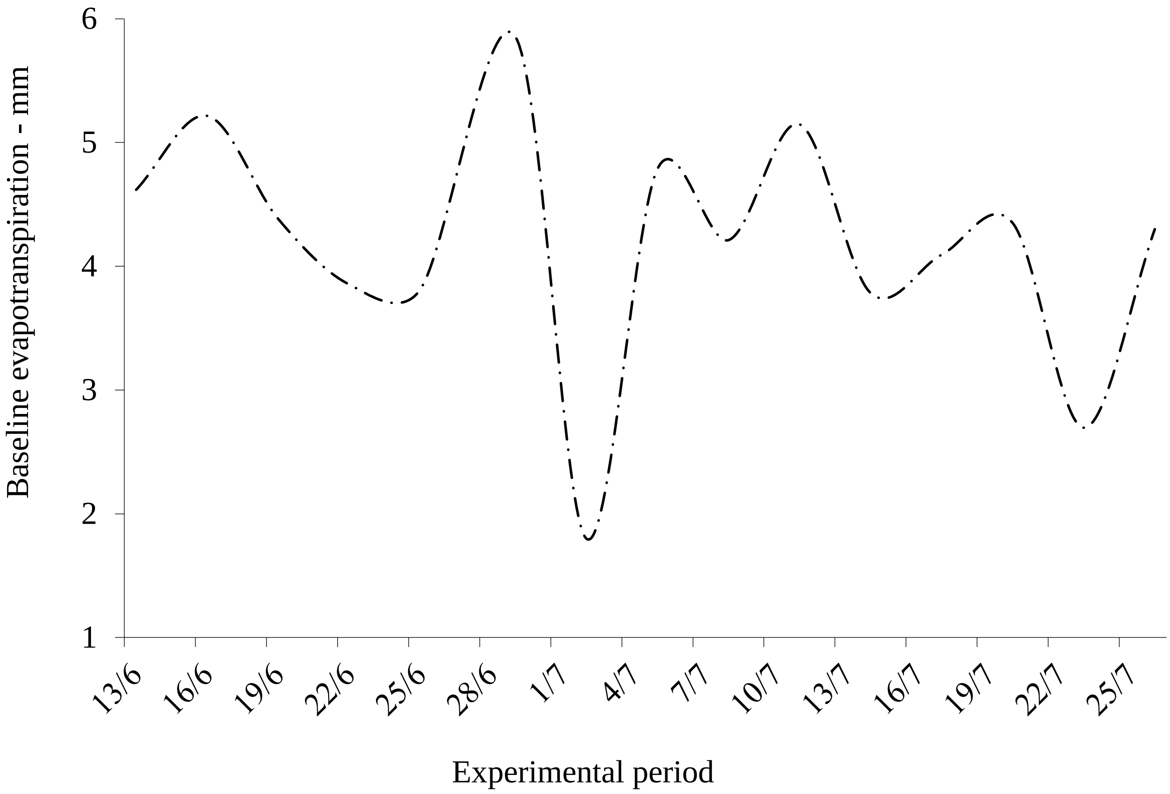

Figure 2. Evapotranspiration recorded by the Class A tank during the experimental period

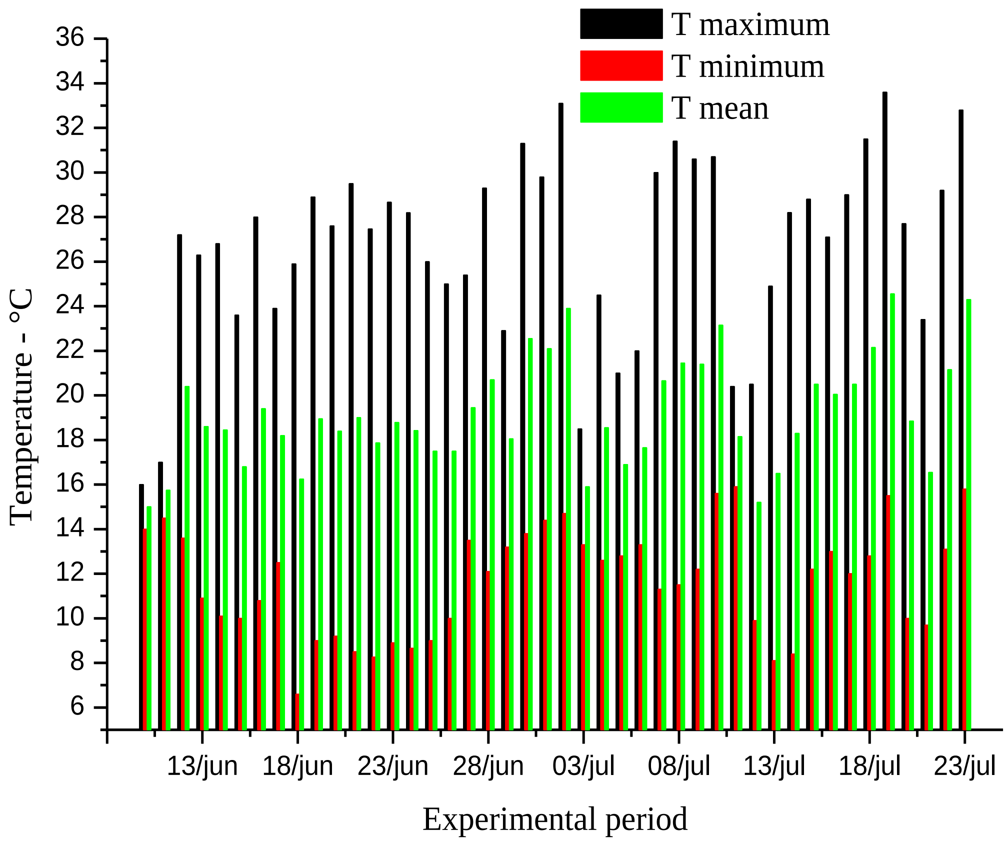

Figure 3. Temperature (maximum, minimum and mean values) during the experimental period (06/14/2014 to 07/26/2014).

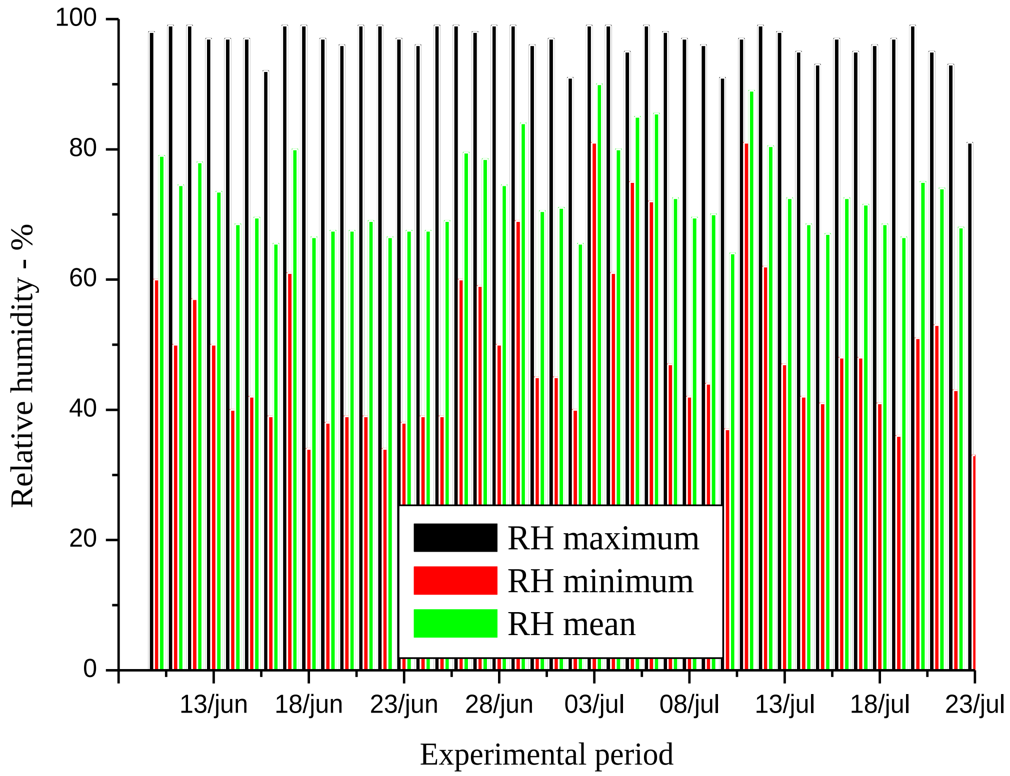

Figure 4. Maximum, minimum and mean relative humidity during the experimental period (06/14/2014 to 07/26/2014).

Results and Discussion

The evaluation of the irrigation system can be observed in Table 5. Sixteen collectors were used, four for each of the four lateral lines. The Christiansen uniformity coefficient (CUC) and coefficient of uniformity of distribution (CUD) indicated an excellent uniformity of distribution. The statistical uniformity index, which assesses the relationship between the mean of the measurements and the standard deviation, was also rated as excellent.

The figure 5 illustrates the distribution of the 16 data points collected relative to the mean. The points do not deviate more than 5% from the average, confirming that all lettuce plants received irrigation equally and that possible differences in productivity were not caused by uneven application of the experimental irrigation system.

Table 5. Number of collectors used in the evaluation system, mean dripper flow, Christiansen uniformity coefficient (CUC), coefficient of uniformity of distribution (CUD) and statistical uniformity index.

Number of collectors	Mean flow Lh^{-1}	CUC %	CUD %	Statistical uniformity index
16	1.33	98.20	97.06	97.81

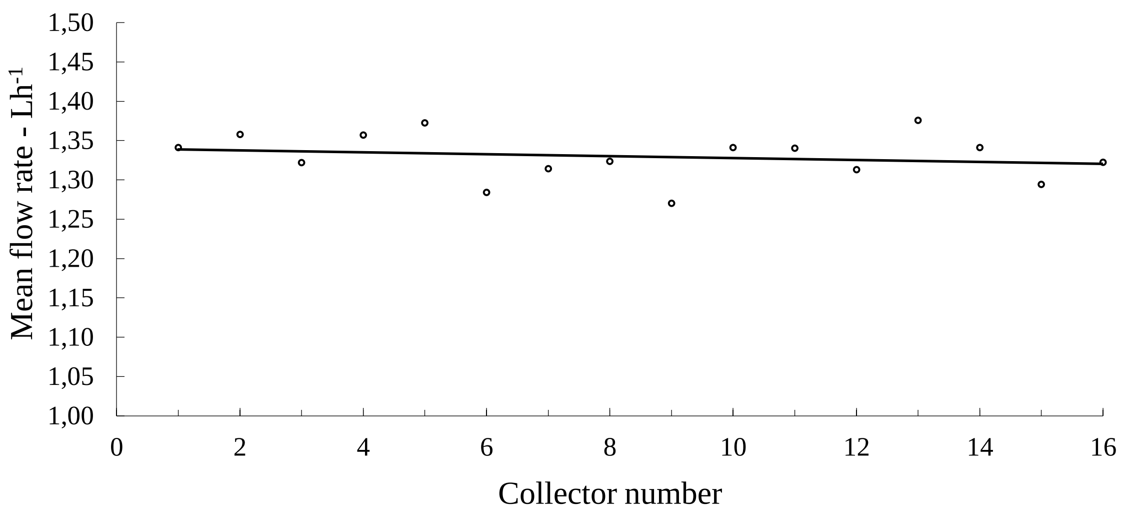

Figure 5. Distribution of the dripper flow rates in the evaluation of the system.

Figure 6 shows the production of green mass relative to the fertigation and soil water potential treatments. The treatment with the greatest soil water potential, P1 (-20 kPa) resulted in lower production than the other potentials for fractionations F1, F2 and F3. Although this treatment received more irrigation, it did not favor the development of the crop when the total fertilizer provided was fractionated into a few applications. The application of irrigation in a localized manner contributed to the leaching of the fertilizer, which percolated to the peripheral regions of the root system, following the wet bulb characteristics of localized irrigation. However, P1 had a tendency towards increased production as a function of the fractionation of fertigation, reaching the third greatest production observed (78.202 g) with four separate fertigations (F4). This result supports the previous argument regarding nutrient leaching caused by intense irrigation because greater fertigation fractionation provided more fertilizer near the root system, thereby minimizing the effect of leaching.

The lowest soil water potential treatment, P3 (-40 kPa), had higher production than the other potentials for fertigations F1, F2 and F3. Despite receiving less frequent irrigation, crops in this water potential treatment benefited from the availability of nutrients near the root system, as the leaching was less intense than in the other water potential treatments, contributing to greater green mass production. The application of all of the nutrients at planting for P3 resulted in the greatest green mass production observed in the experiment (89.489 g), which declined with increasing fertigation fractionation. In general, P2 (-30 kPa) had green mass productivity values that were intermediate between P1 and P3, with little variation in green mass as a function of fertigation fractionation.

In mean (PM), the overall green mass production as a function of soil water matrix potential indicates that the variation in the number of fertigation fractions not causes great variations in the production of green mass, implying that there is no need for fertigation management at potentials between -20 and - 40 kPa.

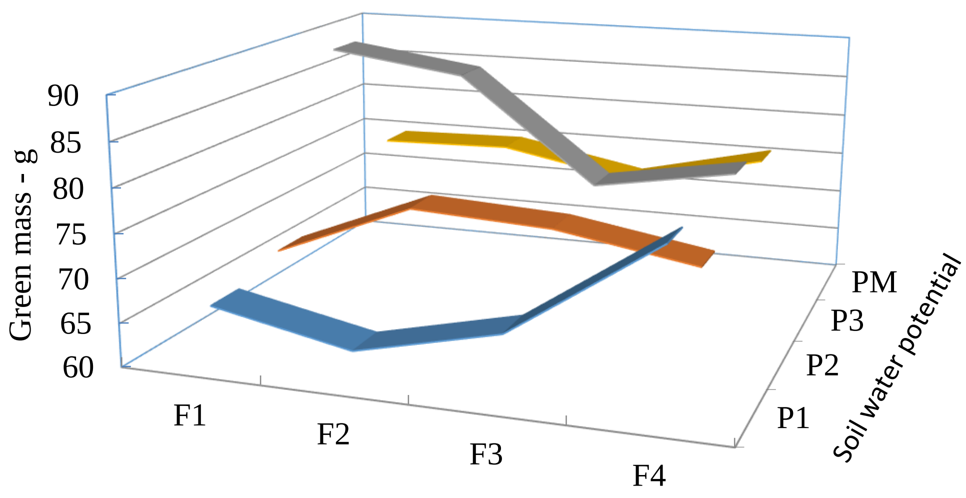

Figure 6. Green mass of lettuce in the fertigation and soil water potential treatments.

Table 6 shows the statistical analysis of the data related to the production of green mass as a function of soil water potential and the number of fertigations. Green mass production with more than three fractionations does not differ significantly among the potentials, and the average variation in the production of green mass is essentially the same for all fertigation treatments, suggesting that increased fertilizer fractionation tends to stabilize production, independent of the amount of water applied, contradicting the results reported by Vilella and Faria (2003) for coffee.

The comparison of the mean green mass produced in the four-fertigation treatments demonstrates that the potential P3 resulted in a greater production of green mass, followed by P2 and P1, respectively. This indicates that excessive irrigation did not contribute significantly to crop development, with the availability of fertilizer in the soil being more important.

Many irrigated crops are managed by soil water potential, which is the simplest method of irrigation management. Given that a soil water potential less than -40 kPa restricts the normal development of most vegetables, in general, lettuce green mass production does not vary significantly when managed by fertigation.

Table 6. Statistical analysis of the production of green mass as a function of number of fertigations and soil water potential.

Potentials	Number of fertigations				Mean (fertigations)
	1	2	3	4	
P1	66.438aB	63.187 aB	67.010 aA	78.202 aA	68.709 a
P2	68.191aB	74.755 aAB	73.928 aA	71.222 aA	72.024 a
P3	89.489aA	87.229 aA	75.055 aA	77.795 aA	82.392 a
Mean (potentials)	74.706 A	75.057 A	71.998 A	75.739 A	
Mean overall production – 74.375 g					
Coefficient of variation – 9.177%					

Minimum significant difference between fertigations– 14.811
Minimum significant difference between potentials – 19.309

Means followed by different letters in the same column differ at 5% probability based on a Tukey's test.

Figure 7 shows the variation in lettuce green mass production as a function of soil water potential and fertigation fractionation. A single application of fertilizer (F1) was used as reference, comparing it with other varied fertigation applications.

The highest soil water potential (P1) had increasing production variation as fractionation increased from F2 to F4, where as the potentials P2 and P3 had decreasing production variation as fractionation increased from F2 to F4. These results demonstrate that fertigation fractionation tends to increase green mass production with increasing soil water potential and, inversely, tends to decrease green mass production for lower potentials. Thus, low intensity irrigation must be accompanied by less fractionation of fertigation.

The maximum variation in production at the P1 potential was approximately 15% positive for F4. This potential generally presented positive variation due to frequent irrigation because the single application of fertilizers in the soil was too diluted or washed away by the wet bulb, hindering the absorption of fertilizers by the roots of the lettuce. In P2, the maximum variation was approximately 9% positive for F2. This variation declined with increasing fractionation. In P3, the maximum variation was 19% negative for F3, indicating an increased availability of the fertilizers in the driest soil, as less frequent irrigation interferes less in the absorption mechanism.

Table 7 shows the statistical analysis of the variation in production relative to fertilizer application in a single dosage. Lettuce green mass production was significantly different as a function of both soil water potential and fractionation. The mean production was negative for the lowest potential, P3, as well as for F3. There was a decrease in the overall production mean, indicating that fractionation of lettuce fertilizer applications in irrigation systems may cause losses in the production of green mass compared with a single fertilizer application.

These results demonstrate that there is a need for more studies of the development of other irrigated crops using fertigation management. Considering the variation in the rate of crop development (Steidle Neto et al. 2010) and that this rate varies with the phenological stage of the crop, fertilizer application is of fundamental importance in growth phases when the crop is more conducive to nutrient absorption.

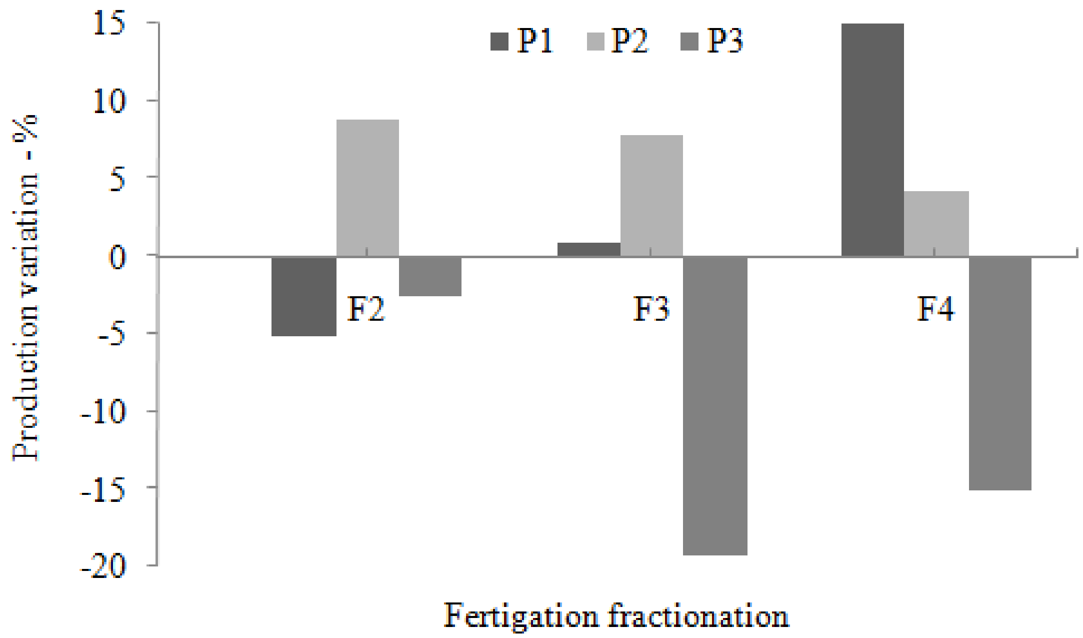

Figure 7. Variation in lettuce green mass production in relation to the number of fertigations and soil water potential.

Table 7. Statistical analysis of lettuce green mass production as a function of the number of fertigations and soil water potential.

Potentials	Number of fertigations			Mean (fertigations)
	2	3	4	
P1	-5.144 bB	0.853 bB	15.042 aA	2.687 a
P2	8.781 aA	7.760 aA	4.256 aB	5.199 a
P3	-2.589 bB	-19.229 bC	-15.031bC	-9.212 b
Mean (potentials)	0.3489 A	-3.5382 A	1.4227 A	

Mean overall production – -0.588 g
Coefficient of variation – 27.153%
Minimum significant difference between fertigations – 6.4222
Minimum significant difference between potentials – 6.4222

Means followed by different letters in the same column differ at 5% probability based on a Tukey's test.

Conclusion

Under the experimental conditions, the following conclusions can be drawn: More irrigation resulted in lower green mass production when correlated with fertigation management.

Lower soil water potential favored the absorption of fertilizers by the lettuce, resulting in greater green mass production. Fertigation management is feasible only when soil water potential is low.

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