ENHANCING GROWTH IN A ROOF TOP GARDEN WITH INDOOR CO_2 FROM HUMAN RESPIRATION

CambPlants

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Background

A rising population, expected to occur mostly in cities, will require increased food production (McKinney 2006; United Nations, 2004). Climate change is another crucial challenge facing humanity over the next century. Both of these issues will place more stress on already crowded urban environments. To mitigate this effect cities should be designed to be sustainable and address climate change at the same time.

One potential approach is to construct rooftop gardens. These can provide many environmental, social, and health benefits (Orsini et al. 2014; Ahmed et al. 2017). A challenge facing edible green roofs is decreased growth due to more extreme environmental conditions such as higher wind and temperatures, heightened solar radiation, and limited soil moisture content. Human breath has high concentrations of CO_2, which builds up in indoor spaces. Excess CO_2 can decrease performance of humans, but can cause a CO_2 fertilization effect in plants, which increases growth (Figure 1). The goal of this project is to enhance growth in rooftop gardens by transporting waste CO_2 from inside of buildings from human respiration.

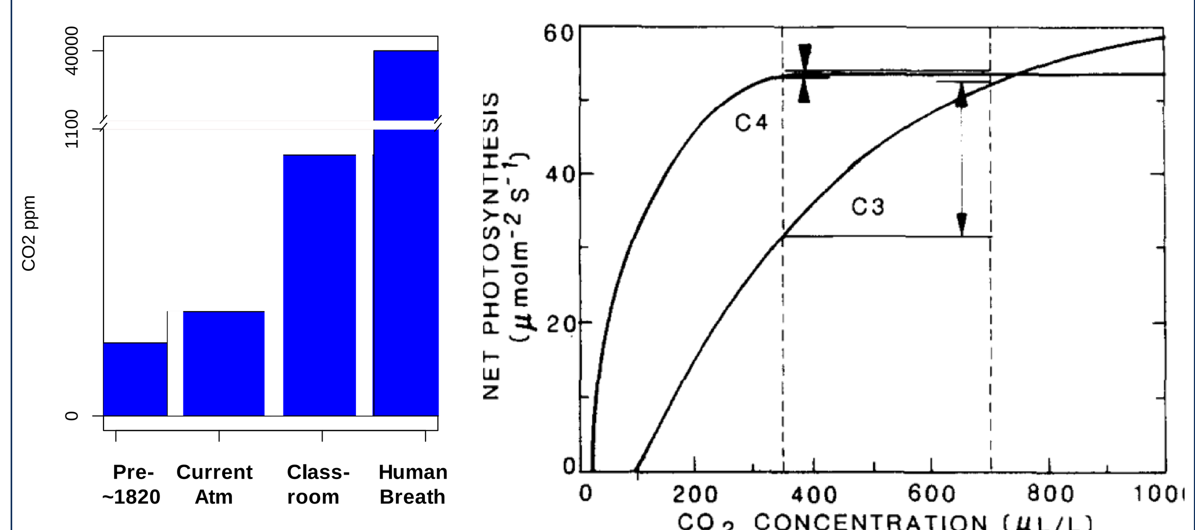

Figure 1. a) **Comparison of CO_2 concentrations** before the industrial revolution, currently in the atmosphere, found in full classrooms, and in human breath. b) **Photosynthetic response curve** to CO2 for C4 and C3 plants (Rogers et al. 1994).

Abstract

Climate change will increase storm intensity, heat waves, and more. Rooftop gardens provide both a source of food in urban communities and a means to combat climate change by increasing carbon storage, decreasing urban heat island, and helping manage stormwater in cities. We enhanced growth in rooftop gardens by applying waste carbon dioxide (CO_2) from inside of buildings produced by human respiration. We first determined the amount of CO_2 within and emitted from exhaust vents at BU buildings and then set up a rooftop garden at the end of an exhaust vent to test for the effect of applied CO_2. Growth increased significantly in the garden exposed to vent air, which experienced higher concentrations of CO_2. The potential for more robust rooftop gardens could encourage the construction of more gardens in cities.

Methods

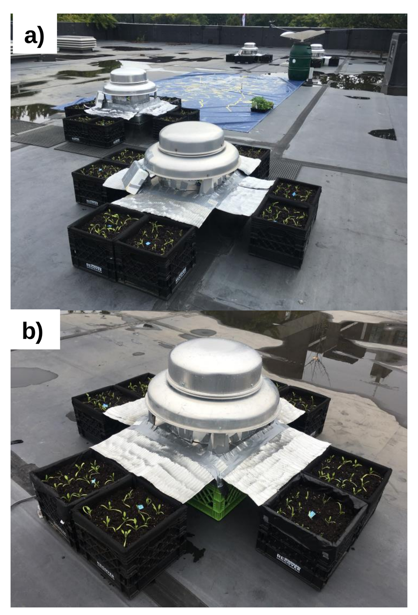

Figure 2. Roof Top Garden set up. Thirty two boxes were set up a) near the two treatment vents in front and two control vents in back with b) eight at each vent.

CO_2 sensors (Onset Hobo MX1102) were placed in 12 classrooms inside of Boston University for one week.

Sensors were also placed on roof top exhaust vents at the Boston University Academy. The first two weeks were before and the second two weeks were during a camp.

Spinach plants were seeded and planted in crates in September. They were grown next to vents connected to indoor air and fans circulating atmospheric air. Plants were harvested wet and dry weight measured.

System and Results

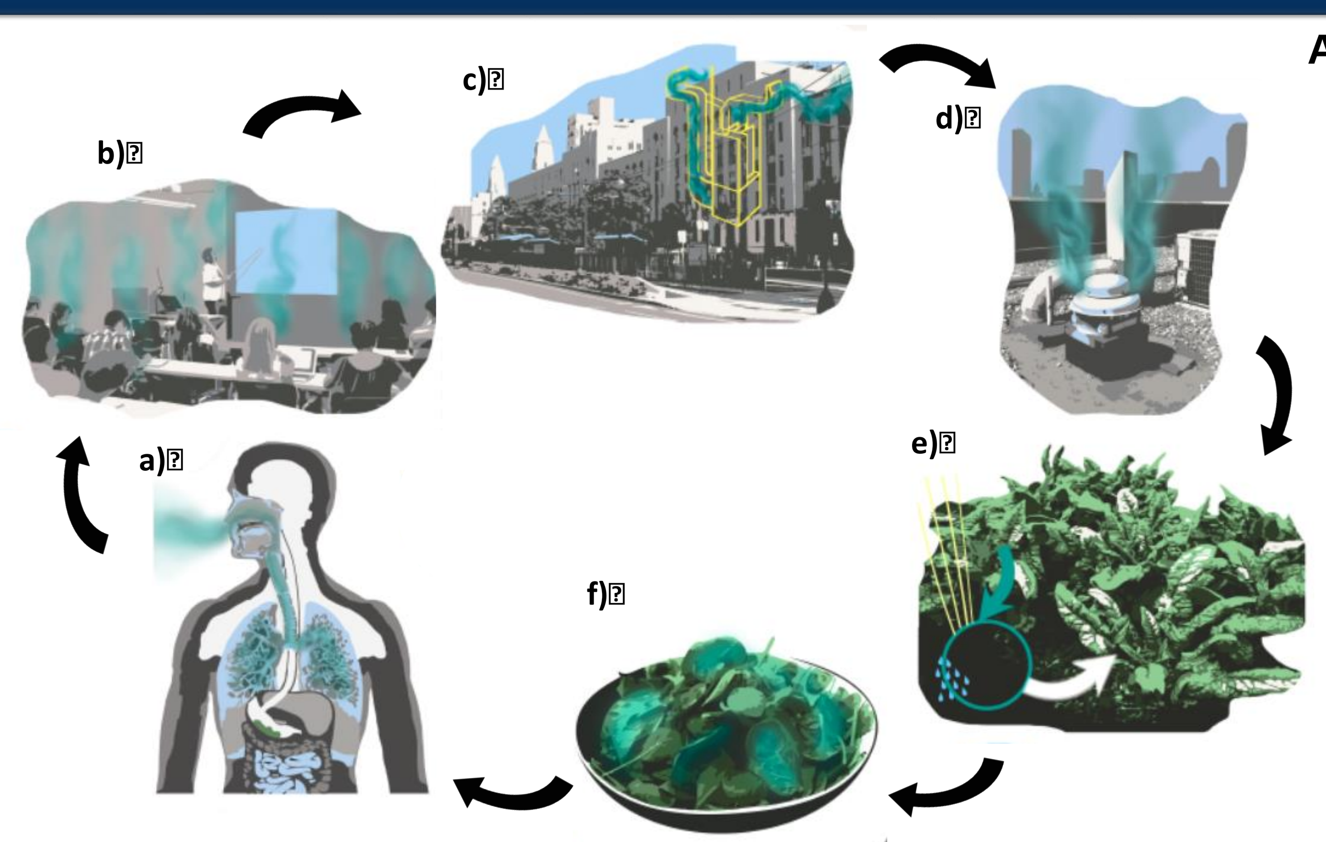

Figure 3 Carbon Cycle Within Experimental Roof Top Garden. CO_2 travels from the human body (a) out into the classroom (b) within a building. This CO_2 then is brought through the ventilation system (c) to the roof top and released through an exhaust vent (d). Our system will apply this CO_2 to plants in a green roof garden (e) after which humans can consume the crops (f) and the carbon can return to the human body.

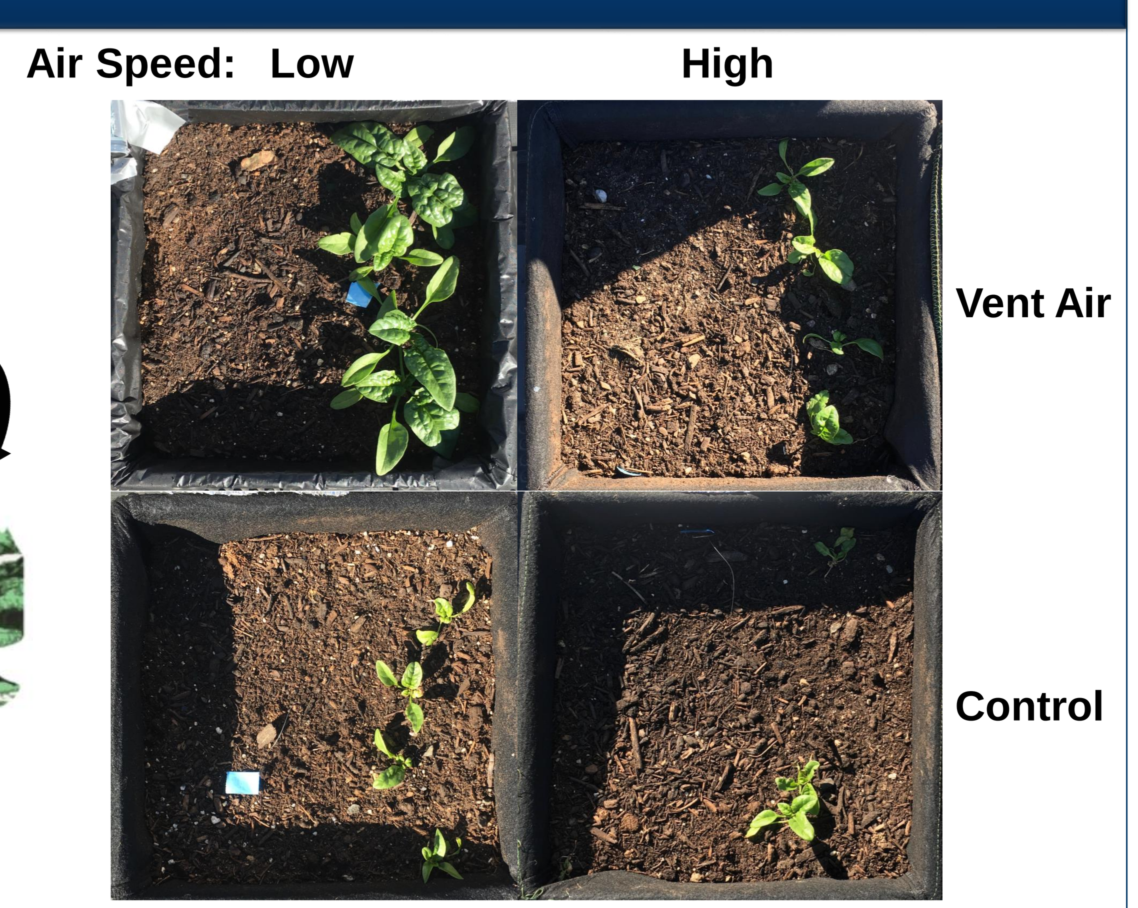

Figure 4. Rooftop Garden Treatment Comparison. Plants were ranked on their growth and these are the 5th rank of boxes from spinach treated with vent air in the top two boxes, control air on the bottom two boxes, low air speed on the left two boxes and high air speed on the right two boxes.

Results

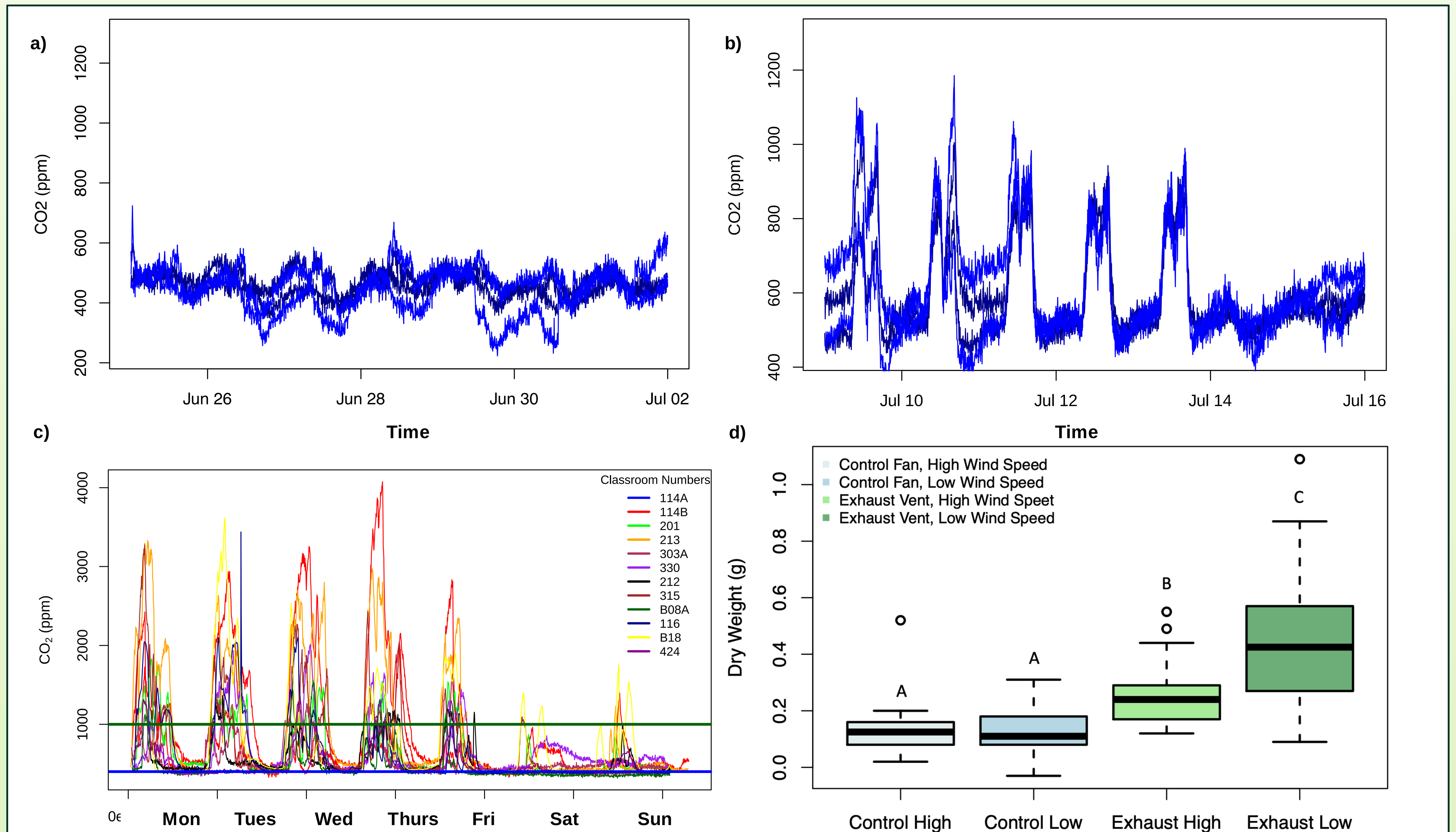

Figure 5. Exhaust vent and classroom CO_2 concentrations and garden growth measurements. CO_2 concentrations were measured from two rooftop exhaust vent on 1 University Rd. Boston MA 02215, a private high school called the Boston University Academy. The a) first measurements were taken from two vents (light and dark blue) over two weeks (weeks are overlapping in the graph) in the summer of 2018 while approximately 10-15 people were in the building. The b) second set of measurements were taken from the same two vents over the following two weeks once a camp began during which approximately 175 people were in the building during the day. Concentrations stayed relatively consistent the first two weeks and increased greatly during the day when a larger number of people were in the building ranging between 400 to over 1000. Measurements in c) 12 different classrooms were also taken over the course of a week each during Spring 2018. These ranged from 400 to 4000 during the day and dropped to atmospheric concentrations, 400 ppm shown by the blue line, at night. They consistently reached and went above 1000 ppm, shown by the green line. The d) wet weight of the plants from spinach grown in the roof top garden next to vents with two different wind speeds (10 and 17 mph). The plants exposed to exhaust vent air weighed significantly more than plants in the control garden and plants exposed to a low wind speed were significantly larger than those exposed to a high wind speed.

Conclusions

- CO_2 in classrooms increases during the day and decreases at night, reaching as high as 4000 ppm, which is far above the recommended limit of 1000 ppm
- Exhaust vent air coming from inside follows similar CO_2 patterns as found indoors
- Spinach plants grown in rooftop gardens exposed to exhaust vent air grow faster and larger than spinach in control gardens exposed to air from the atmosphere
- There is a threshold above which air speed is too fast and can decrease the growth of spinach plants grown in rooftop gardens

Future Directions

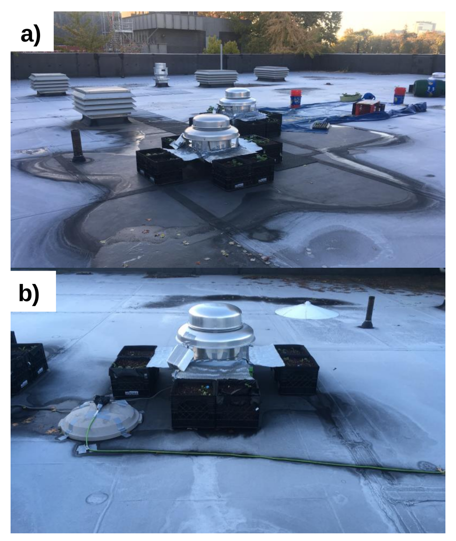

Figure 6. a) Exhaust vent and b) control fan. These pictures were taken on a cold morning when frost was spread across the roof. The exhaust vent cleared the space around it of frost, indicating the reach of the vents.

- Understand the spatial range of the growth effect (Figure 6)
- Determine the separate influence of temperature and other parameters besides CO_2 that differ in exhaust vent air compared to atmospheric air
- Construct a more efficient application system for exhaust air
- Measure concentrations of minerals, nutrients, and secondary chemicals in plants in these systems to understand the impact on crop quality

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