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Original Research Article

Vermicompost Application and Growth Patterns of Lettuce (*Lactuca sativa* L.)

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Abstract

Lettuce is the most important leaf vegetable grown in Argentina mainly in the green belts. This species requires 90 to 100 kg ha^{-1} nitrogen, which can be supplied by synthetic chemical fertilizers or organic supplements. The objective of this work was to evaluate the effect of the application of vermicompost on the growth parameters of lettuce in two commercial types: leaf lettuce (cv Brisa) and butterhead (cv Daguan). Seedlings were produced in plastic trays and were transplanted when two leaves were completed expanded 30 days after sowing after that management was similar to a commercial one. The experimental design was a randomized complete block with four replications. During cultivation and at harvest measurements of fresh and dry weight, leaf number and area, nitrate and reducing sugar concentrations were made. Calculations for yield were performed. At harvest, vermicompost addition affected nitrate content in leaf lettuce (cv Brisa) increasing its concentration. Yield was not affected by vermicompost application.

Keywords: lettuce; organic supplement; vermicompost; leaf crops.

INTRODUCTION

Vegetable crops in Argentina occupy 229,584 ha in different geographical areas and in all the provinces contributing to the agricultural GDP in about 6% (SAGPyA, 2003; Benencia et al., 1997). In particular, the area cultivated with lettuce in our country is 9 734 ha (INDEC, 2004); it is the most important leafy crop. The lettuce is cultivated mainly outdoors and there are only 393 ha of crops protected (INDEC, 2004).

Lettuce can be grown throughout the year using cultivars with different environmental requirements. The lettuce is one of most crop rotations with yield of 30 t ha^{-1} per crop. In certified organic production systems growing lettuce achieves performance close to 6,500 kg ha^{-1} (SENASA, 2001) and in 2006, the amount consumed in the market was 36,301 kg of certified organic lettuce from approximately 6 hectares (SENASA, 2007).

Approximately 50% of the nitrogen demand of the culture occurs during the second half of the growing cycle and is estimated between 1-2.5 kg N t^{-1} dry matter. The organic supplements are alternative sources of nutrients with lower environmental impact than chemical fertilizers and can be obtained by aerobic composting manure and crop residues or by transforming them into humus from worms (*Eisenia fetida*) (Ulle et al., 2004). The combination of raw materials and the composting method used provides particular qualities in terms of physical, chemical and biological composition (Raviv, 2005). The manure affects the environment (emissions of ammonia, methane, nitrous oxide, manure runoff and its components into surface water and nitrate and phosphorus leaching into the groundwater); therefore it is recommended to use materials after composting (Ulle et al., 2004). In particular, the lettuce crop responds positively to the application of organic supplements, although the recommendations on application rates vary between different authors and type of fertilizers (Jae-Jung et al., 2004; Polat et al., 2004; Ulle et al., 2004, Yuri et al., 2004; Mastouri et al., 2005).

There is a positive correlation between the amount of nitrogen available for crops and nitrate concentration in leaves (Drews et al., 1996). The concentration of nitrates in the edible leaves of lettuce are regulated by the European Commission Regulation No 563-2002 which has set upper limits in order to protect consumers from potential toxicological risks following the consumption of nitrate rich foods. In addition, there is an inverse correlation between nitrates and reducing sugars concentration. This phenomenon could be related to the maintenance of osmotic potential in plants because when photosynthetic activity decreases, and therefore the sugar concentration in the tissues increases, the presence of nitrates would compensate the decline of the potential.

The study of the response to the addition of organic supplements on growth and yield of crops is of great interest since they can be applied replacing and/or complementing synthetic chemical fertilizers. This is particularly important in vegetables farms due to the lack of knowledge or expertise of producers since the application of chemical fertilizers in excessive doses can lead to pollution problems of soil and water.

The objective of this work was to evaluate the effect of the application of vermicompost on the growth parameters of lettuce in two commercial lettuce types: leaf lettuce and butterhead.

MATERIALS AND METHODS

The trial was conducted in the experimental field of the Department of Horticulture, Faculty of Agronomy, University of Buenos Aires (34 º 45 'S, 60 º 31' W) in the period from September to November. Lettuce cultivars (*Lactuca sativa* L.) of two commercial types, leaf lettuce cv "Brisa" and butterhead cv "Daguan", were used. The soil has a silty loam texture with 27.5% clay, 52.5% silt and 20% sand. It has moderate to low hydraulic conductivity (28 mm $hour^{-1}$).

Seedlings were produced in plastic trays and were transplanted when two leaves were completely expanded 30 days after sowing. After that seedlings were arranged on beds of 1.1 m wide and 0.2 - 0.3 m in height, at a density of 16 plants m^{-2} (0.25 m × 0.25 m) for both cultivars. The crop management was similar to the commercial one, regular watering by hand to keep the soil with adequate water supply.

Treatments were:

N0 = Control without application of vermicompost

N1 = 24 t ha^{-1} vermicompost (fresh matter)

Chemical fertilizers were not added.

24 t/ha was added to supply approximately 100 kg N. ha^{-1}

Compost was incorporated manually into the planting hole when transplanting at a dose of 150 g vermicompost. Table 1 presents the chemical composition of the applied vermicompost. The experimental design was a randomized complete block split plot with four replications.

Data collection was conducted three times during the crop cycle: at transplant, 40 days after transplant (DAT) and at harvest (60 DAT). Each time three plants per treatment were taken for analysis. Procedures proposed by Hunt (1978, 1982) were used for processing the data at any time.

Total fresh weight (TFW) using an electronic balance (S = 0.1 g) ACCULAB V-1200 was used.

Total dry weight (TDW) was determined by drying in an oven at 60-65 °C.

Number of leaves by counting the number of leaves greater than 2 cm long in each one of the plants sampled.

Leaf Area (AF): for commercial type "butterhead" leaf area was obtained using the equation proposed by Yoshida et al. (1997).

AF (cm^2) = 0.7 × length (cm) × width (cm) -2.4

For estimating the AF of "Brisa" the following method was used:

1) Length and width of all leaves of plants sampled were recorded. It was performed for each treatment and every one of the dates.

2) Groups of leaves were selected from different size sheets, and then they were scanned on a framework of known surface, taking care that the leaf blade would fold and would not underestimate the AF. For this piece each sheet along the dented areas and gentle pressure was exerted with a role in keeping the pieces in a correct position to be scanned. The images were recorded in High Definition JPEG format.

3) All these images were viewed with the same level of magnification (zoom) in Adobe Photoshop 5.5. With this software the leaf area was calculated in pixels along the contour with the mouse pointer leaves or pieces of them.

4) In the same way as with the leaves, the area was calculated in pixels of the framing rectangle sheets or pieces of leaves and finally the results were expressed in cm^2.

5) In a scatter plot surfaces were entered imaginary rectangles product of wide and long leaves scanned in the X axis and the area estimated by the method described in the Y axis

6) Then the corresponding linear function and value of R^2 was calculated. For each treatment and each sample we performed adjustment curve containing data on 30 sheets.

7) Finally, to get the plant joined AF values per sheet obtained by entering the width and length of each leaf sampled into the equation (R^2 = 0.9713).

AF (cm^2) = 0.833 × length (cm) × width (cm) - 5.768

Table 1: Chemical characteristics of the applied vermicompost originated from poultry manure (moisture content 45%)

pH	CE	P	C organic	N total	Ca	Mg	Na	K
---	($ds \cdot m^{-1}$)	(ppm)	(%)	(%)	(ppm)	(ppm)	(ppm)	(ppm)
7.34	3.38	269.86	14.57	0.91	2810.09	395.32	310.26	733.77

Table 2: Soil analysis

pH	CE	P	C organic	N total	Ca	Mg	k	CEC
---	($ds \cdot m^{-1}$)	(ppm)	(%)	(%)	(ppm)	(ppm)	(ppm)	(cmo/kg)
6.9	0.5	122	2.1	0.26	13	2.3	1.6	21

CE: electrical conductivity ($decisiemen \cdot m^{-1}$); CEC: cation exchange capacity ($centimol \cdot kg^{-1}$)

Nitrate and reducing sugar concentration were determined according to Cataldo et al. (1975) and Somogyi and Nelson (1952), respectively.

Yield

At harvest, marketable plants were taken from the three central rows of each plot for yield determination. Thus we obtained the average weight per plant (g); it was affected by planting density.

Statistical analysis

The data obtained were subjected to analysis of variance, using Tukey's test at 5% for the comparison between treatment means. For this we used the InfoStat / Professional Version 2.0.

RESULTS AND DISCUSSION

Total fresh weight (TFW)

At transplant, there were no significant differences between cultivars. At harvest (60 DAT), reaching approximately 250 g per plant, no significant differences between treatments ($p > 0.05$) were observed, whereas 40 DAT Daguan plants with vermicompost added showed high TFW.

Good levels of soil organic matter together with increased temperatures would have positively affected the mineralization, and therefore would be the main reasons for the lack of response.

At this point, Sanchez (2001) reported that butterhead lettuce did not show significant response to the application of vermicompost, justifying these results for the high provision of total soil nitrogen although it should be mentioned that in his essay the percentage of N was higher than in the present study (0.44 versus 0.26%).

Table 3: Total Fresh (g) weight for lettuce Cv Daguan and Cv Brisa with or without the application of vermicompost

Total Fresh Weight (g)				
Cultivar	Dose	Days after transpant (DAT)		
		0	40	60
Daguan	**N0**	0.70 a	94.96 a	245.45 a
	N1	0.70 a	139.00 b	252.35 a
Brisa	**N0**	0.74 a	94.15 a	237.25 a
	N1	0.74 a	100.82 a	263.85 a

Different letters in rows denote significant differences ($p \leq 0.05$)

Total dry weight (TDW)

At transplant and 40 DAT, Daguan had significantly higher TDW than Brisa, whereas, at harvest there were no significant differences between treatments ($p > 0.05$).

Table 4: Total Dry Weight (g) for lettuce Cv Daguan and Cv Brisa with or without the application of vermicompost

Total Fresh Weight (g)				
Cultivar	Dose	Days after transpant (DAT)		
		0	40	60
Daguan	**N0**	0.05 b	6.62 a	29.41 a
	N1	0.05 b	10.05 b	28.14 a
Brisa	**N0**	0.02 a	6.59 a	27.88 a
	N1	0.02 a	7.60 ab	28.04 a

Different letters in rows denote significant differences ($p \leq 0.05$)

At harvest, no significant differences between treatments were found for each cultivar. These results agreed with those reported by Diacomo and Montemurro (2010) who reported that the effect of organic supplement is a long term trait. However, Stancheva and Mitova (2002) determined a significant increase in total dry weight for lettuce in response to vermicompost application.

Number of leaves

At transplant, cultivars differred in the number of leaves significantly, Daguan reaching the greatest number. Forty days after transplant and at harvest (60 DAT) no significant differences between treatments were found for each cultivar. Da Silva et al. (2005) found no significant differences in the number of leaves with different organic fertilizers, however, Porter (1999) and Abdo et al. (2004) reported that the number of leaves per plant increased with increasing dose of compost applied.

Table 5: Number of leaves for lettuce Cv Daguan and Cv Brisa with or without the application of vermicompost

Number of Leaves				
Cultivar	Dose	Days after transpant (DAT)		
		0	40	60
Daguan	**N0**	4.75 b	20.58 ab	47.83 a
	N1	4.75 b	23.08 b	47.83 a
Brisa	**N0**	2.75 a	19.08 ab	42.00 a
	N1	2.75 a	16.25 a	51.16 a

Different letters in rows denote significant differences ($p \leq 0.05$)

Leaf area (AF)

Only 40 DAT application of vermicompost showed a significant effect that was expressed by higher values of AF. At harvest, vermicompost had no effect on leaf area (Table 6). However, Stancheva and Mitova (2002) found that the application of compost significantly increased the leaf area and number of leaves in a lettuce crop.

Table 6: Leaf area (cm^2) for lettuce Cv Daguan and Cv Brisa with or without the application of vermicompost

Leaf Area (cm^2)				
Cultivar	Dose	Days after transpant (DAT)		
		0	40	60
Daguan	N0	45.10 b	1551.23 a	4271.72 a
	N1	45.10 b	2301.87 b	4119.85 a
Brisa	N0	19.91 a	2039.70 ab	5554.10 b
	N1	19.91 a	2293.37 b	6170.11 b

Different letters in rows denote significant differences ($p \leq 0.05$)

Yield

Marketable yield of the crop did not show significant differences. All treatments exceeded 40 t ha^{-1}, being higher than conventional average yields (30 t ha^{-1}).

Table 7: Yield ($tn \cdot ha^{-1}$) for lettuce Cv Daguan and Cv Brisa with or without the application of vermicompost

Cultivar	Dose	Yield (tn ha^{-1})
Daguan	N0	45.51 a
	N1	42.16 a
Brisa	N0	44.15 a
	N1	46.41 a

Different letters in rows denote significant differences ($p \leq 0.05$)

Studies on this subject have found no significant responses in performance with the application of any organic supplement under the conditions of their crops (Pavlou et al., 2007; Valíková et al., 2006). In contrast, other researchers found higher yields in treatments with application of fertilizer (Mastouri et al., 2005; Polat et al., 2004; Yuri et al., 2004; Santos et al., 2001; Vidigal et al. 1995; Ulle et al., 2005 (2); Lora Suva et al., 2007).

Table 8: Nitrate concentration ($mg \cdot kg^{-1}$ FW) for lettuce Cv Daguan and Cv Brisa with or without the application of vermicompost

Nitrate Concentration (mg Kg^{-1} FW)				
Cultivar	Dose	Days after transpant (DAT)		
		0	40	60
Daguan	N0	172.8 a	222.83 a	425.88 ab
	N1	172.8 a	416.60 a	384.23 a
Brisa	N0	684.2 b	623.80 a	532.68 b
	N1	684.2 b	373.53 a	837.63 c

Different letters in rows denote significant differences ($p \leq 0.05$)

Nitrate concentration

Accumulation of nitrates results from an imbalance between the uptake and translocation of nitrates by the xylem, and the reduction of these to ammonia which is subsequently rapidly incorporated into amino acids (Pavlou et al., 2007). Only in cv Brisa higher nitrate contentc were found at harvest with the application of the organic supplement.

The concentration of nitrates in the edible leaves of lettuce are regulated by the European Commission Regulation No 563-2002 which has set upper limits in order to protect consumers from potential toxicological risks following the consumption of nitrate rich foods. Nitrate concentration in our lettuce leaves was far below the upper limits as set in the Commission Regulation (2002).

The results observed in the cultivar Brisa are similar to those reported by Tsai (2005) who described increases in nitrate levels with increasing doses of organic fertilizers due to an increase in the uptake of N.

Reducing sugar concentration

No differences were found in reducing sugar concentration during growing season for both cultivars. Other studies found that high rates of N can reduce the soluble sugar and the sugar content of lettuce (Diacomo and Montemurro 2010).

Table 9: Reducing sugar concentration ($mg \cdot g^{-1}$ FW) for lettuce Cv Daguan and Cv Brisa with or without the application of vermicompost

Reducing Sugar (mg g^{-1} FW)				
Cultivar	Dose	Days after transpant (DAT)		
		0	40	60
Daguan	N0	23.50 a	39.65 a	60.55 a
	N1	23.50 a	46.74 a	49.04 a
Brisa	N0	17.59 a	49.18 a	57.26 a
	N1	17.59 a	55.50 a	33.84 a

Different letters in rows denote significant differences ($p \leq 0.05$)

CONCLUSIONS

At harvest, for the two cultivars, total fresh and dry weight, number of leaves, leaf area and reducing sugar content did not show significant differences. The application of vermicompost significantly increased nitrate concentration at harvest for Brisa cultivar. Marketable yield was not affected by vermicompost application.

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