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Full Length Research Paper

Effect of Compost and Bovine Dry Manure on Soil Chemical Characteristics and Production of iceberg Lettuce (*Lactuca Sativa* L.)

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Lettuce is one of the most important vegetables consumed worldwide. In recent years, lettuce production has greatly increased, and new interest has surged in their cultivation. The use of organic fertilizers in lettuce culture has been demonstrated to augment growth rate, increase yields and improve plant quality. The main goal of this research was to evaluate the effect of application of compost amended with *E. densa* and dry bovine manure in different combinations on the soil chemistry and the productivity of Iceberg lettuce (*L. sativa*). An experimental randomized block design with five treatments and four repetitions was carried out. The treatments were T1S=100% soil, T2SC=50% soil+ 50% compost, T3SCM=50% soil + 25% compost + 25% dry bovine manure, T4CM=50% compost + 50% manure and T5M =100% manure. The plants were grown inside an experimental greenhouse in 20 plastic pots, each with 2 kg of capacity. The experiment lasted 53 days from the transplant of planters to final harvest. At the end of the experimental period, a 1 kg sample of each experimental unit was removed for soil chemistry analysis. Additionally, production was evaluated throughout the experiment. The results indicated that the soil chemical parameters were significantly different (*P*<0.05), especially in the treatments that included organic fertilizers, which enhanced soil quality by increasing CIC, raising pH, and increasing the EC, OM, inorganic N, P, K, Ca, Mg, Zn, Fe, Mn, Cu, B and Na contents. Treatments T1S, T3SCM and T5M resulted in the highest Iceberg lettuce production and reached an acceptable production of fresh weight, thereby confirming the importance of incorporating these fertilizers to increase yields. Moreover, a direct relation between the number of leaves (NL) and foliar area (FA) was observed with respect to lettuce fresh weight (FW). Consequently, the use of both dry bovine manure mixed with soil and a combination of soil, compost and manure can be recommended for the culture of Iceberg lettuce.

Keywords: Iceberg lettuce culture, compost, dry bovine manure, soil chemistry, productive variable, yields.

INTRODUCTION

Lettuce (*L. sativa*) is one of the most important vegetables in worldwide cultivation. Currently, lettuce is cultivated under different climatic conditions and is generally consumed in salads mixed with other vegetables (Moreira *et al*., 2014; Masarirambi *et al*., 2012; Pablo *et al*., 2012).

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In 2012, Mexico produced a total of 335,337 metric tons of lettuce, which made Mexico the ninth largest lettuce producer in the world (FAOSTAT, 2012).The annual *per capita* consumption of lettuce has increased from 1.8 to 2.5 kg in only eight years in our country. However, the commercial balance presented a deficit during the period of 1990 to 2000; to cover the national demand of this product, it has been necessary to import from another countries (Bobadilla *et al*., 2010; Macías *et al*., 2012).

Traditionally, chemical fertilizers have been employed in lettuce cultivation and have provided good results in terms of yields and profitability. Nevertheless, in recent years, the production methods have changed, and the use of organic fertilizers has become more common. The most commonly used organic fertilizers are sugar cane residues, bioactive compounds, and compost amended with manures, vegetable residues and vermin compost (Pablo *et al*., 2012; Reis *et al*., 2013).

Organic fertilizers have also shown several advantages, including increases in yields; enhanced physicochemical properties of soils, comprising their cationic interchange capacity (CIC) and organic carbon content; and an enhanced nutritional quality of the final products (Fagnano *et al*., 2011).

The application of compost in lettuce culture has contributed to an increase the fresh weight and the quantity of N, K, Ca, Mg, Cu, Fe, and Zn ions in leaves, resulting in a notable improvement in nutritive quality (Reis *et al*., 2014). In contrast, manures also contain high quantities of nitrogenous compounds that are easily transformed into ammonium and nitrite. Manures had been used as a medium to improve the microbiological, chemical and physical proprieties of the soils used for agricultural activities and to increase yields (Mahmoud *et al*., 2009; D´Hose *et al*., 2012; Indriyati, 2014).

Compost manufactured with dry manure has some demonstrated advantages over fresh manures by reducing the number of weed seeds and the size and volume of the organic fractions, which allowed for their better distribution in the soil, improved the nutrient balance, stabilized the organic matter and slowed the liberation of nutrients such that plants could better utilize the nutrients (Moral *et al*., 2009; Fagnano *et al*., 2011). There is a relationship between the organic fertilizer and the yield of lettuce. For example, Moreira *et al*. (2014) recommended the use of compost as an important source of organic matter in lettuce culture.

Applying chicken manure to the soils used for lettuce cultivation affected the growth, yield, and nutritive quality of the plants. The application of 60 t/ha is appropriate to achieve a greater yield of lettuce, number of leaves (NL), and height of plant (HP) and a product with a commercially viable size and dry leaf biomass (Masarirambi *et al*., 2012).

In Mexico, a wide variety of manures exist that can be recycled in lettuce cultivation, which contributes to reducing their environmental impact. Another resource is the aquatic macrophyte *Egeria densa*, a member of the family *Hidrocaritaceae*, which can be used as an organic matter source. This species invades bodies of water such as lakes and dam lakes and causes several hydrological and limnological problems. This plant has a high nutrient content and can be utilized for the elaboration of organic fertilizers; furthermore, it can be directly fed to bovine or used as biofertilizer or for compost elaboration (Caro *et al*., 2009).

The objective of this study was to evaluate the effects of dry bovine manure and *E. densa* compost added to soil in different proportions on the soil chemistry parameters and the production of Iceberg lettuce, *L. sativa*.

MATERIALS AND METHODS

Experimental conditions

The experiment was carried out in the experimental greenhouse of the Agriculture Science Centre (ASC) at the Autonomous University of Aguascalientes (AUA), Mexico, from December 10, 2012, to February 3, 2013.

For the experiment, the following products were used: a) *E. densa* compost, b) dry bovine manure and c) agricultural soil. Compost was altered with equal proportions (v/v) of *E. densa*, garden grass and dry bovine manure.

The *E. densa* and the garden grass were cut into small pieces measuring approximately 5 cm with a machete, and dry manure was triturated to afford a product of uniform size and facilitate the mixing of the materials in the humidity. A compost heap was constructed using 20L plastic receptacles; five were full of *E. densa*, five contained dry manure and five had garden grass. The materials were deposited forming a vertical pile; first, the garden grasses residues were added, followed by *E. densa* and dry bovine manure. The composting process lasted for the three months from August to October 2012. During this time, temperature (°C) and humidity (%) were evaluated weekly, and the material was raked outward using as hovel to increase aeration. The composted process was considered finished when the materials' temperature was equal to the environmental temperature.

For this study, a randomized block design with five treatments and four repetitions (5 x 4) was implemented. The treatments were T1S = 100% soil (control); T2SC = 50% soil + 50% compost; T3SCM = 50% soil + 25% compost + 25% dry manure; T4CE = 50% compost + 50% dry manure, and T5M = 100% dry manure. The experiment lasted 53 days from the transplant of the lettuce seedlings to the final harvest.

A total of twenty 2-kg plastic pots were used as experimental units. On December 6, 2012, Iceberg lettuce (*L. sativa* L.) seedlings were transplanted. The selected lettuce seedlings were healthy and vigorous and had an average height of 5 cm. Throughout the experiment, watering was carried out two times per week. During the experiment, some diseases were observed, but they were properly treated with the Aflix, Ambhus, Manzate and Cobrezate chemical compounds.

Chemical and Production Analysis

At the end of the experiment, a one-kg sample of soil was taken from each pot. In the laboratory of Soil, Water and Plant Nutrition of the ASC, the following parameters were quantified: a) apparent density (AD, g/cm^3), b) pH (in a 1:2 soil: d H_2O suspension);c) electric conductivity (EC, dS/m); d) cationic interchange capacity (CIC, cmol$^+$/kg); e) organic matter (OM, %); f) inorganic nitrogen(IN, mg/kg); g) soluble phosphorous (P, mg/kg); h) potassium (K, mg/kg), i) calcium (Ca, mg/kg), j) magnesium (Mg, mg/kg) and k) sodium (Na, mg/kg). Furthermore, the microelements iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and boron (B), mg/kg were also evaluated. All these elements were analyzed with the techniques described in NOM-021-SEMARNAT (2000).

On 13 occasions over the course of the experiment, the number of leaves (NL), the length and width of the largest leaf (LL and WL, cm) of each plant were recorded. The values of LL and WL were used to calculate the foliar area (FA, in cm^2). Furthermore, foliar area rate (FAR) was estimated using the following formula:

FAR = FA of treatment/FA of control test × 100.

Finally, the fresh weight (FW, g) of lettuce harvested from each pot was measured (Carranza *et al*., 2009).

Statistical analysis

The soil chemical characteristics and production indicators collected were deposited in an Excel spreadsheet (Office Window, 2007). For each dataset, the mean and standard deviation were calculated. Subsequently, one-way ANOVA analysis and *a posteriori* Tukey tests of means were performed using the software package Minitab, version 16 (Minitab Inc., State College, PA, USA). A value of $P<0.05$ was considered statistically significant.

RESULTS

Soil chemical parameters

The highest mean values of the soil chemical parameters evaluated in this experiment were found in T4CM (50% of compost and 50% of dry manure) (Table 1). In this treatment, lettuce plants died after 28 days of culture.

AD showed a high mean value of 1.0 g/cm^3 in T1S, which was significantly higher ($P<0.05$) than observed in the other treatments. The lower values of approximately 0.5 g/cm^3 were observed in the treatments T4CM and T5M. The mean values of CIC ranged from 12.7 cmol$^+$/kg in T1S to 40.2 cmol$^+$/kg in T4CM. This last treatment was significantly different ($P<0.05$) from the other treatments. The pH ranged from 7.4 to 8.2. The lowest value 7.4 was found in treatment T1S, and the highest of 8.2 occurred in T2SC; these means were both significantly different ($P<0.05$) from the other treatments. The lowest value of EC was found in T1S (0.5 dS/m), whereas T4CM presented the highest value (4.9 dS/m), which was significantly different ($P<0.05$) from the other treatments (Table 1).

T4CM, which had the highest value of EC, was where the Iceberg lettuce plants died. T1S had the lowest percentage OM content, 4.1%, and the highest values were observed in treatments T4CM and T5M, with 22.7 and 21.9%, respectively. These two treatments were significantly different ($P<0.05$) from the other treatments. The mean value of inorganic N in T1S was 15.1 mg/kg and 70.1 mg/kg in treatment T4CM; these levels were both significantly different ($P<0.05$) from the other treatments. There were significant differences ($P<0.05$) in the content of soluble phosphorous in the experimental treatments. The mean value of 23.5 mg/kg in T1S was lowest, and the mean value in T4CM was highest, at 194.2 mg/kg (Table 1).

Higher mean values of K, Ca, Mg, Zn, Cu and B were registered in treatments T4CM and T5E, and these treatments both presented significant ($P<0.05$) differences from the other experimental treatments (Table 1).Treatments T4CM and T5M had higher values of Zn with 7.4 and 7.8 mg/kg, respectively. These treatments were significantly different from the other treatments in this respect (Table 1).The Cu mean values fluctuated in the experiment from 0.6 to 4.9 mg/kg; the lowest value was registered in the control treatment (T1S), and the highest value was obtained in T5M. The results obtained in our experiment exhibited high values of Boron (3.8 to 23.7 mg/kg). The highest values were observed in treatments T4CM and T5M, which were significantly different ($P<0.05$) from the other treatments. The highest concentrations of Fe ions were observed in treatment T1S and reached an average value of 21.8 mg/kg, which was significantly different ($P<0.05$) from the other treatments. The Mn content was highest in T2SC (23.3 mg/kg), which was significantly higher ($P<0.05$) than in the other treatments. Finally, the sodium levels were highest in T4CM, with 1,693 mg/kg, which was significantly different ($P<0.05$) from all other treatments (Table 1).

Productivity variables

The type of soil and the inclusion of compost and bovine dry manure had a direct influence on Iceberg lettuce growth. In T1S, the mean values of leaf length (LL), leaf width (WL), and foliar area (FA) were significantly higher ($P<0.05$) than the other treatments. However, in terms of the final fresh weight (FW), the highest value was observed in T5M, followed by T3SCM and T1S. These two last

Table 1: Average values (± standard deviation) of chemical soil variables registered in experimental treatments.

Variables	Treatments				
	T1S	T2SC	T3SCM	T4CM	T5M
AD	$1.0±0.1^{c}$	$0.9±0.0^{b}$	$0.9±0.0^{b}$	$0.6±0.0^{a}$	$0.6±0.0^{a}$
CIC	$12.7±0.5^{a}$	$31.8±1.6^{b}$	$24.2±2.3^{c}$	$40.2±4.9^{d}$	$36.2±5.1^{b}$
pH	$7.4±0.2^{a}$	$8.2±0.2^{d}$	$7.9±0.3^{b}$	$7.5±0.2^{ab}$	$7.7±0.1^{c}$
EC	$0.5±0.1^{a}$	$3.4±0.2^{c}$	$1.4±0.5^{b}$	$4.9±0.5^{d}$	$3.0±0.8^{c}$
OM	$4.1±0.5^{a}$	$8.2±0.7^{b}$	$6.9±0.6^{b}$	$22.7±0.8^{c}$	$21.9±2.3^{c}$
IN	$15.1±8.5^{a}$	$61.7±25.4^{d}$	$37.5±22.7^{b}$	$70.1±29.5^{e}$	$54.1±21.3^{c}$
P	$23.5±11.7^{a}$	$144.5±23.8^{c}$	$126.5±4.5^{b}$	$194.2±14.8^{d}$	$184.6±11.8^{d}$
K	$622.7±57.0^{a}$	$3029.8±150.6^{c}$	$1881.2±286.7^{b}$	$4130.4±240.2^{d}$	$3041.2±211.4^{c}$
Ca	$1518±49.1^{a}$	$2750±144.9^{b}$	$2635±161.7^{b}$	$3320±953.2^{c}$	$3310±700.5^{c}$
Mg	$122.7±1.1^{a}$	$351.6±16.0^{b}$	$341.6±19.4^{b}$	$694.2±6.9^{c}$	$743.4±8.7^{d}$
Na	$583±50.1^{a}$	$1709±205.5^{d}$	$782±245.8^{b}$	$1693±52.0^{d}$	$1316±314.8^{c}$
Fe	$21.8±1.1^{c}$	$16.5±0.7^{b}$	$18.7±2.2^{b}$	$11.6±1.1^{a}$	$9.4±0.2^{a}$
Mn	$23.3±0.3^{c}$	$22.5±0.7^{c}$	$19.2±1.1^{b}$	$8.6±1.1^{a}$	$10.9±0.2^{b}$
Zn	$5.6±0.2^{a}$	$6.4±0.2^{a}$	$5.9±0.3^{a}$	$7.4±0.1^{b}$	$7.8±0.2^{b}$
Cu	$0.6±0.0^{a}$	$1.6±0.1^{b}$	$1.6±0.1^{b}$	$3.2±0.1^{c}$	$4.9±0.3^{d}$
B	$3.8±0.4^{a}$	$7.4±0.6^{b}$	$6.1±1.0^{b}$	$20.8±1.3^{c}$	$23.7±5.7^{c}$

T1S = 100% soil; T2SC = 50% soil and 50% compost; T3SCM = 50% soil, 25% compost and 25% manure; T4CM = 50% compost and 50% manure; T5M = 100% manure. Treatment with different uppercase letters in file means are significant differences(P<0.05); DA = apparent density (g/cm^3), CIC=cationic interchange capacity ($cmol^+/kg$), pH, EC = electric conductivity (dS/m), OM = organic matter (%); IN = inorganic nitrogen (mg/kg), P = Phosphorous (mg/kg), K, Ca, Mg, Na, Fe, Mn, Zn, Cu y B (mg/kg).

Table 2: Productive variables registered in the experimental treatments.

Treatments	NL	LL	WL	FA	FAI	FW
T1S	$11.2^{a}±0.5$	$14.4^{a}±0.4$	$11.7^{a}±0.6$	$169.7^{a}±17.8$	100^{a}	$91.8^{ab}±22.1$
T2SC	$7.2^{a}±4.8$	$6.2^{b}±4.4$	$6.0^{b}±4.1$	$50.4^{b}±38.9$	29.7^{c}	$45.9^{bc}±31.0$
T3SCM	$11.2^{a}±1.5$	$9.2^{b}±1.0$	$7.7^{ab}±1.7$	$72.9^{b}±23.7$	43.0^{b}	$110.8^{ab}±29.3$
T4CM	$0.0^{b}±0.0$	$0.0^{c}±0.0$	$0.0^{c}±0.0$	$0.0^{c}±0.0$	0.0^{e}	$0.0^{c}±0.0$
T5M	$11.5^{a}±1.7$	$7.1^{b}±1.4$	$3.9^{bc}±1.0$	$26.8^{bc}±2.5$	15.8^{d}	$138.0^{a}±62.8$

NL= number of leaves, LL=leaf length (cm); WL=wide of leaf (cm); FA=foliar area (cm^2), FAI=foliar area index (%); FW=fresh weight (g/pot). Different lowercase letters in each row indicate significant differences (P<0.05).

treatments exhibited no significant differences (P>0.05) (Table 2).

The number of leaves (NL) was similar in all experimental treatments, with a mean value of 11 leaves, except for treatment T4CM, in which the plants died after 28 days of culture (Table 2).

Plants from T5M showed lower values of FA and FAI, but their final fresh weight was significantly higher (P<0.05) than those from the other treatments. During the experimental period, treatment T1S showed a constant growth rate of FA. In the other treatments, FA growth was slower (Figure 1).

The FAR obtained after 53 days of culture in treatment T1S was considered to be 100%. Taking this value as the base and comparing it with other treatments, treatment T3SCM reached 43%, followed by T2SC with 29.7%, and treatment T5M with 15.8% (Table 2).

DISCUSSION

Chemical parameters of soil

The soils that are used for intense production in livestock and cropping systems generally have a nitrogen deficit and an acidic pH (Revelli *et al.*, 2010). If we compare the chemical properties recorded in our study, higher mean values of pH, inorganic nitrogen (IN), phosphorous (P) and organic matter (OM) were recorded. However, these values were never higher than those recommended by the

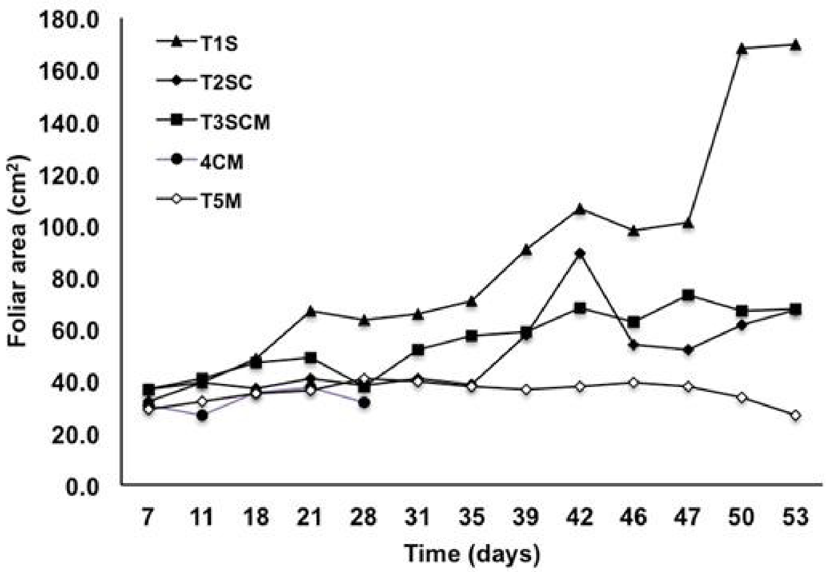

Figure 1. Mean values of foliar area (FA) of Iceberg lettuce in the experimental treatments. T1S = 100% soil; T2SC = 50% soil and 50% compost; T3SCM = 50% soil, 25% compost and 25% manure; T4CM = 50% compost and 50% manure; T5E = 100% manure.

Environment Agency of Portugal (APA, 2008), which suggests that the organic fertilizers employed in our experiment increase the mean values of these parameters but never reached critical levels, which would negatively affect lettuce growth, except for T4CM, where all of the lettuce plants died.

The use of organic manures had demonstrated benefits for soil quality because of the reduction of apparent density (AD) and the increase of cationic interchange capacity (CIC) due to the many negative charges present within organic matter (Diacono and Montemurro, 2010). Moreover, their use contributed to reduce nitrogen loss and slower N mineralization, thereby keeping the cultivation conditions safe (Reiss *et al.*, 2013).

Vermin compost increases nitrite concentration in soils without affecting the commercial lettuce size (Pablo *et al.*, 2012). Soils mixed with vermin compost have augmented quality, exhibiting mean values of pH of 6.9, EC of 0.5 dS/cm, 122 mg/kg of P, 0.26% of N, 13 mg/kg of Ca, 2.3 mg/kg of Mg, 1.6 mg/kg of K and a CIC of 21cmol$^+$/kg. The compost and bovine dry manure utilized in our experiment contributed to an increased specific surface area for adsorption-desorption processes and to an increased water retention capacity, porosity and soil aeration (Torres *et al.*, 2006; Jaurixje *et al.*, 2013).

The normal CIC values in soils range from 5 to 35 cmol$^+$/kg. Treatments with compost of *E. densa* and bovine dry manure had increased CIC, which contributed to the retention of cations and the maintenance of an ionic equilibrium in the soil that helps reduce pH fluctuations. When the CIC values increase in soil, its capacity to absorb minerals increases, thus providing benefits for lettuce growth (Micó *et al.*, 2008). According with values recorder in our work organic fertilizers are appropriate for lettuce culture. Jaurixje *et al.* (2013) established that metals are more soluble in acid pH and that when the pH increases, solubility diminishes. The pH requirements for the majority of cultivated plants range from 5.5 to 7.0. Nevertheless, in this experiment, the treatments with organic fertilizers were slightly alkaline.

Carranza *et al.* (2009) denoted a threshold tolerance for lettuce of 1.3 dS/m. Lettuce growth may be reduced by 13% for each dS/m by which EC exceeds this level. However, saline soils with EC values up to 5.0 dS/m may generally be used for agriculture (Morales, 2009).

Lettuce cultures irrigated with waters containing different salinities affect production but also exhibit improved product quality within a short post-harvest time. Iceberg lettuce is not affected by irrigation with saline water of up to 4.4 dS/m, and some lettuce varieties may be more tolerant to salts than others; further, the salinity tolerance increases with plant age (Carranza *et al.*, 2009). Our results indicated that a value of 4.9 dS/cm might be a critical point for this Iceberg lettuce.

OM improves the physical characteristics of soil by reducing the AD and increasing the hydraulic conductivity, soil aggregation and CCI, which allows for a higher availability of nutrients for growing plants (Arévalo and Castellanos, 2009). Comparing the soils utilized in the experimental treatments with volcanic soils, the levels of OM were superior because of the added compost and dry manure (NOM-021-SEMARNAT-2000).

The availability of inorganic N for plants depends on several factors, such as the presence of soil microorganisms, soil humidity and soil temperature. Moreover, soil pH, humidity, temperature, aeration and the quality of plant residues all affect the mineralization process. The degradation of organic residues mobilizes inorganic N in cultivated soils (Rivero and Paolini, 1995). In this way, organic fertilizers contributed to the observed increases in inorganic N levels that facilitated the growth of Iceberg lettuce.

Mean P content was higher in treatments with organic fertilizers. The values in this study were higher than those reported by Rivero and Paolini (1995) who mentioned the presence of higher values of phosphorous in soils treated with vegetal residues, and reported values that ranged from 6.5 to 12.0 mg/kg. Nonetheless, it has been demonstrated that the long-term application of organic manures results in higher levels of mobilized P as well as higher organic carbon and potassium contents (Diacono and Montemurro, 2010).

The incorporation of organic fertilizers produces significant changes that increase the values of CIC and the content of inorganic N, P and K, thereby increasing agricultural yields (Rivero and Paolini, 1995).

High concentrations of Zn, Cu, and others heavy metals may be reduced with the application of fertilizers containing phosphorous. Similarly, the inclusion of fertilizers containing N, P and K significantly reduced Cd, Zn and Mn content in the tissues of lettuce (Sterrett *et al*., 1996).

Kabata and Mukhergee (2007) mentioned that Zn is an element associated with both the organic and the mineral fractions of soil. The critical level of Zn in soil is over 3 mg/kg (ICA, 1992). Higher values of Cu, between 120 to 180 mg/kg, alter the metabolism of plants due to oxidative stress; specifically, in lettuce, there may be a metabolic connection between enzyme responses and non-enzymatic anti-oxidants (Teklic *et al*., 2008).The values of Cu in this experiment were lower, and no symptoms of Cu toxicity were observed.

According to Liu *et al*. (1981), higher values of soluble B in soil of 2.0 mg/kg are not suitable for agricultural activities. This study showed that compost and dry bovine manure increased the amount of B in soil, a feature that should be considered wherever organic fertilizers are used.

Interchangeable, soluble forms of Fe are considered highly mobile and available for plants. Yongfeng *et al*. (2008) considered that organic matter content positively affects Fe uptake in cultivated plants because of their acidified and reductive characteristics and the capacity of certain humic substances to form chelates in adverse pH conditions. A value of 5 mg/kg is considered low, and values greater than 10 mg/kg are considered high (ICA, 1992). In the experimental treatment, higher values of Fe content were observed.

Na is accumulated at the soil surface, especially in semi-arid and arid regions; this condition affects the structure of soil and has repercussions on the water and air. Moreover, sodium accumulation has a direct effect on the pH and interferes with the acquisition of nutrients. Compost and dry bovine manure are important sources of Na. In all treatments, the mean values reached the critical level of 5 mg/kg established by Sillampaa (1982) and Sims and Johnson (1991). In particular, the value from treatment T4CM was considered negative for lettuce; in this soil, Iceberg lettuce did not prosper, and the plants died 28 days after transplantation.

Some studies have suggested that soil might be enriched by the application of high quantities of organic matter because its decomposition releases high amounts of nitrogen, which might directly increase yields and improve nutrient uptake (D´Hose *et al*., 2012).The nitrogen content in compost with added chicken manure more effectively increased plants yields than did urea. The use of chicken manures may reduce the application of inorganic fertilizers (Indriyati, 2014). Masarirambi *et al*. (2012) found that lettuce fertilized with high levels of chicken manure showed higher growth rate and better production; Magkos *et al*. (2003) established that lettuce cultured in soils with high quantities of organic manures produced more dry matter than did lettuce produced under conventional methods.

Production parameters

Masarirambi *et al*. (2012) observed significant differences in the NL in lettuce that was cultured with different fertilization rates using chicken manure. At the end of their experiment, NL ranged from four to 13 leaves per plant. Furthermore, they observed that the number of leaves decreased when the fertilizer rates were reduced, and the lowest value was obtained in the treatment with inorganic fertilizer. The NL values registered in our experiment were similar to those obtained when 40 t/ha of chicken manures were used. Pablo *et al*. (2012) did not find significances in the NL after forty days of lettuce culture.

This study's results show that the addition of the organic fertilizers used in this work resulted in better aeration, better retention of humidity and a permanent presence of nutrients, which allowed lettuce to grow faster.

Lower values of FA may be explained by a relationship between the growth rate of leaves and the expansion of young leaves produced by the cellular division of the meristem tissues, which, under certain conditions, inhibited leaf growth and the expansion of new leaves (Carranza *et al*., 2009). This situation occurred in T4CM, where all of the lettuce plants died.

In general, the mean values of FAI in the experimental treatments were superior to those reported in other studies of lettuce. Carranza *et al*. (2009) reported a maximum value of 6.78%in lettuce cultured in saline soils. These lower values were due to the hydric stress from saline soil, which affected the photosynthesis of plants, limited the stomatal action, reduced the supply of CO_2 and inhibited the metabolic process.

Compared with other reports, the fresh lettuce production obtained in this experiment may be considered low. For example, Raigon *et al*. (2006) found mean weights of fresh lettuce from 197 to 857 g in the Mediterranean lettuce production region. Terry *et al*. (2012) reported weights of fresh lettuce ranging from 151.2 to 178.2 g within 50 days of culture, using different bioactive substances. Arcos *et al*. (2011) reported mean weights of 500 and 529 g under hydroponic conditions in greenhouses. Fagnano *et al*. (2011) achieved mean weights of 279 to 284 g with compost elaborated with municipal wastes. Moreira *et al*. (2014), using different organic manures, harvested lettuce ranging from 42.0 to 254.3 g in weight, and they concluded that dry manures incorporated into the cultivation soil were the best source of organic matter for lettuce due to their regulation of soil temperature and water retention. The values previously mentioned were similar to those obtained in our experiment, which ranged from 45.9 to 138.1 g, thus reinforcing the importance of incorporating organic matter in lettuce systems to increase production in saline soils.

All of the chemical parameters evaluated in this experiment were demonstrated to have contributed to the improved production in Iceberg lettuce, and the compost and manure are important for restoring the organic fertility of soils. Fagnano *et al*. (2011) found that 30 tons of compost per hectare contributed to stabilizing soils under cultivation, thereby improving C fixation and the nutritive quality of the produced lettuce.

CONCLUSION

According to the results obtained in the present study, compost amended with *E. densa,* and dry bovine manure can improve soil quality by increasing the cation interchange capacity, raising pH, raising conductivity, and improving the OM and inorganic N, P, K, Ca, Mg, Zn, Fe, Mn, Cu, B and Na content. The productivity of Iceberg lettuce was best in the T1S, T3SCM and T5M treatments, which reached an acceptable production of fresh weight, thus confirming the importance of incorporating these fertilizers to increase yields. Moreover, a direct relation between NL and FA was observed with respect to FW. Consequently, the use of dry bovine manure mixed with soil and a combination of soil, compost and manure can be recommended for the culture of Iceberg lettuce under the experimental conditions. The results of this experiment are useful for future studies, and the use of composted *E. densa* and dry manures provides a productive application for these sources of contamination.

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