Viability of Myrtle Trees as Natural Filter for the Gaseous Emissions of Internal Combustion Engines

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Received: December 8, 2010 Accepted: December 27, 2010 doi:10.5539/mas.v5n2p37

Abstract

This paper was aimed to test the control role of myrtle tree against the gaseous emissions of stationary internal combustion engines (ICEs). CO and NO_2 gaseous emissions, chlorophyll content index (CCI) and leaf surface area were studied prior and after the expose of myrtle tree the exhaust of 2 KW Gasoline fueled, power generator that was operated four hours per day for a period of 24 consecutive weeks. Myrtle have shown efficient performance in reducing the amounts of these emissions, where records of CO and NO_2 have shown reductions to about 18% and 27% of their initial levels as emitted from the source, respectively. Although it was not encouraging at the first few weeks, the CCI has shown significant development of 38% as compared to its initial value, which was incorporated with about 77% increase in average leaf`s surface area. Statistical analyses have proved good positive correlations between CO and NO_2 removal process from one side and the CCI and leaf surface area from the other. Atmospheric temperature was proved to have high negative correlation coefficient with both CCI and leaf surface area. These results encourage further biological and statistical tests to prove and determine the causal relations between these variables.

Author would like to acknowledge the support of the Institute of International Education IIE, Scholars Rescue Fund SRF and Russ College of Engineering, Ohio University.

Keywords: Chlorophyll content, Gaseous emission, Leaf surface area, Myrtle

1. Introduction

Utilization of stationary internal combustion engines (ICE) has diverse forms ranging from power generation to irrigation, and depending on the application, sizes of ICE range from relatively small; 1 Kilowatt for agricultural irrigation purposes to hundreds Kilowatts for power generation. A variety of fuels can be used for ICE including diesel and gasoline among others. The operation of ICE results in the emission of hydrocarbons, carbon monoxide (CO), nitrogen oxides (NOx), and particulate matter (PM), the concentration of which was attributed to the engine type, operation mode and duration and of course the type of fuel used. Various emission control technologies exist for ICE which can afford substantial reductions in all these four criteria pollutants such as the catalyst control technologies, the adoption of which involved the need for technical facilities and experiences in addition to their operational and maintenance costs.

There were considerable scientific evidences of beneficial effects of plants in the interior environment. Researchers have shown that common house plants such as Areca Palm, Australian Sword Fern, Boston fern, Dwarf Date Palm, English Ivy, and others, were powerful natural air cleaners. In laboratory studies, test plants removed as much as 87% of indoor air pollutants within 24 hours (Kobayashi, Kaufman, Griffis, and McConnell, 2007). Plants absorb pollutants through their leaves, roots and the bacteria that live on them and then convert these substances to food. The major health and wellbeing benefits of interior plants include; cleaning pollutants out of the air / absorption of harmful substances, filtration of dust and dirt from the environment, producing oxygen and add humidity to the indoor environment, dampening of sound levels, cooling effect, counteracting the common sick building disease, enhancing the beauty of our homes and offices, and last, but not least, the very presence of plants has been shown to increase positive feelings and reduce feelings of stress, anxiety, anger and sadness. The toleration of outdoor plants for fires was studied by Alessio, De Lillis, Fanelli, Pinelli and Loreto (2004), whom observed that Myrtle leaves exposed to elevated temperatures started to emit mono-terpenes, especially α-pinene that was not associated directly with photosynthesis, as it peaked immediately after treatment and decreased with time, which may also have other important ecological consequences, reducing flammability and slowing down combustion of the burning biomass (Owens, Lin, Taylor, and Whisenant, 1998). Myrtle plant was observed as a potentially strong emitter of isoprenoids, where intact leaves emit large amount of isoprene (Affek & Yakir 2003), which indicated that monoterpenes were stored in tightly sealed structures without being diffused out of the leaf, and were uncoupled from photosynthesis. Loreto, Pinelli, Manes, and Kollist, (2004) also observed a stimulation of monoterpene emission in Quercus ilex leaves recovering from ozone stress. It was unclear whether the stimulation of isoprene emission was a non-specific response to any environmental stress. The functional role of isoprenoids could be to quench reactive oxygen species formed under virtually all stressful conditions. From another side Myrtle and Viburnum tinus were found tolerant and no symptoms were observed on any of the plants following 35 days of exposure to 30 ppb ozone (Orendovici, Skelly, Ferdinand, Savage, Sanz, and Smith, 2003).

Myrtle plant is an evergreen bush or small tree with dense foliage that has been cultivated for centuries especially at the Middle East and Mediterranean regions and was known as highly drought tolerant. The leaves were strongly scented when crushed and used as an antiseptic and anti-inflammatory agent (Cakir, 2004). Summer was remarked as blooming time and the best culture for myrtle was best cultured in light shade to full sun.

This study was aimed to examine the possibility of use myrtle plant as a cheap and simple outdoor bio filter against the gaseous emissions of stationary ICE such as home power generators.

2. Experimental setting and procedures

The possible role of myrtle plant in decreasing CO and NO_2 gaseous emissions of ICEs was tested via well watered three years myrtle plant tree of about 50 cm thickness and 150 cm height, that was exposed to the exhaust emissions of a 2 KW gasoline fueled home generator located 20 cm aside in order to avoid the possible burning of its leaves. Generator was continuously operated for 4 hour on daily basis; from 2:00-6:00 pm, for consecutive 24 weeks so as to tolerate for acclimation and involve the possible effect of prevailing seasonal temperature variations. Also, the generator was operated without any maintenance (except the change of oil and gasoline) in order to involve the worst operation circumstances. CO and NO_2 emissions and their concentrations on the other side of the myrtle tree were measured via TG-501 gas analyzer, to inspect the control role of myrtle regarding these gases. In addition, the chlorophyll content was monitored via the use of CCM-200 plus, and dimensions of randomly selected plant leaves from different depths of the trajectory gas stream were recorded in order to examine the effects of ICEs` emissions on the plant`s growth process. These records were measured weekly at the end of that day`s operation period, altogether with the prevailing temperatures.

3. Results and discussions

First indication regarding the gaseous emissions was that both CO and NO_2 were increased by time due to the accumulation of gasoline burning wastes in the burning chamber and the exhaust pipes.

Although first few weeks of operation have shown some leaves` damages, especially the frontier ones, and decline in the CCI of the leaves tested from their initial average of 13 to values in the range of 5, the majority of leaves have proved complete recovery after the fifth week and there was no apparent damage or significant losses. As shown in fig.1, the CCI was significantly increasing with time until it reached the range of 17-18 by the tenth week, which accounts for about 38% increase in CCI as compared with the initial value, after that, no significant changes have been recorded. This increase in CCI may be attributed to the adsorption of CO that may be converted to CO_2 via oxidation which in turn assists in increasing the rate of photosynthesis process. Also, the average leave area has not shown any significant change during the first five weeks of operation, after which it began moderately increasing. This increase was pursued slightly less after the week 16 until it reached the value of about 209 mm^2 by the end of testing period, that represented about 77% increase in average leaves area (fig.2). These two indications; CCI and leaf surface area, were good indications for the tolerance and durability of myrtle plant against the emissions of ICEs.

From the other side, regarding the control ability of myrtle plant versus gaseous emissions, tests had proven remarkable decrease in CO and NO_2 concentrations for locations beyond the myrtle tree as shown in fig.3 and fig.4. While the emitted CO concentrations before passing through the tree were measured to have an average of 65.79ppm and standard deviation of 6.23, the concentrations at the other side of myrtle tree have had an average of 11.96ppm and standard deviation of 5.1. Also, the emitted NO_2 before passing through the tree were measured with an average of 0.55ppm and standard deviation of 0.15, while these beyond the tree were of an average of 0.31ppm and standard deviation of 0.07. These results interpret that myrtle tree have average removal efficiencies of about 82% and 73% against CO and NO_2 gases respectively. These remarks were enhanced by the test of correlation between the removal of each CO and NO_2 gases from one side and each of CCI and leaf size from the other side as summarized by table 1. Although, these high positive Pearson correlation factors (r) do not necessarily point out causal relations between CO and/or NO_2 removals from one side and CCI and/or leaf size from the other, but they encourage further tests, especially noting that scatter diagrams of these data as represented in figures 5-8, suggest strong causal possibilities that might be close to the predicted formulae listed in table 1 with their significantly high coefficients of determination (R^2). Prevailing temperature has proved strong negative correlation with CCI, and stronger negative correlation with leaf surface area as was demonstrated by fig.9 and fig.10 respectively. These correlations point out the highly important role of atmospheric temperature on the performance and tolerability of myrtle tree against the emissions of ICEs, as they both enhanced with lower temperatures compared with their status under high temperatures.

4. Conclusions

The viability of myrtle tree to be used as cheap, natural and safe control mean against the gaseous emissions of small ICEs like home power generators was studied focusing on the control of CO and NO_2 gases and the possible effects of these emissions on the leaves CCI and surface area. Results have proved remarkable role of myrtle tree on that regard where removal efficiencies of about 82% and 73% were achieved for CO and NO_2 respectively. Also, myrtle tree has proved high strength against these emissions, where no significant damages were observed on its leaves except for the early few weeks of study. On the contrary, the CCI and leaf surface area, as indicators for healthy life, have expressed remarkable increase during the exposure to these emissions and that was reflected also by the statistical correlation and scattered diagram tests, which encourage for more statistical and biological tests to discover the causal relations between these factors. Prevailing atmospheric temperature was observed as an important factor that affected the leaves CCI and average surface area while exposed to ICE emissions, where higher values of these two indicators were achieved under lower temperatures and vise-versa.

Results of this study are of crucial importance for dense populations of underdeveloped regions where electrical power is scarce and their major sources are via small home power generators, with all known hazardous health consequences. The plantation of such trees like myrtle would be great to reduce or slow these consequences.

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Table 1. Summary of primary statistical analysis between different variables under study

Variable 1 (X)	Variable 2 (Y)	Analysis		
		Equation (predicted)	Coefficient of determination R^2	Coefficient of correlation r
CO removed ppm	CCI	$Y = -41.38 + 1.858 * X - 0.0146 * X^2$	0.798	0.84
NO_2 removed ppm		$Y = -11.78 + 214.02 * X -387.91* X^2$	0.94	0.90
Temperature C		$Y = -14.65 + 2.46 * X - 0.046 * X^2$	0.89	- 0.86
CO removed ppm	Average leaf surface area mm^2	$Y = \exp(0.02 X) * 53.625$	0.673	0.80
NO_2 removed ppm		$Y = \exp(2.62 * X) * 85.031$	0.781	0.86
Temperature C		$Y = 580.68 - 21.103 * X +0.238 * X^2$	0.973	- 0.96

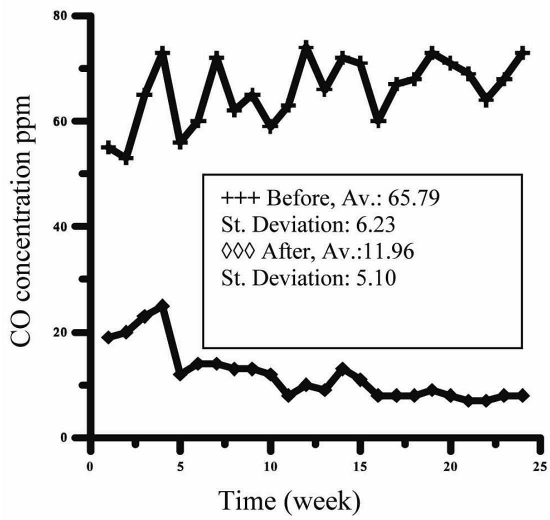

Figure 1. CO gas concentrations before and after passing through myrtle tree vs. operation time

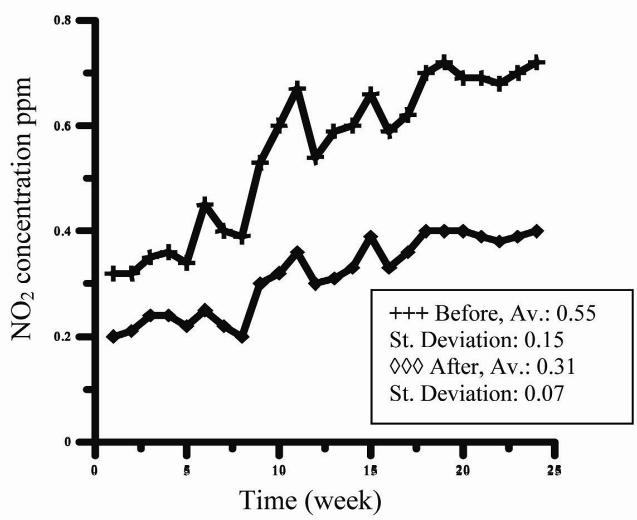

Figure 2. NO_2 gas concentrations before and after passing through myrtle tree vs. operation time

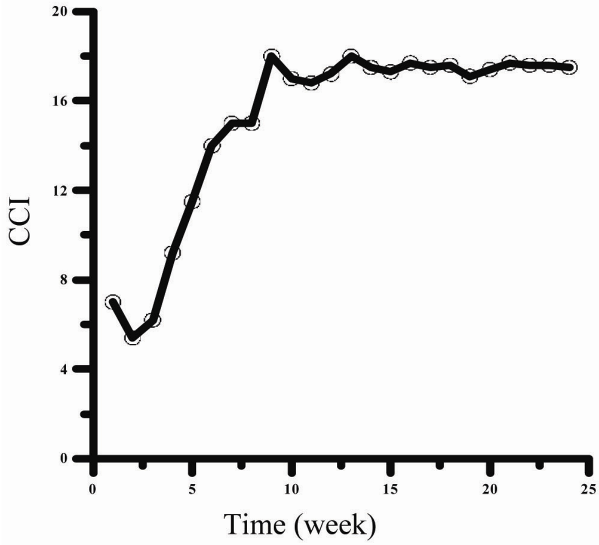

Figure 3. Myrtle tree CCI vs. operation time

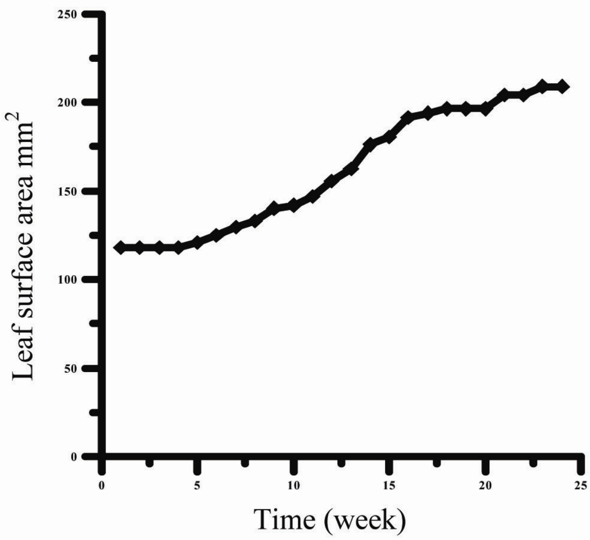

Figure 4. Average surface area of Myrtle tree leaves vs. operation time

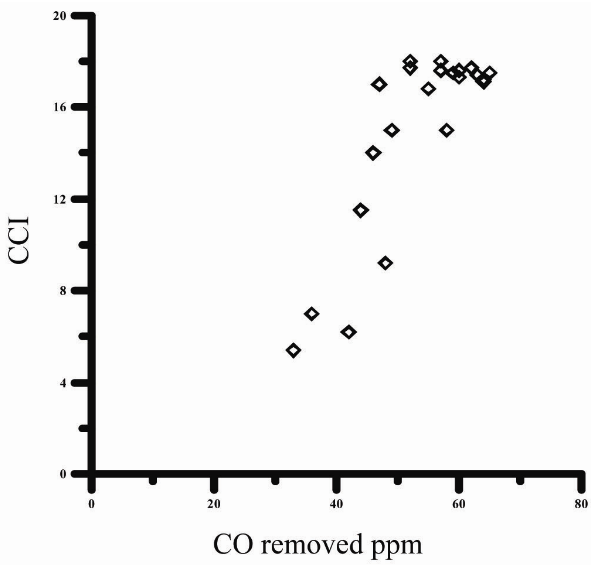

Figure 5. Scatter diagram of CCi vs. CO removed

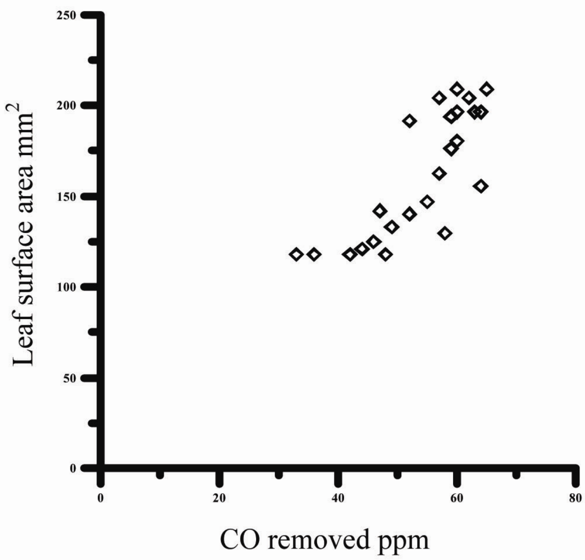

Figure 6. Scatter diagram of average leaf surface area vs. CO removed

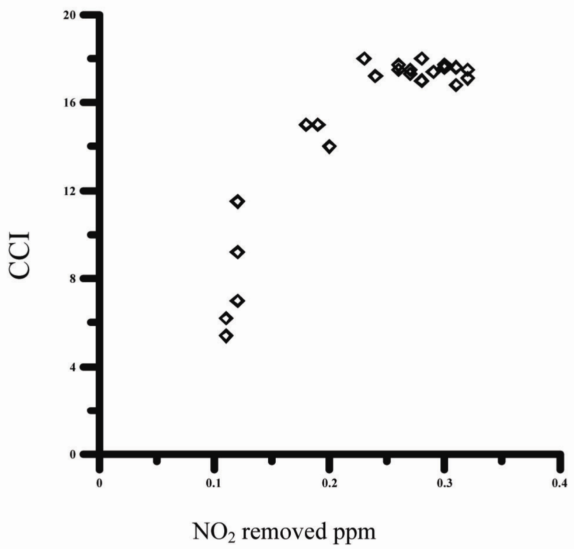

Figure 7. Scatter diagram of CCi vs. NO_2 removed

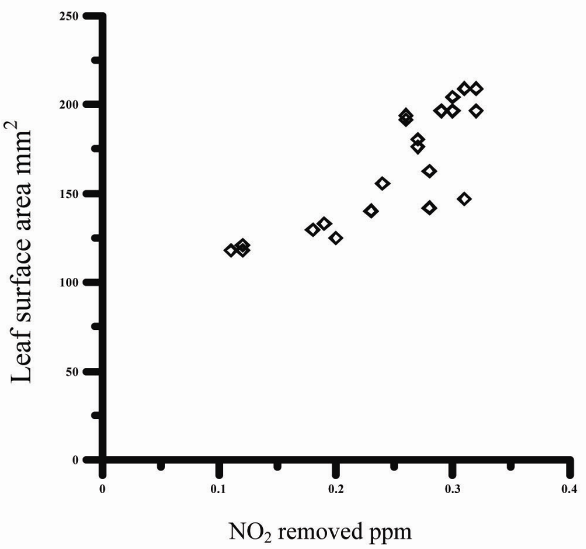

Figure 8. Scatter diagram of average leaf surface area vs. NO_2 removed

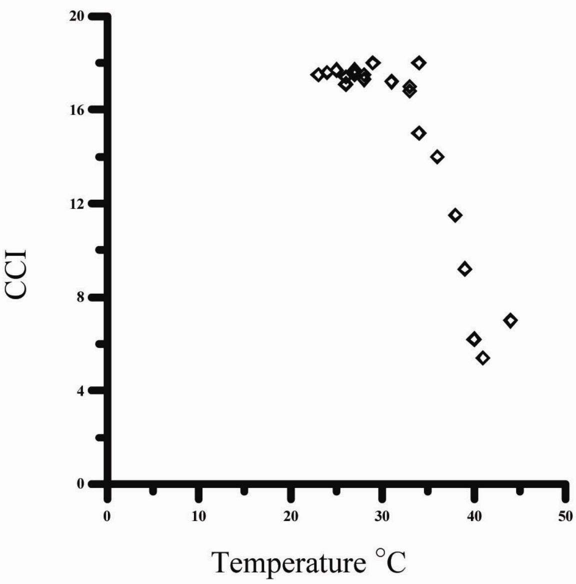

Figure 9. Scatter diagram of CCi vs. temperature

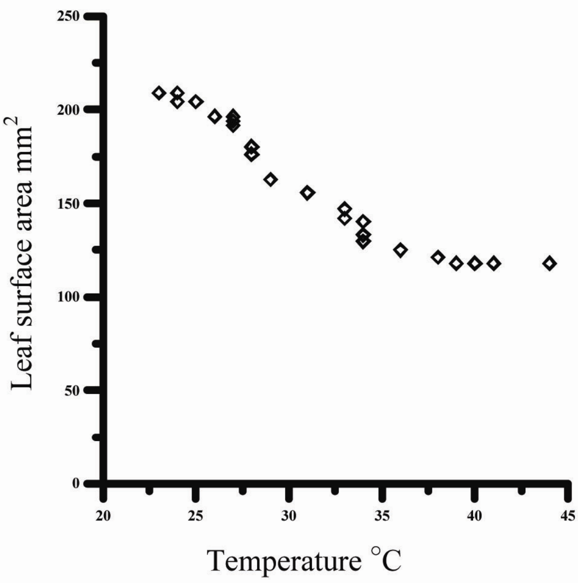

Figure 10. Scatter diagram of average leaf surface area vs. temperature