academicJournals

Vol. 10(12), pp. 1407-1411, 19 March, 2015
DOI: 10.5897/AJAR2014.9218
Article Number: E7E53CA51811
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Agronomic performance of lettuce produced in trays with different cell number and field spacings

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Received 9 October, 2014; Accepted 11 March, 2015

The cultivation of lettuce is notable in the field of olericulture due to its worldwide economic and food importance. This study aimed to evaluate the agronomic performance of mimosa lettuce cv. Lavínia produced in a polystyrene tray system with different cell number and field spacings. Seedlings were produced in trays of 128, 200 and 288 cells and cultivated in a protected environment. Twenty-five days post-sowing, the seedlings were transplanted to beds with spacings of 30 × 40; 35 × 40; 40 × 40; and 45 × 40 cm. The experiment followed a split-plot randomized block design with four replicates. Harvesting was performed at 45 days after transplanting. Phytometric characteristics of the plants were evaluated after the crop cycle: number of leaves, plant height, stem length and diameter and fresh and dry weight of the shoot. Data were subjected to analysis of variance, and means were compared by Tukey's test at p<0.05. The agronomic performance of mimosa lettuce cv. Lavínia is favored when plants are produced in trays with 200 cells and is not influenced by field spacings.

Key words: *Lactuca sativa*, mimosa, cultivar Lavínia, seedling production, phytometric characteristics.

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is a crop of great economic and food importance for the majority of the population (Mota et al., 2003). It is a leaf vegetable cultivated in several regions of the world, with estimated global production of about 25 million t ano^{-1} (lettuce and chicory), and the China is the main producer (Faostat, 2013). Consumed in natura, lettuce is a source of vitamins and minerals; due to its low calorie content, it is recommended for diets rich in fiber (Filgueira, 2008).

The indication of the productive potential of a species depends on its genotype, on the environment, and on management practices such as spacing. The choice of a cultivar is crucial for the success of the cultivation system adopted (Echer et al., 2001).

Primary productivity is the most accessible and accurate means to evaluate development and to make inferences about the contribution of different physiological processes to plant behavior (Lopes et al., 2007). The accumulation of material resulting from photosynthesis is a physiological aspect of utmost importance for growth analysis (Benincasa, 2003).

In the production of lettuce seedlings, the most common method employed is the multi-cellular expanded polystyrene tray system and subsequent transplanting to the field, from which vigorous and productive plants can be obtained (Marques et al., 2003). This method

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contributes to save water, substrate and space within the nursery; uniformity of seedlings; a high rate of establishment after transplanting; a minimization of phytosanitary treatments; and low root damage during transplanting, enabling early harvests (Cañizares et al., 2002; Filgueira, 2008).

Some studies have shown that cell number influences the phytometric characteristics of plants after transplantation. For instance, Godoy and Cardoso (2005) recommend producing seedlings in trays of 128 cells for the cultivation of *Brassica oleracea* var. *Botrytis*. Similarly, Marques et al. (2003) concluded that trays with greater cell volume allow the formation of seedlings with greater strength and field potential for *L. sativa* cultivation. However, other authors such as Piovesan and Cardoso (2009), found no effect of tray cell number on the phytometric characteristics evaluated in *Cucurbita moschata*.

Still, the absence of recommendations for the spacing for each cultivar indicates the need for studies on this issue. Thus, the present study aimed to evaluate the agronomic performance of mimosa lettuce cv. Lavínia produced in a polystyrene tray system with different cell number and field spacings.

MATERIALS AND METHODS

The experiment was conducted in the municipality of Umuarama, State of Paraná, Brazil, from April to June 2010 at the geographic coordinates 23° 47' 55'' S and 53° 18' 48'' W and an altitude of 430 m. According to the Köeppen system, the climate in the region is classified as Cfa, subtropical humid mesothermal. The mean temperature in the cold months remains lower than 18°C and in the warm months is above 22°C, with sporadic frosts during the winter. Rainfall varies between 1200 and 1600 mm, with a trend of rainfall concentration in summer months (Iapar, 2000).

The seedlings were produced in trays of 128, 200 and 288 cells, wherein each cell measures 0.014354; 0.012074 and 0.010897 m^3, respectively; filled with the commercial substrate Plantmax HT® (Eucatex), and were cultivated in a greenhouse with intermittent irrigation every 90 min. At 7 and 20 days after emergence, the seedlings received supplemental foliar fertilization consisting of calcium nitrate (0.3 g L^{-1}) and magnesium sulfate (0.2 g L^{-1}).

Twenty-five days post sowing, the seedlings had three leaves in addition to the cotyledonary leaves and were transplanted to beds formed of split plots with spacings of 30 × 40; 35 × 40; 40 × 40; and 45 × 40 cm, with 16 plants per plot. The plots consisted of four rows established according to the spacing being evaluated, with the two central lines being considered the useful area, totaling four plants. Plants on the edges were discarded. A split-plot randomized block experimental design was used, with four replicates.

The experiment was installed on soil classified as RED LATOSOL (Embrapa, 2013). The area was prepared by plowing and harrowing, and beds were built manually with the aid of a hoe. The amounts of NPK fertilizer applied followed the recommendations for lettuce (Trani et al., 1997). The fertilizers applied were simple superphosphate, potassium chloride and ammonium sulfate, incorporated at 5 days after transplanting (DAT) as the base fertilizer, and ammonium sulfate as top-dressing between rows, incorporated at 15 DAT. During crop growth, irrigation was performed through sprinkling, and the experimental area was monitored for pests, diseases and weeds.

The harvest was performed manually at 45 DAT in the useful area of the plot. The following phytometric characteristics were evaluated: Number of leaves (NL) – obtained by counting the leaves of each plant; Plant height (PH) – the distance measured with the aid of a graduated ruler from the plant collar to the top edge of the highest leaf, in centimeters; Stem length (SL) and mean diameter (SD) – measured with a caliper, the SD was obtained by averaging two perpendicular diameters and both are expressed in centimeters.

The shoot fresh weight (SFW) was determined by weighing the leaves, and the results are expressed in g $plant^{-1}$. The shoot dry weight (SDW) was measured by drying the fresh samples, which were stored in paper bags and dried to constant weight in a 65°C forced air oven. The samples were then weighed, and the results are expressed in g $plant^{-1}$.

Data underwent analysis of variance, and the means were compared by Tukey's test at $p<0.05$ (R Development Core Team, 2014).

RESULTS AND DISCUSSION

The tray × spacing interaction and the isolated factor spacing did not significantly affect the variables evaluated in this study. There were significant changes in the number of leaves and in stem length and diameter in response to the isolated tray effect, but no significant effect was detected on the variable plant height (Table 1).

The plants derived from seedlings produced in trays of 128 and 200 cells were superior to those from 288-cell trays, resulting in more leaves on the plants grown in the field. Regarding the variables stem length and diameter, the plants produced in trays of 128 cells were superior to those from 288-cell trays but did not differ significantly from those grown in trays of 200 cells (Table 1).

Godoy and Cardoso (2005) evaluated the yield of *B. oleracea* produced in trays with different cell number (128 and 288 cells) and noted that the variables analyzed, including the fresh weight of the head, number of leaves per plant, head diameter, total production and percent of commercial heads, also displayed better performance when using seedlings derived from trays with 128 cells compared to those of 288 cells, corroborating the results of the present study.

These authors stated that the superior development of seedlings produced in trays of 128 cells indicates that plant development is influenced by the substrate volume available to be exploited by the seedling root system at the time of production. This volume may be associated with the availability of nutrients to the plants, allowing increased seedling growth and manifesting as an increase in the production variables evaluated at the end of the crop cycle.

Marques et al. (2003) confirmed the relationship between the number of cells per tray used for seedling production and the potential of *L. sativa* cultivation in the field: plants from seedlings produced in trays with 128 and 200 cells displayed superior performance, with increased root length and plant fresh weight, compared to seedlings from trays with 288 cells. This implies that

Table 1. Number of leaves (NL), plant height (PH), stem length (SL) and stem diameter (SD) of mimosa lettuce cv. Lavínia produced in three trays with different cell number and four field spacings.

Causes of variation	Variables analyzed			
	NL	PH (cm)	SL (cm)	SD (cm)
Tray[1]				
128	27.30[a]	21.25	4.08[a]	2.15[a]
200	27.15[a]	21.41	3.77[ab]	2.09[ab]
288	23.29[b]	19.58	3.00[b]	1.61[b]
Spacing[2]				
0.30 × 0.40	25.00	19.60	3.65	1.95
0.35 × 0.40	24.65	20.40	3.49	1.74
0.40 × 0.40	26.57	21.10	3.55	2.05
0.45 × 0.40	27.41	21.90	3.76	2.07
F value				
Tray (T)	6.58*	1.36[ns]	6.28*	4.24*
Spacing (S)	1.11[ns]	0.98[ns]	0.41[ns]	1.25[ns]
T * S	0.57[ns]	0.44[ns]	0.36[ns]	0.53[ns]
CV[1] (%)	13.66	16.77	24.58	29.16
CV[2] (%)	16.51	16.54	17.91	23.97

Means followed by the same letter within a column do not differ by Tukey's test ($p < 0.05$). * Values significant at a 5% probability level; [ns] non-significant values.

seedlings with poor root development develop into inferior adult plants.

Thus, it again becomes clear that a smaller volume of substrate influences plant behavior and may affect plant architecture, development, weight and quality, thereby influencing production. These authors therefore recommended the use of polystyrene trays with 200 cells for the production of lettuce seedlings, which results in superior adult plants and has the advantages of using a smaller physical space in the greenhouse and saving substrate compared to trays with 128 cells.

For Seabra Júnior et al. (2004), seedlings produced under a higher substrate volume (121.2 cm^3) exhibited doubled leaf area compared to those produced under a smaller substrate volume (34.6 cm^3), regardless of the seedling age. These results are most likely due to the larger volume of substrate surrounding the root system, contributing to growth and the supply of nutrients, water and light and consequently to a higher production of leaves for the plant's growth and development (Menezes Júnior et al., 2000).

Studies with trays containing fewer cells have also been performed, such as that by Piovesan and Cardoso (2009), which evaluated phytometric characteristics in *C. moschata* plants derived from seedlings produced in polystyrene trays with 72 and 128 cells; however, the authors did not observe any effects of tray cell number on the fruit variables total and neck length, seed cavity and neck diameter, and yield, number and weight of fruits per plant.

Regarding the spacing effect, Gualberto et al. (1999) evaluated the competition of lettuce cultivars in three spacings (25 × 20; 25 × 25; and 25 × 30 cm) and did not find significant differences for the isolated effect of spacing, as observed in the present study (Table 1).

Nevertheless, a significant spacing effect was observed in Reghin et al. (2002), which evaluated the miniature lettuce cv. AF-469-Mini lisa and observed that plant height showed a decreasing linear response with increasing spacing among plants in the greenhouse and in the field. According to those authors, this type of response is associated with the density of plants because when there was a decrease in population density, there was lower height development, and when there was an increase in plant spacing (from 10 to 25 cm), there was an increase in the number of leaves, in contrast to the pattern shown in Table 1.

Silva et al. (2000) found that higher competition for light in denser spacings contributed to lettuce plants growing taller, but no significant differences in the number of leaves were observed.

The tray factor had a significant effect on the variables fresh and dry weight of the shoot (Table 2); plants derived from trays with 128 cells were superior to those from 288-cell trays but did not differ significantly from those grown in 200-cell trays.

However, Barbosa et al. (2010), when evaluating the development of *Calendula officinalis* seedlings in polystyrene trays of 128 and 288 cells, observed that the variables shoot dry weight, root dry weight and total dry weight of the seedlings were not significantly influenced by the cell volume, which had no effect on seedling quality. In that case, trays with a higher number of cells may be chosen, maximizing seedling production in a smaller space and saving on substrate.

Likewise, Piovesan and Cardoso (2009) observed that the variables fresh and dry weight of the shoot and root of *C. moschata* seedlings were also not influenced by different tray cell volumes when assessing expanded polystyrene trays with 72 and 128 cells. Moreover, Medeiros et al. (2010), when evaluating seedlings before transplanting, found no significant difference between trays of 128 and 200 cells for the variables percentage of seedling emergence, shoot height, number of leaves, root length, and shoot and root dry weight in *Cucumis melo* seedlings. It important to note that in the present study, the phytometric characteristics of plants were evaluated only after the cultivation cycle, with no data collected on seedlings before be transplanted in the field.

There was no effect of field spacing on the variables fresh and dry weight of the shoot of mimosa lettuce cv. Lavínia (Table 2). Likewise, Gualberto et al. (1999), when evaluating the competition of lettuce cultivars under three spacings (25 × 20; 25 × 25; and 25 × 30 cm), found no significant differences for the isolated effect of spacing on shoot dry weight.

Table 2. Shoot fresh weight (SFW) and shoot dry weight (SDW) of mimosa lettuce cv. Lavínia produced in three trays with different cell number and four field spacings.

Causes of variation	Variables analyzed	
	SFW (g.plant^{-1})	SDW (g.plant^{-1})
Tray[1]		
128	274.98^{a}	8.85^{a}
200	262.90^{ab}	8.42^{ab}
288	177.34^{b}	5.68^{b}
Spacing[2]		
0.30 × 0.40	201.89	6.50
0.35 × 0.40	234.73	7.50
0.40 × 0.40	253.58	8.12
0.45 × 0.40	263.42	8.48
F Value		
Tray (T)	4.35*	4.35*
Spacing (S)	1.08^{ns}	1.09^{ns}
T * S	0.10^{ns}	0.10^{ns}
CV[1] (%)	42.80	43.04
CV[2] (%)	37.76	37.78

Means followed by the same letter within a column do not differ by Tukey's test ($p < 0.05$). *Values significant at a 5% probability level; ^{ns} non-significant values.

However, Echer et al. (2001) found that as spacing decreases and population density increases, within certain limits, there is a trend toward increased total production per area, possibly resulting in higher profitability for the producer.

Lima et al. (2004), while working with crisp-leaf lettuce and spacings of 20 × 20 and 20 × 30 cm, observed that cv. Vera and Veronica exhibited greater shoot fresh weight in the larger spacing. For Echer et al. (2001), the cultivars Vera and Veronica did not differ significantly from each other in 20 × 20 or 25 × 25 cm spacings, although the cv. Vera was superior in regard to the shoot fresh weight. Conversely, Silva et al. (2000) found that smaller spacings (20 × 20 cm) result in superior shoot dry weight, diverging from the data obtained in the present study (Table 2).

When studying seedling production, assessment of the development after transplanting is of paramount importance because a seedling exhibiting satisfactory development at transplanting will not always favor greater productive potential in the field (Piovesan and Cardoso, 2009).

The results of the present study indicate that the polystyrene trays with 128 and 200 cells have the potential for use in the production of seedlings of mimosa lettuce cv. Lavínia. Thus, the use of trays with 200 cells is recommended, enabling the production of quality plants, in addition to the advantages of using a lower physical space in the greenhouse, obtaining a higher number of seedlings and saving substrate and water. This will result in a greater optimization and profitability for the producer.

Regarding the factor plant spacing, considering that it had no effect on the phytometric characteristics evaluated, using the lowest spacing evaluated (0.30 × 0.40 cm) is recommended, aiming to enhance the use of the planting area to increase yield and income for the producer of mimosa lettuce cv. Lavínia.

Nevertheless, further studies should be performed to clarify the performance of other cultivars and/or localities, in addition to evaluating variables associated with the seedlings when they are suitable for transplanting.

Conclusion

The agronomic performance of mimosa lettuce cv. Lavínia is favored when plants are produced in trays with 200 cells and is not influenced by field spacing.

Conflicts of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGMENTS

The authors thank the Coordination for the Improvement of Higher Education Personnel (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES) for the fellowship granted to the first author and the Araucária Foundation (Fundação Araucária) for the productivity fellowship granted to the second author.

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