RESEARCH

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EFFECT OF VERMICOMPOST AND COMPOST ON LETTUCE PRODUCTION

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ABSTRACT

A greenhouse study was conducted to evaluate the effect on total growth and leaf nutritional content in lettuce (*Lactuca sativa* L.) in the Agrotechnology Sciences Department of the Universidad Autonoma de Chihuahua, Mexico in 2007. Three types of fertilization treatments were analyzed: two organic and one conventional or inorganic. Both vermicompost and compost were produced from cattle manure in a 25-wk process. The study included 12 experimental units made up of lettuce plantlets var. Great Lakes. A linear model was fitted for statistical analysis using a completely randomized experimental design. ANOVA was performed and means were compared by orthogonal contrasts. Results showed differences in weight and leaf content for the N and K variables, and the highest mean values for these variables were in the urea treatment. Leaf content of Ca, Mg, and Mn showed higher values in organic fertilization treatments. The vermicompost treatment showed a higher contribution of Mg, Fe, Zn, and Cu, and lower Na in lettuce leaf content when compared to compost usage.

Key words: fertilization, nutrient, growth, quality.

INTRODUCTION

Crop success depends on nutrient input during growth. The excessive use of chemical products in agriculture is an issue of concern for the various problems it causes, such as the level of pollutants that the fruit may contain, decrease in soil fertility, soil and groundwater pollution through the excessive use of N fertilizers (e.g. urea), and animal waste (e.g. untreated cattle manure) causing an increase in nitrate concentration ($N\text{-}NO_3$).

Organic waste has traditionally been considered a source of pollution and has not been sufficiently evaluated as a by-product of agricultural activity which could produce organic fertilizers by composting and vermicomposting. Furthermore, due to the high cost of substrates and imported inputs, there is a need for stable and quality material produced locally. Vermicompost and compost can meet the nutrient demand of greenhouse crops and significantly reduce the use of synthetic fertilizers (Kowalchuk *et al*., 1999; Rodríguez *et al*., 2008), and for vermicompost in particular, it increases soil fertility without polluting the soil, as well as the quantity and quality of harvested products (Castillo *et al*., 2002).

Avilés and Tello (2001) mention the need to define parameters for compost stability and its effects on germination and crop growth. Furthermore, various limitations of using organic fertilizers have been pointed out, such as the difficult access to trustworthy sources of information and the lack of specific research (Giulietti *et al.,* 2008). The objective of this study was to evaluate the growth response on lettuce (*Lactuca sativa* L.) plants treated with 25-wk vermicompost and compost as organic fertilizers, and then to compare them to urea, the traditional chemical fertilizer. Results will encourage farmers and vendors usage of both compost and vermicompost as organic fertilizers, as well as the increase of the consumers confidence level of organic products.

MATERIALS AND METHODS

The experiment was initiated on August 2007 in the State of Chihuahua, Mexico in a 16 x 45 m span-type greenhouse constructed with a galvanized iron structure, and covered with fiberglass. Two organic fertilizers, obtained from composting and vermicomposting of cattle manure and sawdust, were employed. Raw manure of cattle was obtained from 2 to 5 yr old Holstein cows of a dairy farm,

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confined in a 50 x 40 m^2 area and fed with rolled corn (*Zea mays* L.), wheat bran (*Triticum aestivum* L.), cottonseed meal, soybean meal (*Glycine max* (L.) Merr.), alfalfa (*Medicago sativa* L.), and corn silage. Cattle manure was mixed with fine-particle (< 2 mm) pine (*Pinus* sp.) sawdust from a local wood company as a source of C for the preparation of the initial composting mixture with a 25/1 C/N ratio which is within the range suggested as optimal for composting and vermicomposting processes (Labrador, 2001; Hansen *et al.,* 2001). Vermicompost and compost employed had a maturity of less than 25 wk (Table 1). Three types of fertilization were evaluated: two organic types -one based on vermicompost and the other on compost- and a third type based on urea (46% N), the conventional inorganic fertilizer. Treatments were carried out in 3 L pots, with 12 replicates. Seedbeds were used to grow 10-cm high lettuce seedlings var. Great Lakes. Sandy clay loam soil supported plant growth (Table 2). Based on the criterion used by Castellanos *et al*. (2000) for soil texture, apparent density, and low organic matter content (0.74%), the necessary quantity of organic matter to be added to the soil to reach a high level of this enhancer (1.5% for sandy clay loam texture) was estimated and corresponded to incorporating 18.5 t ha^{-1} organic fertilizer. Organic fertilizer treatments were prepared in the following way: T1 with 3.5 kg soil plus 26.2 g dry weight (DW) vermicompost and T2 with 3.5 kg soil plus 26.2 g DW compost. In the case of T3, based on inorganic fertilization, pots with 3.5 kg soil were fertilized 1 wk after transplanting with 0.021 g of urea per experimental unit. In accordance with the estimated mean of N incorporated by vermicompost and compost in T1 and T2 with a mean organic N of 1.5%, and considering that only approximately 2.5% of organic N benefits the immediate crop cycle (Ortiz and Ortiz, 1990), contribution was estimated at 278 kg N ha^{-1}.

Table 1. Vermicompost and compost nutritional parameters for 25-week process.

Nutrient	Vermicompost	Compost
C, %	24	21
N-total, %	1.6	1.4
C/N	15.5	17.1
N-NO_3, mg kg^{-1}	345	347
P, %	0.014	0.016
K, %	0.21	0.55
Ca, %	0.62	0.60
Mg, %	0.21	0.27
Na, %	0.08	0.14
Fe, mg kg^{-1}	991	1049
Mn, mg kg^{-1}	141	144
Zn, mg kg^{-1}	76	69
Cu, mg kg^{-1}	16	15
pH	7.3	8.5

Table 2. Physical-chemical description of soil used in pots to evaluate different organic fertilizers.

Characteristic	Value
Sand, %	57.94
Lime, %	20.82
Clay, %	21.24
pH	6.76
Organic matter, %	0.74
$CaCO_3$, %	1.045
Apparent density, g mL^{-1}	1.38
Electrical conductivity, dS m^{-1}	1.5

Evaluated variables

The evaluation considered plant height during the first 6 wk and was interrupted for the rosette-shaped crop growth characteristics. The aerial part of the lettuce was cut and its weight recorded at the end of the experiment. Leaf material was washed with an H_2O plus HCl 4 N solution, rinsed with distilled water, air-dried, and then oven-dried at 60 ºC for 1 d. It was ground with a Wiley mill (Thomas Scientific 800-345-2100, New York, USA) to quantify total N, P, K, Ca, Mg, Na, Fe, Zn, Mn, and Cu by means of the following methodologies:

Total nitrogen. It was quantified by the micro-Kjeldahl method. A 0.1 g sample of dry sieved substrate was weighed. Reagent, 0.3 g of Se, plus 3 mL of concentrated sulfuric acid were added to a Kjeldahl flask and digested until pistachio green. The digested sample was distilled for 5 min until the solution changed to turquoise. Then, titration was carried out with hydrochloric acid (HCl) 0.2 N until the color changed to brick red.

Total Cu, Fe, Mn, Zn, and Na. One gram of the sample plus 25 mL tri-acid mixture (HNO_3, $HClO_4$, and H_2SO_4 in a 10:1:0.25 ratio) was put into a 250 mL beaker, digested, and filtered. The sample was decanted with deionized H_2O to 50 mL. Concentration was determined by using an atomic absorption spectrophotometer (Perkin Elmer Analyst 100, New Jersey, USA) to read the elements Cu, Fe, Mn, and Zn.

Total Ca, Mg, and K. A 1 mL sample from the previous digestion was diluted to 100 mL with deionized H_2O, and Ca, Mg, and K were read in the atomic absorption spectrophotometer (Perkin Elmer Analyst 100, New Jersey, USA).

Total P. A 5 mL aliquot was taken from the extract resulting from the previous determination and 10 mL of ammonium vanadate with molybdenum were added [22.5 g $(NH_4)6MoO_{24}$ in 400 mL of deionized H_2O, 1.25 g of ammonium vanadate (NH_4VO_3) were dissolved in 300 mL of boiling deionized H_2O. Then, 250 mL of HNO3 were added and decanted to 1 L]. It was decanted to 50 mL. Determination was carried out by UV-visible spectrophotometry.

Statistical analysis

The study was carried out with a completely randomized design with three treatments and 12 replicates, and a pot was the experimental unit for a total of 36 units. A linear model was constructed, using the fertilization type as the fixed effect. Means comparison was carried out by the following orthogonal contrasts: conventional based on inorganic fertilization *vs*. organic fertilization treatments, and vermicompost *vs*. compost. ANOVA was executed with the PROC GLM command of the SAS version 8.2 (SAS Institute, Cary, North Carolina, USA).

RESULTS AND DISCUSSION

Plant height

Plants in T1 and T2 (vermicompost and compost) showed greater growth during the first 4 wk as compared to plants in T3. As of week 5, plant growth and development in T3 exceeded T1 and T2 which showed a small increase in growth and development during the following 3 wk. This effect could be due to the presence of phytohormones in organic fertilizers that stimulate plant growth (Blandon *et al.,* 1999; Gajalakshmi *et al.,* 2001; Nogales *et al.,* 2005).

Weight

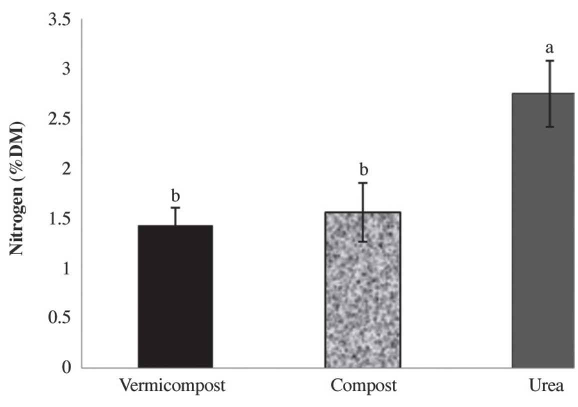
Weight of the harvested lettuce showed significant differences for T3 (mean 72.34 ± 2.76 g) as compared to T1 and T2. There were no significant differences between organic treatments with means of 37.72 ± 2.76 g and 35.42 ± 2.76 g for T1 and T2, respectively. These results concur with those presented by Añez and Espinoza (2003) who reported that the short lettuce cycle (transplanting-harvesting), the high C/N ratio of the vermicompost and compost used (15.5 and 17.1, respectively), and the mean environmental temperature around 18 ºC explain the low mineralization range of the organic fertilizers present and added to the soil, and its slight contribution in crop production.

Total nitrogen

Leaf N concentration in T3 (mean 2.75 ± 0.2%) was significantly higher than in T1 (1.44 ± 0.2%) and T2 (1.58 ± 0.2%), while without any significant differences between T1 and T2 (Figure 1). No treatment reached the N sufficiency level according to the classification proposed by A&L Agricultural Laboratories (1990) which register an optimal content range of 3.5 to 6.0% for leaf crops. Reduced growth of lettuce in this study was directly related to its leaf N content due to the action of this nutrient on the process since N is necessary for cell multiplication and plant organ development. Furthermore, N is the main yield factor and considered as the characteristic constituent of functional plasma, an integral part of chlorophyll molecules, proteins, amino acids, nucleic acids (RNA and DNA), nucleotides, phosphotides, alkaloids, enzymes, coenzymes, hormones, and vitamins (Castellanos *et al.,* 2000).

Organic fertilizers and soil enhancers are used for their organic matter contribution and nutrients, mainly N and P (Fuente *et al.,* 2006) since around 98% N (Castellanos *et al*., 2000) and 33 to 67% total P (Ortiz y Ortiz, 1990) found in soils are associated with organic matter. For Melgarejo *et al.* (1997), availability of nutrients in organic fertilizers does not depend on its total content in the material but on the dynamics of the process; thus, some elements can become more available because of pH, moisture, and aeration, or in composting for the temperature allowing the development of specialized organisms. Likewise, the earthworm's action can affect, in one way or another, the availability of an element. Furthermore, organic matter decomposition rate and nutrient regeneration are regulated by a series of factors including environmental conditions, hydrological regime, substrate quality, soil microbial biomass, and electron receptor availability (McLatchey and Reddy, 1998).

Moreover, compost must be "mature" to decrease the risk of crop growth and yield reduction due to N immobilization caused by a high C/N ratio. According



Vertical bars indicate mean standard error; DM: dry matter.

Figure 1. Mean leaf N content of lettuce under different fertilization treatments.

to Fricke and Vogtmann (1993), compost must have a C/N ratio of 18 or less for production purposes and to prevent N competition in plants and soil microorganisms. Immature compost can also contain high organic acid concentrations that interfere with root function, and therefore, have an impact on plant growth (Wolkowski, 2003). In this study, a 25-wk decomposition process was used for vermicompost and compost with C/N ratios of 15.5/1 ± 1.4 and 17.0/1 ± 1.4, respectively, ratios at the upper limit of the suggested optimal range which should promote slow N mineralization. In addition, compost is considered as a slow release nitrogen fertilizer because it only mineralizes a fraction of total N, estimated at 2% in a crop cycle (Castellanos *et al*., 2000; Sikora and Szmidt, 2005). Given these results, the need arises to carry out fraction analysis of soil N compounds, as well as their relationship with cumulative N removal in plants.

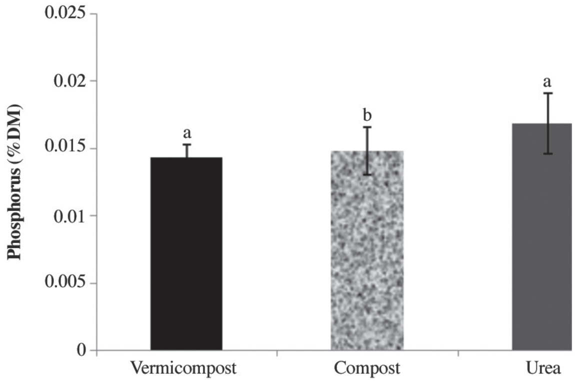
Melgarejo *et al*. (1997) indicate that materials from biodegradable, kitchen, and garden waste with N contents of less than 2% could cause immobilization of this element in the soil where it is added, fact consistent with the results of this study since the vermicompost and compost used had a lower content than the above-mentioned, while urea is characterized as an N-rich source (Arroyo *et al*., 2003) with high solubility of this nutrient (Capulín *et al*., 2001).

Wolkowski (2003) reported that relatively high applications of composted waste should be added to supplement crop N needs and produce yields similar to those found with recommended doses of commercial fertilizer.

Bar-Tal *et al*. (2004) found that incorporating compost has a positive effect in crops only when additional N applications are carried out, and that the organic matter content and net N mineralization increases over time in soils treated with compost. Other authors have demonstrated that after incorporating some manure and compost, net N immobilization in the first crop season can occur followed by mineralization during the second crop (Lynch *et al*., 2004). Considering the importance of soil organic matter mineralization, it would have been important to measure the evolution of soil N concentration and its relationship with cumulative N removal in plants.

Total phosphorus

There is no significant difference in P content in leaf tissue between T3 (mean 0.017 ± 0.001%) and T1 (0.014 ± 0.001%) and T2 (0.015 ± 0.001%) (Figure 2). The latter, in turn did not show any significant differences. Phosphorus concentrations found in the evaluated treatments did not reach the sufficiency level for this element according to A&L Agricultural Laboratories (1990) which provide a range of 0.40 to 1.00%.



Vertical bars indicate mean standard error; DM: dry matter.

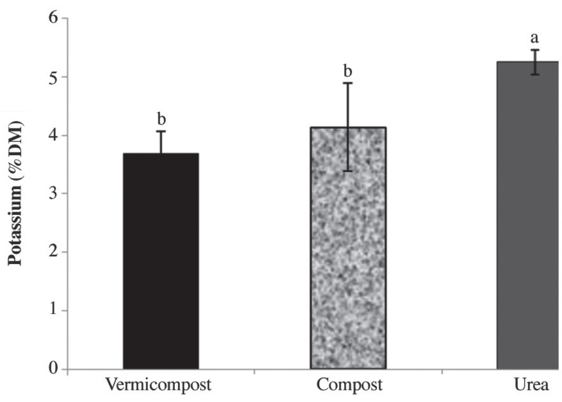
Figure 2. Mean leaf P content of lettuce under different fertilization treatments.

Fricke and Vogtmann (1993) indicated that only 20 to 40% of total P content in compost is available to plants. Based on this, and in accordance with low P content found in vermicompost (0.014 ± 0.0009%) and compost (0.015 ± 0.0009%) used in the study, these do not represent an important source of available P for the crop.

Potassium

Leaf K content in T3 (mean 5.27 ± 0.2%) was higher than T1 (3.72 ± 0.2%) and T2 (4.14 ± 0.2%) which did not show any significant differences (Figure 3). Results from the three treatments reached the K content proposed by A&L Agricultural Laboratories (1990) which provides a concentration of this element between 3.5 and 8.00% for leaf crops.

Fricke and Vogtmann (1993) indicate that more than 85% of total K content in compost is available to the plant, thus emphasizing the importance of compost as a potential source of K for crops.



Vertical bars indicate mean standard error; DM: dry matter.

Figura 3. Mean leaf K content of lettuce under different fertilization treatments.

Calcium, magnesium, and sodium

Leaf Ca content showed significant differences between T3, which had the lowest Ca concentration (mean 1.04 ± 0.1%), and T1 (1.37 ± 0.1%) and T2 (1.28 ± 0.1%) and with no significant differences on the effect of organic fertilization (Figure 4). Magnesium content showed significant differences between T3, which had the lowest leaf Mg content (mean 0.63 ± 0.04%), and leaf content of T1 (0.84 ± 0.04%) and T2 (0.67 ± 0.04%) (Figure 4). Similarly, there were significant differences between T1 and T2.

Vermicompost and compost produced in this study is not a source Na since no differences were found between T3, which showed a mean of 0.42 ± 0.01% for Na concentration, and leaf Na content shown by T1 (0.40 ± 0.01%) and T2 (0.44 ± 0.01%) which did show significant differences between them (Figure 4).

According to the nutrient sufficiency range proposed by A&L Agricultural Laboratories (1990), Ca concentration in lettuce plants fertilized with T1 and T2 is within the normal sufficiency range reported as 1.25 to 2.50%; however, concentration of this element in lettuce plants in T3 did not reach the recommended level. In the case of Mg, the sufficiency range is between 0.30 and 1.00% so that the three treatments are within this range. However, in the case of Na, the three treatments showed higher concentrations than the range established for leaf crops given as 0.01 to 0.20%. The use of vermicompost in this study represented the best contribution of Ca and Mg macronutrients in the lettuce crop, indicating greater availability of the above-mentioned nutrients in relation to compost. In like manner, vermicompost showed lower Na content levels, which is an especially important result since the use of organic and inorganic fertilizers with high Na contents must be avoided because the accumulation of salts, especially from Na, represents an important risk for soil salinization and crop toxicity.

Micronutrient contents

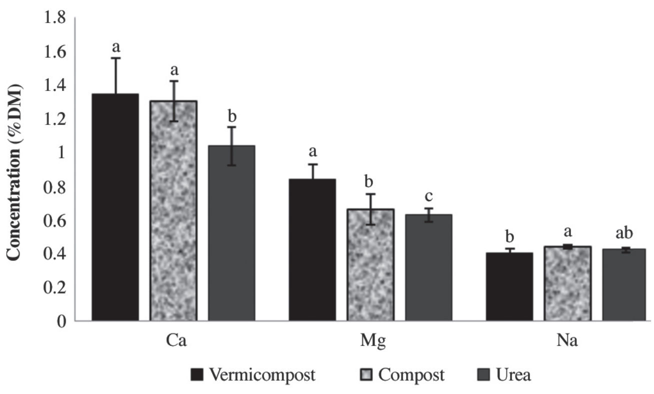
Mean Fe concentration did not show significant differences between T3 (mean de 91 ± 6 mg kg^{-1}) and T1 (112 ± 6 mg kg^{-1}) and T2 (76 ± 6 mg kg^{-1}), but did show significant differences between the effect of T1 and T2 (Figure 5).

Treatment T3 did not show significant differences in Zn content (mean 45 ± 2.5 mg kg^{-1}) as regards T1 (43 ± 2.5 mg kg^{-1}) and T2 (35 ± 2.5 mg kg^{-1}) (Figure 5). Means for Zn content in T1 showed significant differences with those in T2. In relation to Mn content, T3 (mean 44 ± 3.5 mg kg^{-1}) showed significant differences with T1 (65 ± 3.5 mg kg^{-1}) and T2 (57 ± 3.5 mg kg^{-1}), and no significant differences between T1 and T2 (Figure 5).

Leaf Cu content did not show any differences between T3 (mean 12 ± 0.9 mg kg^{-1}) and T1 (14 ± 0.9 mg kg^{-1}) and T2 (9 ± 0.9 mg kg^{-1}). In contrast, the effects of T1 and T2 did show a significant difference between them (Figure 5).

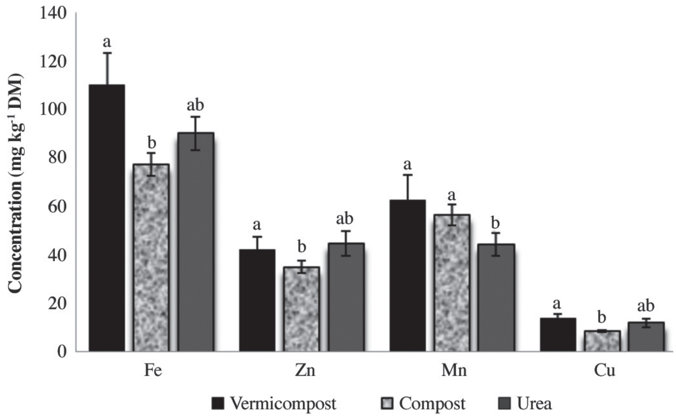
According to the nutrient sufficiency range for leaf crops proposed by A&L Agricultural Laboratories (1990), concentration ranges for Fe (60 to 200 mg kg^{-1}), Zn (30 to 50 mg kg^{-1}), and Cu (6 to 20 mg kg^{-1}) were considered normal for lettuce. In the case of Mn, the three treatments exceeded normal levels for this element which are in the 25 to 40 mg kg^{-1} range without reaching the limits defined as excessive. Furthermore, Mn availability depends on the organic contribution of microbial activity and soil pH which increases as the latter decreases. However, Mn toxicity is rare since the Mn^{2+} ion is easily washed in the soil and toxicity generally occurs in soils with a pH less than 5.4 (Castellanos *et al*., 2000).

Wright *et al*. (2007) found that applying compost significantly increases soil Mn and Cu concentration extractable with DTPA (diethylenetriaminepentaacetic acid) up to 11 month after it was applied. In contrast, Fe and Zn decreased 3 months after compost was applied,



Vertical bars indicate mean standard error; DM: dry matter.

Figure 4. Mean leaf Ca, Mg, and Na content of lettuce under different fertilization treatments.



Vertical bars indicate mean standard error; DM: dry matter.

Figure 5. Mean leaf Fe, Zn, MN, and Cu content of lettuce under different fertilization treatments.

and significantly increasing at 16 month with the higher application rates.

In this study, T1 showed a greater contribution of Mg, Fe, Zn, and Cu nutrients available for the lettuce crop in relation to T2, fact coinciding with that reported by Ferrera and Alarcón (2001) and Nogales *et al*. (2005) who pointed out that vermicompost is a chemically and biologically enriched material in relation to compost. Furthermore, pH of the vermicompost used seems to exert a strong influence on the availability of these nutrients (Wright *et al.,* 2007).

CONCLUSIONS

Applying vermicompost and compost processed for 25 wk using dairy cattle manure added at a rate of 18.5 t ha^{-1} was sufficient to obtain optimal leaf nutrient concentrations of K, Ca, Mg, and Mn in lettuce var. Great Lakes from the first year that it was incorporated. However, the above-mentioned rate was not the best for macronutrients such as N and P. Leaf content of Mg, Fe, Zn, and Cu was increased and Na concentration was lower with vermicompost, which can be an advantage for using this product over traditional compost.

It is important to point out that further studies are needed to evaluate the effect of periodic inputs and distinct fertilization rates based on organic fertilizers and the availability of their nutrient contents, as well as the effect of incorporating organic fertilizers in the soil in the medium- and long-term.

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RESUMEN

Efecto de vermicompost y compost en la producción de lechuga. Con el fin de evaluar la respuesta en el crecimiento y contenido nutricional foliar en lechuga (*Lactuca sativa* L.), durante el año 2007 se realizó un estudio bajo condiciones de invernadero en la Facultad de Ciencias Agrotecnológicas de la Universidad Autónoma de Chihuahua, México. Tres tipos de fertilización fueron utilizados, de los cuales dos fueron orgánicos y uno convencional o inorgánico. Ambas, vermicompost y compost, fueron elaboradas a partir de estiércol vacuno lechero con 25 semanas de transformación. Los tratamientos se realizaron con 12 unidades experimentales constituidas por plántulas de lechuga var. Grandes Lagos. Para el análisis estadístico se ajustó un modelo lineal, utilizando un diseño experimental completamente al azar. Se realizó ANDEVA y la comparación de medias a través de contrastes ortogonales. Los resultados mostraron diferencias para las variables peso y contenido foliar de N y K encontrándose las medias más altas de estas variables en el tratamiento con urea. Con relación al contenido foliar de Ca, Mg y Mn destacaron los tratamientos a base de fertilización orgánica. La fertilización con el uso de vermicompost mostró mayor aporte de los nutrientes Mg, Fe, Zn y Cu y menor aporte en Na en el contenido foliar del cultivo de lechuga en comparación con el uso de compost.

Palabras clave: fertilización, nutriente, crecimiento, calidad.

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