Research title
The relationship between CAM plants stomatal density and size with their effectiveness to reduce PM 2.5 level in the air

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Abstract

This research has been studying on the relationship between CAM plants stomatal density and size with their effectiveness to reduce PM 2.5 level in the air. The objective of the study is: 1) To compare the ability of three selected CAM plants to reduce PM 2.5 level 2) To describe the relationship between the density, size of stomata and ability of reducing PM 2.5 dust of three selected CAM plants. The selected three CAM plants are *Sansevieria trifasciata*, *Aechmea fasciata* and *Sansevieria stuckyi.*

The study was divided into three sections which are Section 1: Explore the possible related factors and environment, Section 2: Study the ability to reduce the amount of PM 2.5 of three selected CAM plants by measuring PM 2.5 with Air Quality Detector in the test chamber before and after putting the CAM plants then calculate the percentage of PM 2.5 amount that was reduced and Section 3: Measure the density and size of the stomata by taking photo of the stomata under a microscope and calculate with ImageJ program. Then the result was used to study the relationship between the density, size of stomata and ability to reduce PM 2.5 of three selected CAM plants.

From the research, we concluded that all selected CAM plants can reduce PM 2.5. The most effective CAM plants to reduce PM 2.5 is *Sansevieria stuckyi* (33.84%), whereas the least is *Aechmea fasciata* (19.76%). The plants that have higher stomatal density will have more effectiveness to reduce the level of PM 2.5. There is no relationship between size of CAM plant's stomata and PM 2.5 level.

Keywords: PM 2.5 reduction, CAM plants, stomata density, stomata size

Introduction

The PM 2.5 has a significant impact on Thai people's living. According to Berkeley Earth statistics, there is high PM 2.5 in Thailand. The average scale of dust based on Air Quality Index (AQI) is yellow (Medium air quality). For example, in January 2020, PM 2.5 in Bangkok and nearby cities was higher than 100 micrograms/cubic meters which exceeded the average standard. The PM 2.5 affects many aspects such as transportation - the visibility is reduced because dust in the atmosphere has the ability to reflect and absorb light, economy - PM 2.5 affects plants growth directly because it destroys tissues and slows the growth of plants. The most important is health effect, the number of patients with various diseases are increasing. PM 2.5 can cause respiratory diseases in some people, such as chronic obstructive lung disease. If the dust gets into the eyes, it will cause irritation and red eyes. For the skin, the dust can cause rash and itchy. The accumulation of this dust in long-term will lead to some chronic diseases such as coronary artery disease, heart attack, cerebrovascular disease, lung cancer, or death. (Department of Mental Health, 2019). Therefore, various agencies are trying to propose the methods to prevent and solve the problem of PM 2.5 such as using an air purifier, encouraging to reduce the source of dust. One of the methods that we can see on the public media is to have potential plants that are capable in trapping dust at home. This method is considered as an effective long-term solution to improve air quality and the investment is low. (Thamarat Phutthai, Kampanad Bhaktikul and Sura Pathanakiat, 2019)

We have found that there is a group of plants that is suitable to plant in a house because they are easily to plant and they do not release carbon dioxide at night. These plants are Crassulacean Acid Metabolism plant (CAM plant). The stomata of CAM plant remains shut during the day to reduce evapotranspiration, but open at night to collect carbon dioxide, and allow it to diffuse into the mesophyll cells The opening and closing of stomata in the leaves of this group plants are different from other plants. Some of CAM plants is known as plants that can reduce PM 2.5. Therefore, we are interested in the effectiveness of CAM plants to reduce the amount of PM 2.5.

From the study of Panthawat WongRak and et al 's (2010) that study about the ability to reduce carbon dioxide of toxic absorbing plant in the building, Dracaena fragrans (L.) Ker Gawl. 'Massangeana' had the best ability to reduce carbon dioxide among the tested plants. One of the tested plants was Sansevieria trifasciata which can do well at night and the rate of carbon dioxide reduction was clearly different from other plants which was probably due to the internal photosynthesis structure that were different from other plants because Sansevieria trifasciata is CAM plant. However, there is no research studying about the certain factors that affect CAM plants to reduce toxic and dust. The researchers think that one of the important factors is the stomata because it is the passage of gas and vapor. When plants transpire through the stomata, this vapor may help trapping dust. Therefore, we are interested in the effectiveness of CAM plants, and the relationship between their stomatal density and size to reduce the amount of PM 2.5.

Objective

1. To study the ability to reduce PM 2.5 of three CAM plants namely *Sansevieria Trifasciata*, *Aechmea fasciata* and *Sansevieria stuckyi*.
2. To compare the ability to reduce PM 2.5 of three CAM plants namely *Sansevieria Trifasciata*, *Aechmea fasciata* and *Sansevieria stuckyi*.
3. To study the relationship between density, size of CAM plants’ stomata and the ability to reduce PM 2.5 of those CAM plants.

Research question

1. Can CAM plants reduce PM 2.5?
2. Which is the most effective CAM plants namely *Sansevieria trifasciata*, *Aechmea fasciata* and *Sansevieria stuckyi* to reduce PM 2.5?
3. Is the density of the stomata and stomata size related to the ability of CAM plants to reduce PM 2.5?

Research hypothesis

1. If CAM plants are capable of trapping dust; therefore, studied CAM plants namely *Sansevieria trifasciata*, *Aechmea fasciata* and *Sansevieria stuckyi* are capable to reduce PM 2.5.
2. If the studied CAM plants namely *Sansevieria trifasciata*, *Aechmea fasciata* and *Sansevieria stuckyi* can reduce the amount of PM 2.5, *Sansevieria trifasciata* would be the most effective plant.
3. If the density and size of stomata of the CAM plant affect the reduction of PM 2.5. Therefore, the density of the stomata and the size of the stomata is related to the ability to reduce the amount of PM 2.5.

Equipment and Methodology of research

The research of relationship between densities, size of stomata and ability to reduce PM2.5 of CAM plants is separate into three sections which are

Section 1 Explore the possible related factors and environment

Section 2 Study the ability to reduce the amount of PM 2.5 of three selected CAM plants

Section 3 Studying the relationship between the density, size of stomata and ability to reduce PM2.5 of CAM plants

Research Equipment

1. Thermometer
2. FLIR TG165 Spot Thermal Camera (Surface temperature)
3. Universal indicator and Litmus paper
4. Digital Hygrometer
5. Air Quality Detector (PM2.5 detector)
6. Microscopes
7. Camera
8. Test chamber (1.2 x 0.5 x 1 meter)
9. ImageJ program
10. Nail Polish
11. Slides
12. Clear tape
13. Studied plants- *Sansevieria trifasciata*, *Aechmea fasciata*, and *Sansevieria stuckyi*

Research Methodology

1. We determine the point for study at Kasetsart University Laboratory School, Ngamwongwan Road, Chatuchak district. Geographical coordinates 13°5105N 100°3401E / 13.851360°N 100.566990°E.
2. We consider the determinant, environment and scrutinize sort of CAM plants in our school namely *Sansevieria trifasciata*, *Aechmea fasciata*, and *Sansevieria stuckyi* as we contemplate determinant that related to CAM plants such as soil PH, soil temperature, soil humidity, air temperature, and leaf's surface temperature following Globe protocol's process.

   2.1. Analyzation soil PH

   In a cup or beaker, mix 40 g of dried and sieved soil with 40 mL of distilled water (or other amounts in a 1:1 soil to water ratio) using a spoon or other utensil to transfer the soil. Stir the soil/water mixture with a spoon or other stirrer until it is thoroughly mixed. Stir the soil/water mixture for 30 seconds and then wait for three minutes for a total of five stirring/waiting cycles. Then, allow the mixture to settle until a supernatant (clearer liquid above the settled soil) forms (about 5 minutes).

   Measure the pH of the supernatant using the pH paper or meter. Dip the pH paper or calibrated pH meter in the supernatant. Record the pH value on the Soil pH Data Sheet. If pH meter requires calibration, gloves should be worn.

   2.2. Analyzation soil temperature

   Use the nail to make a 5 cm deep pilot hole for the thermometer. If the soil is extra firm and you have to use a hammer, make the hole 7 cm deep. Pull the nail out carefully, disturbing the soil as little as possible.

   Gently push the thermometer into the soil and wait 2 minutes. Record the temperature after that wait 1 minute and record the temperature. If the 2 readings are within 1.0˚ C of each other, record this value and the time on the Soil Temperature Data Sheet as Sample 1, 5 cm reading.

   2.3. Analyzation leaf surface temperature

   Use FLIR TG165 Spot Thermal Camera measuring leaf surface temperature before and after the process started at the same time of measuring PM 2.5 dust in the test chamber.

   2.4 Analyzation of the amount of the PM 2.5 dust in the air.

   Use Air Quality Detector measuring the dust in the test chamber compare to the air outside the chamber for 1 month between 12 December 2019 - 12 January 2020.

   2.5 Analyzation air temperature

   Use A Digital multi-day Maximum/Minimum measuring air temperature and record for 1 month between 12 December 2019 - 12 January 2020.

3. We consider the relative between the density, the size of the stomata and the capability to decrease the number of the dust of CAM plants

    3.1. We determine the environment that we use to consider CAM plants by following this step

        3.1.1. We scrutinize sort of CAM plants in our school namely *Sansevieria trifasciata*, *Aechmea fasciata*, and *Sansevieria stuckyi*

        3.1.2. We determine the environment by creating 4 test chambers in the size of 1.2x0.5x1 meter and wrap with a clear film for a closed system

        3.1.3. We borehole at the bottom of the test chamber so we can put the test plants inside it.

4. We analyze the density, the size of the stomata of CAM plants through this step

    4.1. We analyze the density of the stomata by coat with nail polish on the leaf surface. Then, wait for 10 minutes and collect it with clear tape after that put it on a glass slide for study the stomata under the microscope

    4.2. Put a glass slide that we have been collected in the previous step by using 40x and 100x zoom and take a photo of it for calculate in the ImageJ program.

    4.3. Take the photo that we have been collected from the microscope and analyze it by count in the ImageJ program compare to 1 square millimeter.

    4.4. Measure the stomata from the photo that we have been collected in the ImageJ program.

5. We analyze the capability to decrease the number of the PM 2.5 dust of CAM plants following this step.

    5.1. Put 3 examples of CAM plants into 3 test chambers at 6:00 pm. and record air quality at the same time.

    5.2. Wait over the night (14 hours) and record again at 8:00 am.

    5.3. Repeat 5.1.- 5.2 for 3 times.

    5.4. We compare the 6:00 pm. record and 8:00 am. record by calculating its percentage to see the difference of the number of the PM 2.5 dust. Then, find the average of those percentages from the repeated step.

6. We analyze all of the data to see the relationship between them.

Section 2 Result of the ability of each CAM plants to reduce PM2.5.

Table 2, 3, and 4 show and compare the result of ability to reduce PM2.5 of 3 CAM plants which are Sansevieria trifasciata, Aechmea fasciata, and Sansevieria stuckyi.

<u>Table 2</u> Percentage of PM2.5 that reduced during the night from using each CAM plants

CAM plants	1st experiment			2nd experiment			3rd experiment			Average Percentage of PM2.5 that reduced
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	
Sansevieria trifasciata	51	27	47.06	48	34	29.17	52	38	26.92	34.38
Aechmea fasciata	50	35	30.00	48	40	16.17	52	42	19.23	21.80
Sansevieria stuckyi	50	22	56.00	48	35	27.08	52	35	32.69	38.59

** A represent PM2.5 in the test chamber before the experiment (no plants)

B represent PM2.5 in the test chamber after 14 hours (with plants)

C represent percentage of PM2.5 that reduced during 14 hours

From table 2, all 3 CAM plants can reduce PM2.5 during the night (14 hours; 6pm-8am). In average, Sansevieria trifasciata can reduce PM2.5 by 34.38%, Aechmea fasciata 21.80%, and Sansevieria stuckyi 38.59%.

<u>Table 3</u> Percentage of PM2.5 that reduced during the day from using each CAM plants

CAM plants	1st experiment			2nd experiment			3rd experiment			Average Percentage of PM2.5 that reduced
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	
Sansevieria trifasciata	45	31	31.11	46	37	19.57	45	32	28.89	26.52
Aechmea fasciata	45	34	24.44	46	42	8.70	45	36	20.00	17.71
Sansevieria stuckyi	45	32	28.89	46	37	25.00	45	30	33.34	29.08

** A represent PM2.5 in the test chamber before the experiment (no plants)

B represent PM2.5 in the test chamber after 10 hours (with plants)

C represent percentage of PM2.5 that reduced during 10 hours

From table 3, in average every CAM plant can reduce PM2.5 during the day (10 hours; 8am-6pm) less than the night. In average, *Sansevieria trifasciata* can reduce PM2.5 by 26.52%, *Aechmea fasciata* 17.71%, and *Sansevieria stuckyi* 29.08%.

Table 4 Percentage of PM2.5 that reduced in a day (24hours) from using each CAM plants

CAM plants	Average Percentage of PM2.5 that reduced during the night	Average Percentage of PM2.5 that reduced during the day	Average Percentage of PM2.5 that reduced in a day (24 hours)
Sansevieria trifasciata	34.38	26.52	30.45
Aechmea fasciata	21.80	17.71	19.76
Sansevieria stuckyi	38.59	29.08	33.84

From table 4, the average percentage of PM2.5 that 3 CAM plants reduced in 24 hours is calculated from mean of average percentage of PM2.5 that reduced during night and day. In average, *Sansevieria stuckyi* can reduce the most (33.84%), *Sansevieria trifasciata* can reduce 30.45%, and *Aechmea fasciata* can reduce the least (19.76%).

Section 3 Result of the relationship between densities, size of stomata and ability to reduce PM2.5 of CAM plants

Table 5 The relationship between densities, size of stomata and ability to reduce PM2.5 of 3 CAM plants

CAM plants	Average Percentage of PM2.5 that reduced in a day (24 hours)	Amount of stomata (Unit)	Area of plant leaf photos (sq.mm.)	Density of stomata (Unit/sq.mm.)	Average stomata size (micrometer)	
					wide	length
Sansevieria trifasciata	30.45	138	79.1	1.71	160	163
Aechmea fasciata	19.76	110	77.9	1.41	100	113.33
Sansevieria stuckyi	33.84	212	78.2	2.71	120	116.67

From table 5, the most effective CAM plants to reduce PM 2.5 is Sansevieria stuckyi (33.84%). It has the densest stomata (2.71 unit/sq.mm.), with the size of 120 micrometers wide and 116.67 micrometer length. Sansevieria trifasciata can reduced PM2.5 less than Sansevieria stuckyi (30.45%), its stomata are dense at 1.71 unit/sq.mm., with the size of 160 micrometers wide and 163 micrometers length. The least is Aechmea fasciata (19.76%), its stomata are dense at 1.41 unit/sq.mm., with the size of 100 micrometers wide and 113.33 micrometers length.

Conclusion

1. There are three CAM plants in this study which including *Sansevieria trifasciata*, *Aechmea fasciata*, and *Sansevieria stuckyi*. According to the research, all CAM plants can reduce PM2.5. However, the most effective CAM plants to reduce PM 2.5 is *Sansevieria stuckyi* (33.84%).
2. The density of stomata seems to have direct relationship with the ability to reduce PM2.5. The plant that has higher stomatal density will have more effectiveness to reduce the level of PM 2.5. From the studied, *Sansevieria stuckyi*, which has density of 2.71 unit/micrometers, reduced PM2.5 by 33.84%.
3. There is no relationship between CAM plant's stomatal size and the ability to reduce PM2.5.

Discussion

From our study, we assume that there is the direct relationship between the ability to reduce PM2.5 of CAM plants and the density of stomata. The highest stomatal density plant is *Sansevieria stuckyi* (2.71 unit/micrometers), which has the best ability to reduce PM2.5 of 33.84%. The reason may be when the stomata opens and plants transpire, PM2.5 move into the leaf along with carbon dioxide gas. *Sansevieria stuckyi* has lots of stomata so there are many gateways for PM 2.5 to move into the leaf. In addition, from observing the leaf surface, the leaf of *Sansevieria stuckyi* has longitudinal groove, so PM2.5 might be caught on the leaf surface. Therefore, when we test the ability of CAM plants to reduce PM2.5, *Sansevieria stuckyi* has the best ability to reduce PM2.5 among these three plants.

Suggestion

1. The future study should be focused on other CAM species on the ability to reduce PM2.5 whether there are any CAM plants that can reduce PM2.5.
2. The future study should pay attention on the correlation between CAM plants stomatal density and the reduction rate of PM2.5.
3. The future research should be studied on other plants as an alternative to reduce PM2.5.

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References

กรมควบคุมมลพิษ. 2549. **เกร็ดความรู้เรื่องฝุ่นละออง**. [online]. Access from: www.pcd.go.th [11 January 2020]

ธรรมรัตน์ พุทธไทย. 2562. ต้นไม้ดูดฝุ่น [online]. Access from: https://today.line.me/th/pc/article [12 January 2020]

พนธวรรธน์ วงษ์รักษ์. (2553). การวิจัยสมรรถนะการลดก๊าซคาร์บอนไดออกไซด์ของพืชดูดสารพิษเพื่อคุณภาพอากาศที่ดีภายในอาคาร. กรุงเทพมหานคร: มหาวิทยาลัยเกษตรศาสตร์