

## Abstract

This work was developed with the objective of evaluate effects of different organic composts on the photosynthesis, gas exchange, chlorophyll fluorescence in lettuce grown under nursery conditions. The experiment was accomplished following a randomized design, with 14 treatments and four replications. Using the following treatments: T1 to T6 (sugarcane based substrates), T7 to T12 (coconut based substrates), T13 (manure) and T14 (mineral fertilization). The following parameters were evaluated: photosynthesis rate, respiration, stomata conductance, the ratio of internal to external CO<sub>2</sub> concentrations (C<sub>i</sub>/C<sub>a</sub>), the efficiency of water use (A/E) and carboxylation efficiency (A/C<sub>i</sub>), chlorophyll concentrations, maximum quantum yield of photosystem II (F<sub>v</sub>/F<sub>m</sub>). The plants of lettuce grown with mineral fertilization and manure showed higher values of stomatal conductance. The treatments with sugarcane based substrates showed higher rates of photosynthesis, transpiration, carboxylation efficiency and chlorophyll content, indicating that the better photosynthetic capacity when grown on these substrates.

**Key words:** Gas exchange; chlorophyll fluorescence; organic composts

## Introduction

Lettuce (*Lactuca sativa* L.) is an herbaceous plant, annual, and it is considered the leaf vegetable of major importance as food for Brazilians (SANTOS et al., 2010), being traditionally growth by small producers, which gives it great economical and social importance, presenting significant factor of aggregation of the country worker (NAKAGAWA, et al., 1992). Allied to that, there is a great necessity from the culture of organic fertilization, making this vegetable an important compound on the holistic approach of the organic agriculture (VILAS BÓAS et al., 2004).

Nowadays, organic fertilizers from several origins are used in the cultivation of this vegetable, with emphasis in the organic compound which, besides providing improvement of the physical and chemical properties of the soil, reduces the necessity of use of mineral fertilizers, besides improving its productivity (SILVA et al., 2010).

## Photosynthetic measurements in lettuce submitted to different agroindustrial residue composting

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In addition, one alternative of organic fertilizer that is noteworthy in the agricultural means is the residue generated in the agroindustry, as the solid sugarcane residue, the vinasse and the coir dust (COSTA et al., 2008). These residues gain importance for presenting variable amounts of nutrients, mainly nitrogen, phosphorus and potassium, besides, they are very efficient in providing conditions of high retention of humidity in the soil and nutritional quality appropriated in different cultures (ROSA et al., 2002; COSTA et al., 2008; AMARAL, et al., 2010), benefiting plants and soil.

In study of plant nutrition, photosynthesis has been receiving special attention since it is the main source of organic carbon, from energy to the growth and production of plant biomass. (LAWLOR, 2002). LARCHER (2004) affirms that the influence of the nutritional state of the plant over the photosynthesis occurs in several ways, considering that almost always higher photosynthetic rates are reached through fertilization. According to COSTA et al.

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(2001), changes in the absorption of nutrients lead to alteration in the plant physiology, among other factors, to the stomata opening and the increase or reduction of the leaf area, being these factors closely linked to the photosynthetic efficiency.

Several studies with legumes show positive correlations between treatments with fertilization and gas exchanges, as those observed in spinach (VERHOEVEN et al., 1997), aubergine (BRANDÃO FILHO et al., 2003), cucumber (LIANG et al., 2009), kale and pepper (VILANOVA and SILVA JUNIOR, 2010), however, studies discussing how these patterns occur in lettuce are still scarce.

Among the works related to the photosynthetic capacity and stomata conductance in lettuce it is noteworthy the work in nitrogen fertilization (BROADLEY et al., 2001), and submitted to different situations of stress, sanity (BIE et al., 2004), light intensity (KIM et al., 2004) and responses to the variation of temperature (HE et al., 2009). Therefore, the aim of more information about the source physiology (photosynthetic organs) of the lettuce culture becomes of major importance.

Even tough measures of gas exchanges are important to determine the photosynthetic rates, they may not be efficient to evaluate the deleterious effects in the chloroplasts. Thus, an alternative is the evaluation of the quantum efficiency of the photosystem II (PSII) obtained from the fluorescence of the chlorophyll *a*, being a non destructive method which reveals the level of excitement of the energy which is directed to the photosynthesis and provide subsidies to estimate the inhibition or damage in the process of transference of electrons of the PSII (MAXWELL and JOHNSON, 2000). According to BAKER and ROSENQVST (2004), the efficiency of operation of the PSII is correlated to the assimilation of CO<sub>2</sub> and has lead to the use of parameters of the fluorescence of the chlorophyll to examine the photosynthetic performance of plants in response to the nutritional supply of the soil.

Studies performed in the lettuce culture show the use of parameters of the kinetics of emission of fluorescence being used to detect damages caused by different types of stress (CALATAYUD and BARRENO, 2004; HE and LEE, 2004;

PROKOPOVÁ et al., 2010).

There is, nowadays, a restrict number of references about the relation of fertilization and substrate, allied to the effect in the photosynthetic activity in legumes. Few reports were found in literature referent to photosynthetic responses of lettuce in different substrates. Studies of this nature, however, are of major importance to comprehend the processes of the photosynthetic potential of the lettuce and its relations with the environment in which they are developing, enabling thus the enlargement of the knowledge about its adaptability to cultivation conditions. In this context, the present work aimed to evaluate the effect of doses of organic compounds, obtained from agroindustrial residues, in the gas changes and in the fluorescence of the chlorophyll *a* in lettuce plants cultivated in semi-protected environment.

## Material and Methods

The experiment was conducted under conditions of nursery, semi-controlled environment, formed by polyethylene screen with 75% of shading, located in the Centro de Ciências Agrárias (CECA – Center of Agricultural Sciences) of the Universidade Federal de Alagoas (UFAL – Federal University of Alagoas), in Rio Largo, State of Alagoas, located at 9°28'01" of latitude and 35°49'32" of longitude, with altitude of 141 m. The area is inserted in region with average temperature of the last year of 24.7°C, relative humidity of 82% and accumulated rainfall of 1691 mm year<sup>-1</sup>.

The soil used in the composition of the substrates came from the arable layer of and Argissolo<sup>1</sup>, texture Areia-france, sampled in an area located in the municipality of Coruripe and presented the attributes which can be seen in Table 1.

The soil was homogenized and passed in sieve with mesh of 4 mm and conditioned in vases with capacity of 3.7 kg of soil. It was sealed the openings in the inferior part of the vases, in order to avoid the loss of nutrients after the irrigation.

It was used the lettuce (*Lactuca sativa* L.) cultivar Saia Veia, which it was seeded in polystyrene

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1 According to Brazilian soil classification

**Table 1.** Physical and chemical characteristics of the soil samples used in the experiments.

Attributs	Pindorama Soil
pH in (H <sub>2</sub> O) (1:2.50)	6.19
P available (mg dm <sup>-3</sup> )	2.67
K available (mg dm <sup>-3</sup> )	62.00
Na (mg dm <sup>-3</sup> )	5.25
Exhcangable Ca + Mg (cmol <sub>c</sub> dm <sup>-3</sup> )	3.20
Exchangable Al (cmol <sub>c</sub> dm <sup>-3</sup> )	0.12
H+Al (cmol <sub>c</sub> dm <sup>-3</sup> )	1.71
Sum of bases (cmol <sub>c</sub> dm <sup>-3</sup> )	3.38
CTC effective (cmol <sub>c</sub> dm <sup>-3</sup> )	5.09
Base saturation (%)	66.40
Aluminum saturation (%)	3.43
Soil density (g cm <sup>-3</sup> )	1.24
Particle density (g cm <sup>-3</sup> )	2.65
Total porosity (%)	53.00
Texture classification (SBCS)	Areia-franca

tray for the obtaining of seedlings.

The adopted design was the completely randomized blocks, with 14 treatments and four replications. From the treatments used, 12 were constituted by organic compounds obtained through two basic mixtures (MB<sub>cane</sub>, mixture containing cane bagasse + filter cake+ cattle manure + natural phosphate and MB<sub>coconut</sub>, mixture in which the sugarcane bagasse was substituted by green coconut bagasse) submitted to solutions with increasing concentrations of vinasse or potassium sulfate. Thus, the used compounds were: T1 = MB<sub>cane</sub> + water; T2 = MB<sub>cane</sub> + solution with vinasse at 25%; T3 = MB<sub>cane</sub> + solution with vinasse at 50%; T4 = MB<sub>cane</sub> + solution with vinasse at 75%; T5 = MB<sub>cane</sub> + 100% vinasse; T6 = MB<sub>cane</sub> + water + potassium sulfate; T7 = MB<sub>coconut</sub> + water; T8 = MB<sub>coconut</sub> + solution with vinasse at 25%; T9 = MB<sub>coconut</sub> + solution with vinasse at 50%; T10 = MB<sub>coconut</sub> + solution with vinasse at 75%; T11 = MB<sub>coconut</sub> + 100% vinasse; T12 = MB<sub>coconut</sub> + water + potassium sulfate. Some characteristics of the used compounds are presented in Table 2.

The treatments which presented potassium sulfate were formulated by the combination: MB<sub>cane</sub> added to a liquid phase of 722 L m<sup>-3</sup> or (3.9 kg m<sup>-3</sup> of K<sub>2</sub>SO<sub>4</sub>); MB<sub>coconut</sub> was increased 533 L m<sup>-3</sup> or (3.9 kg m<sup>-3</sup> of K<sub>2</sub>SO<sub>4</sub>). The filter cake was obtained from the mixture of the milled sugarcane bagasse and sludge settling. The vinasse was obtained from the residue of the process of distillation for the obtaining of the

ethanol of the sugarcane.

The filter cakewas obtained through the mixture of the milled sugarcane bagasse and sludge settling. Vinasse was obtained from the residue of the distillation process for the obtaining of the sugarcane ethanol.

Treatments T13 and T14, respectively, consisted in a control cultivated with cattle manure and a control cultivated with mineral fertilizers. The dose of the organic material (102 g per vase) corresponded to 3% (in dry base) of the soil matter used. The dose used for the control with mineral fertilizers was based in the recommendation resulting from the soil analysis, using 0.18 g of urea, 1.6 g of simple superphosphate and 0.28 g of potassium chloride per vase.

The measurement of the gas exchange was performed in the period of the morning 41 days after seeding with a portable analyzer of CO<sub>2</sub> at infrared (IRGA) ADC, model Lci, (Hoddesdon, UK) with light source of 1123 μmol m<sup>-2</sup> s<sup>-1</sup>. The measures were made in the second pair of leaves from the apex, being obtained the following variables: net photosynthesis (A); transpiring (E), stomatal conductance (gs), ratio between concentrations of CO<sub>2</sub> intra/extracellular (Ci/Ca), efficiency of carboxylation (A/Ci) and instantaneous efficiency of the use of water (A/E).

The measures of maximum quantum efficiency of the photosystem II (Fv/Fm) were

**Table 2.** pH, electrical conductivity (EC), concentration of nitrogen (N), of phosphorus ( $P_2O_5$ ), of potassium ( $K_2O$ ), of carbon (C) and relation C/N in 12 types of organic compounds in the cultivation of lettuce (*Lactuca sativa* L.) in polyethylene screen, 41 days after seeding in Rio Largo, State of Alagoas.

Treatments	Basic mixture	Vinhaça %	pH	EC (mS)	N ( $g\ kg^{-1}$ )	$P_2O_5$ ( $g\ kg^{-1}$ )	$K_2O$ ( $g\ kg^{-1}$ )	C ( $g\ kg^{-1}$ )	C/N
T1		0	7.09	0.09	0.112	0.141	0.094	1.359	12.16
T2	MB <sub>cane</sub>	25	7.39	0.14	0.107	0.139	0.132	1.332	12.50
T3		50	7.38	0.23	0.108	0.159	0.164	1.618	14.94
T4		75	7.70	0.33	0.095	0.211	0.366	1.793	18.91
T5		100	7.51	0.23	0.091	0.275	0.223	1.918	21.02
T6		$K_2SO_4$	7.46	0.41	0.091	0.213	0.300	1.766	17.42
T7		0	7.30	0.33	0.115	0.211	0.296	1.793	18.91
T8	MB <sub>coconut</sub>	25	7.40	0.45	0.103	0.187	0.421	1.779	17.32
T9		50	7.40	0.29	0.097	0.226	0.228	1.832	18.83
T10		75	7.56	0.30	0.091	0.212	0.305	2.103	23.24
T11		100	7.59	0.31	0.086	0.209	0.267	1.940	22.67
T12		$K_2SO_4$	7.14	1.14	0.091	0.25	0.774	2.108	23.19
	MB <sub>cane</sub>	Average	7.40	0.238	0.101	0.190	0.213	1.630	16.20
	MB <sub>coconut</sub>	Average	7.40	0.470	0.097	0.216	0.382	1.930	20.70

determined after adaptation of the leaves to the dark, for 20 minutes with leaf clips, using a measure of modulated fluorescence meter 051-FL (OPTI-SCIENCES). The readings were performed with saturating light pulses, to promote the closing of the centers of reaction of the PSII, according to the method described by MAXWELL and JOHNSON (2000). The content of chlorophyll (SPAD index) was estimated by a portable equipment, SAPD-502 (Minolta, Japan), in the same leaves in which it was measured the gas exchange and parameter of fluorescence, considering the measure obtained from eight readings in the same leaf.

The data were submitted to analysis of variance with comparing of measures by Scott-Knott test at 5% of probability and also it was performed contrast of all the treatments among themselves.

## Results and discussion

In this study, it was found that for the variable stomata conductance, higher averages for P3 (treatments with mineral fertilizers) and P4 (treatment with manure) observing significant differences between these treatments which stood out over the others (Table 4). On the other hand, in the combination P2 (treatments with basic mixture

coconut) presented lower values for the same variable, which suggests that the mixture P2 influenced in the stomata closing (Table 4)

Plants cultivated with mineral fertilizers and with manure presented values of stomata conductance higher than those obtained with basic mixtures, with average of  $0.69\ mol\ m^{-2}\ s^{-1}$  and  $0.66\ mol\ m^{-2}\ s^{-1}$ , respectively (Table 5). When comparing treatments with manure (T13) and mineral fertilizer (T14) to the others with basic mixture of cane (Table 5), it was observed similar values in treatment T5 ( $0.60\ mol\ m^{-2}\ s^{-1}$ ), which received 100% of vinasse.

Comparing T13 and T14 to the treatments with mixture based on coconut (Table 6) it was verified lower values of stomata conductance ( $0.08\ mol\ m^{-2}\ s^{-1}$ ) in the treatment T8, characterizing the stomata closing, and values superior than  $0.53\ mol\ m^{-2}\ s^{-1}$  in T12 (treatments based on  $K_2SO_4$ ) which presented values close to T13 and T14, of  $0.69$  and  $0.66\ mol\ m^{-2}\ s^{-1}$  respectively, suggesting that the presence of potassium in T12 influenced in the stomata opening in this treatment. According to EPSTEIN and BLOOM (2006), potassium is one of the important nutrients to the plant, since it participates in processes as opening and closing of the stomata, photosynthesis, transport of carbohydrates and respiration. Besides, the effective regulation of

**Table 4.** Stomata conductance (gs), transpiration (E), photosynthesis (A), ratio between concentrations of CO<sub>2</sub> intra/extracellular (Ci/Ca), instantaneous efficiency of the use of water (A/E), efficiency of the carboxylation (A/Ci), reading SPAD-502 (SPAD Chlorophyll unit) and maximum quantum efficiency of the photosystem II (F<sub>v</sub>/F<sub>m</sub>) of lettuce (*Lactuca sativa* L.) submitted to different types of treatments, cultivated in polyethylene screen, 41 day after seeding, in Rio Largo, state of Alagoas.

Treatments (averages)	gs mol m <sup>-2</sup> s <sup>-1</sup>	E mmol m <sup>-2</sup> s <sup>-1</sup>	A μmol m <sup>-2</sup> s <sup>-1</sup>	Ci/Ca	A/E	A/Ci	Chlorophyll (units SPAD)	F <sub>v</sub> /F <sub>m</sub>
P1	0.40B	4.1A	13.30A	0.68B	3.23A	0.052A	21.5A	0.65A
P2	0.27C	2.9C	9.93B	0.63C	3.45A	0.043B	18.7B	0.70A
P3	0.69A	3.5B	11.36B	0.81A	3.23A	0.040B	16.3B	0.70A
P4	0.66A	3.7B	12.81A	0.78A	3.34A	0.045B	17.0B	0.68A
Cv%	13.9	6.8	11.2	7.3	8.3	13.3	8.7	7.3

P1 – Treatments with basic mixture cane

P2 – Treatments with basic mixture coconut

P3 – Treatments with mineral fertilizers

P4 – Treatments with manure

\*Averages followed by the same letter, in column, do not differ statistically at the level of 5% of probability by the Scott-Knott test.

the stomata opening is fundamental so that the plants may have a good development.

For the parameters photosynthetic rate and transpiration (Table 4), it was observed higher averages in the combination P1 (Treatments with basic mixture cane) of 13.30 μmol m<sup>-2</sup> s<sup>-1</sup> and 4.1 mmol m<sup>-2</sup> s<sup>-1</sup> respectively, which differed significantly from treatments P2 (basic mixture coconut), P3 (mineral

fertilizer) and P4 (manure). However, when analyzed Table 5 and 6, it was not found differences between the compounds with basic mixtures. However, high values were also observed in treatments based on cane T5 (100% vinasse) with photosynthesis of 16.4 μmol m<sup>-2</sup> s<sup>-1</sup> and transpiration of 5.4 5,4 mmol m<sup>-2</sup> s<sup>-1</sup> (Table 5), being noteworthy. These evidences must be an indicative that the cultivated plants with substrates

**Table 5.** Stomata conductance (gs), transpiration (E), photosynthesis (A), ratio between concentrations of CO<sub>2</sub> intra/extracellular (Ci/Ca), instantaneous efficiency of the use of water (A/E), efficiency of the carboxylation (A/Ci), reading SPAD-502 (SPAD Chlorophyll unit) and maximum quantum efficiency of the photosystem II (F<sub>v</sub>/F<sub>m</sub>) of lettuce (*Lactuca sativa* L.) submitted to different types of treatments based on the mixture of the cane T1 to T6, cultivated in polyethylene screen 41 day after seeding, in Rio Largo, state of Alagoas.

Treatments (averages)	gs mol m <sup>-2</sup> s <sup>-1</sup>	E mmol m <sup>-2</sup> s <sup>-1</sup>	A μmol m <sup>-2</sup> s <sup>-1</sup>	Ci/Ca	A/E	A/Ci	Chlorophyll (SPAD units)	F <sub>v</sub> /F <sub>m</sub>
T1	0.35B	4.0A	14.0A	0.67B	3.47A	0.057A	20.6A	0.70A
T2	0.38B	3.9A	13.2A	0.69B	3.23A	0.049A	20.5A	0.57A
T3	0.30B	3.6A	13.2A	0.66B	3.56A	0.052A	22.0A	0.68A
T4	0.38B	4.3A	13.6A	0.70B	3.10A	0.053A	21.4A	0.63A
T5	0.60A	5.4A	16.4A	0.71B	3.04A	0.064A	21.0A	0.64A
T6	0.24B	3.4A	9.3A	0.67B	2.80A	0.039A	21.1A	0.65A
T13	0.69A	3.5A	11.3A	0.81A	3.20A	0.039A	16.3B	0.68A
T14:	0.66A	3.7A	12.8A	0.78A	3.40A	0.045A	17.1B	0.70A
Cv%	29.1	8.3	24.6	12.4	10.6	24.4	9.4	12.4

T1: MBcane + water; T2: MBcane + water + 25% vinasse; T3: MB<sub>cane</sub> + 50% vinasse; T4: MB<sub>cane</sub> + 75% vinasse; T5: MB<sub>cane</sub> + 100% vinasse; T6: MB<sub>cane</sub> + water + K<sub>2</sub>SO<sub>4</sub>; T13: Manure; T14: Mineral fertilizers (without soil mass).

\*Averages followed by the same letter, in the column, do not differ statistically at the level of 5% of probability by the Scott-knott test.

based on cane presented conditions more favorable to the photosynthetic process because according to TAIZ and ZEIGER (2004), the appropriated nutritional balance of the plant may maintain its photosynthetic capacity in balance.

BIE et al. (2004), studying the photosynthetic capacity of the lettuce leaves submitted to the nutritive solution  $\text{Na}_2\text{SO}_4$  and under salt stress  $\text{NaHCO}_3$  found average values of approximately  $8.3 \mu\text{mol m}^{-2} \text{s}^{-1}$  in non stressed plants. HE et al. (2001) verified values close to  $15 \mu\text{mol m}^{-2} \text{s}^{-1}$  in plants developed in controlled environment.

BROADLEY et al. (2001), studying the effect of doses of nitrogen in lettuce, verified that plants with limitation of nitrogen presented lower photosynthetic rate. The authors associated this reduction with adjust of stomata frequency which responded directly to the signs induced by privation of nitrogen or by the increase of the partial pressure of  $\text{CO}_2$  in the sites of carboxylation. In spinach (*Spinacia oleracea*) it was also verified lower capacity of photosynthesis in plants which received low nitrogen in its fertilization (VERHOEVEN et al., 1997). In studies performed with wild cabbage, *Brassica oleracea* (ISSARAKRAISILA et al., 2007) and oregano (*Origanum vulgare* L.) (MARQUES et al., 2009), the authors verified positive correlation

between photosynthesis and transpiration in plants developed in controlled environment.

The highest averages found for the ratio  $C_i/C_a$  in lettuce leaves were in treatments T13 (0.81), T14 (0.78) and T12 (0.74) which differed significantly from the others (Table 5 and 6). It can be verified in these treatments that the increase of the  $g_s$  led to the increase of the  $C_i$ , increasing, consequently, the photosynthesis. In the efficiency of carboxylation (A/Ci), the highest averages were found in the combination P1 (Treatments with basic mixture cane) (Table 4), although, it was not verified difference between the different treatments applied (Table 5 and 6).

In the efficiency of the use of water (A/E) it can be verified that there was difference in the treatments based on the mixture of coconut, with highest averages in T8 and T12 (treatments based on  $\text{K}_2\text{SO}_4$ ). Other studies found that in different species cultivated in controlled environment, with high concentration of  $\text{CO}_2$ , it occurred an instantaneous increase of the efficiency of the use of water, related to the decrease of the conductance and transpiration (CANIZARES et al., 2004; ERISMANN et al., 2006).

When comparing the groups of measures of contrast between treatments, it can be verified in

**Table 6.** Stomata conductance ( $g_s$ ), transpiration (E), photosynthesis (A), ratio between concentrations of  $\text{CO}_2$  intra/extracellular ( $C_i/C_a$ ), instantaneous efficiency of the use of water (A/E), efficiency of the carboxylation (A/Ci), reading SPAD-502 (SPAD Chlorophyll unit) and maximum quantum efficiency of the photosystem II ( $F_v/F_m$ ) of lettuce (*Lactuca sativa* L.) submitted to different types of treatments based on the mixture of the coconut T7 to T12, cultivated in polyethylene screen 41 day after seeding, in Rio Largo, state of Alagoas.

Treatments (averages)	$g_s$ $\text{mol m}^{-2} \text{s}^{-1}$	E $\text{mmol m}^{-2} \text{s}^{-1}$	A $\mu\text{mol m}^{-2} \text{s}^{-1}$	$C_i/C_a$	A/E	A/Ci	Chlorophyll (SPAD units)	$F_v/F_m$
T7	0.26B	3.7A	12.5A	0.65B	3.4B	0.053A	19.3A	0.68A
T8	0.08B	1.8A	7.6A	0.45C	4.3A	0.045A	17.1A	0.70A
T9	0.13B	2.4A	7.2A	0.63B	2.8B	0.031A	18.0A	0.72A
T10	0.22B	3.3A	10.3A	0.64B	2.9B	0.044A	18.7A	0.69A
T11	0.33B	3.4A	11.7A	0.68B	3.6A	0.047A	20.9A	0.70A
T12	0.53A	2.8A	10.1A	0.74A	3.7A	0.036A	18.4A	0.64A
T13	0.69A	3.5A	11.3A	0.81A	3.2B	0.039A	16.3A	0.68A
T14	0.66A	3.7A	12.8A	0.78A	3.4B	0.045A	17.1A	0.70A
Cv%	48.4	37.9	35.4	9.3	13.4	34.0	11.2	7.9

T7:  $MB_{\text{coconut}} + \text{water}$ ; T8:  $MB_{\text{coconut}} + 25\% \text{ vinasse}$ ; T9:  $MB_{\text{coconut}} + 50\% \text{ vinasse}$ ; T10:  $MB_{\text{coconut}} + 75\% \text{ vinasse}$ ; T11:  $MB_{\text{coconut}} + 100\% \text{ vinasse}$ ; T12:  $MB_{\text{coconut}} + \text{water} + \text{K}_2\text{SO}_4$ ; T13: Manure; T14: Mineral fertilizer (without land mass).

\*Averages followed by the same letter, in the column, do not differ statistically at the level of 5% of probability by the Scott-knott test.

treatments in which it was used mixture based on coconut with vinasse (C3) that it was not observed statistic differences for any of the studied variables (Table 7). In treatments based on  $K_2SO_4$  (C6) the variables efficiency of carboxylation ( $A/C_i$ ), ratio  $C_i/C_a$  and photosynthesis were significantly contrasting. Treatments containing mixture based on cane is  $K_2SO_4$  (C2) and the mixture of cane and vinasse (C1) is noteworthy in the efficiency of use of water ( $A/E$ ) (Table 7). This shows that the substrates which presented in the composition mixture based on cane provided favorable conditions to the photosynthetic process in lettuce plants.

The estimate of the content of chlorophyll presented difference when compared the lettuce plants cultivated with treatments based on mixture of cane with the conventional fertilization and

manure (Table 4 and 5). In treatments in which it was used the mixture of coconut it was not observed differences for this variable analyzed (Table 6). The highest averages for this variable were presented for treatments with basic mixture of cane, with averages of 20.6 and 22.5 SPAD units for T1 and T2, respectively. Similar results were found by VILLAS et al. (2004) in lettuce cultivated in two types of organic compounds, eucalyptus bark and bean straw. The same authors observed, trough measures of SPAD-502, significant difference between these organic compounds, presenting averages of three replications of 19.8 (SPAD unit) for eucalyptus bark in bean straw 21.6 (SPAD unit).

These results are consistent with those obtained by VIANA et al. (2008) who evaluated the effect of the lettuce culture in doses of nitrogen of

**Table 7.** Comparison of groups of averages, using contrast of stomata conductance (gs), transpiration (E), photosynthesis (A), ratio between concentrations of  $CO_2$  intra/extracellular ( $C_i/C_a$ ), instantaneous efficiency of the use of water ( $A/E$ ), efficiency of the carboxylation ( $A/C_i$ ), reading SPAD-502 (SPAD Chlorophyll unit) and maximum quantum efficiency of the photosystem II ( $F_v/F_m$ ) of lettuce (*Lactuca sativa* L.) submitted to different types of treatments based, cultivated in polyethylene screen 41 day after seeding, in Rio Largo, state of Alagoas.

Contrasts	gs mol m <sup>-2</sup> s <sup>-1</sup>	E mmol m <sup>-2</sup> s <sup>-1</sup>	A μmol m <sup>-2</sup> s <sup>-1</sup>	$C_i/C_a$	A/E	A/ $C_i$	Chlorophyll (SPAD units)	$F_v/F_m$
C1	0.44	4.3	14.13	0.69	3.23*	0.055	21.26	0.63
C2	0.31	3.3	9.35	0.67	2.80*	0.037	21.15	0.67
Cv%	22.1	38.1	36.4	7.3	6.3	34.0	7.9	4.9
C3	0.22	2.7	9.2	0.60	3.4	0.042	18.7	0.70
C4	0.53	2.8	11.7	0.74	3.7	0.036	18.4	0.64
Cv%	59.7	43.8	36.8	14.9	13.6	24.9	4.9	8.12
C5	0.30	3.6	12.0*	0.65	3.35	0.050*	19.98	0.67
C6	0.38	3.2	9.7*	0.71	3.24	0.037*	19.81	0.64
Cv%	48.4	25.6	25.3	9.1	18.3	18.3	9.9	9.0
C6	0.38	3.2	9.7	0.71*	3.24	0.04	19.81	0.64
C7	0.32	3.6	12.0	0.65*	3.35	0.05	19.98	0.67
Cv%	18.73	15.2	18.6	3.9	6.1	17.4	3.07	4.2

C1: Treatments with basic mixture cane and vinasse (T2 + T3 x T4 x T5)

C2: Treatments with basic mixture cane and  $K_2SO_4$  (T6).

C3: Treatments with basic mixture coconut and vinasse (T8 x T9 x T10 x T11).

C4: Treatments with basic mixture coconut and  $K_2SO_4$  (T12).

C5: Treatments with basic mixture cane, coconut and vinasse (T2 x T3 x T4 x T5 + T8 x T9 x T10 x T11).

C6: Treatments based on  $K_2SO_4$  (T6 + T12).

C7: Treatments without the addition of  $K_2SO_4$  (T1 + T2 x T3 x T4 x T5 + T7 x T8 x T9 x T10 x T11).

421 kg ha<sup>-1</sup>, obtaining values of 22.9 and 20.9 (SPAD unit). The authors verified that the portable measurer of chlorophyll SPAD-502 represented an alternative to evaluate the content of chlorophyll and may be considered an indicator of the level of this nutrient for the culture of the lettuce.

According to AMARANTE et al. (2008), the quantification of chlorophylls using the SPAD-502 reading is one of the non destructive indirect methods which allow the evaluation in real time of the nutritional state of the plant, enabling adjustments in the program of nitrogen fertilization, still during the culture cycle. This method has been used to predict the nutritional state in different legume as kale (AMARANTE et al., 2008) and okra (SEDIYAMA et al., 2009).

The maximum quantum efficiency of the photosystem II ( $F_v/F_m$ ) did not show significant difference between treatments with conventional fertilization and manure with the other treatments of basic mixture (Table 5 and 6), verifying highest averages in T1 (0.70), T9 (0.72) e T14 (0.70); these values are inferior to those considered ideal by MAXWELL e JOHNSON (2000). According to these authors, plants with values of  $F_v/F_m$  inferior to 0.75 indicate situation of stress and, therefore, reduction of the photosynthetic potential of the plant. BOLHÄR-NORDENKAMPF et al. (1989) affirmed that when a plant is with its photosynthetic apparatus intact, the values of  $F_v/F_m$  range from 0.75 to 0.85.

In works performed with the lettuce crop submitted to different types of stress, among them

light intensity (HE and LEE, 2004), response to pathogens (PROKOPOVÁ et al., 2010) and in response to ozone (CALATAYUD and BARRENO, 2004), the referred authors found, in normal conditions, values superior to 0.70 of  $F_v/F_m$  and between 0.40 and 0.60 during the stress.

The results mentioned above suggest that the maximum potential quantum efficiency of the photosystem II in lettuce was not changed in function of the different doses of organic compounds. In relations to the other photosynthetic variables, as the parameters stomata conductance and SPAD reading present more expressive values in the treatments with basic mixture of cane. It can be proposed, thus, that these variables constitute sensitive parameters to determine physiological differences related to the lettuce culture cycle and concentration of nutrients in the soil solution.

## Conclusion

Plants fertilized with mineral fertilizers (T14) and with cattle manure (T13) obtained a higher stomata conductance, favoring the gas exchanges of the lettuce.

Plants which were conditioned to the substrates of basic mixture of cane presented better performance in the variables photosynthesis, transpiration, efficiency of carboxylation and content of chlorophyll, being noteworthy as the best substrate for plant development.

The treatments did not compromise the photosynthetic apparatus of the lettuce plants.

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