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ARTICLE

Six BC Pinophyta Conifers' Dust Retention Ability and Impact on Photosynthesis Productivity

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Dust in the air, especially particles of 10 microns or less, can cause haze when present in large amounts. Nowadays, haze appears around the globe in populated cities due to rapid urbanisation (Mao et al., 2013). Emerging mainly from wildfires, haze is also a big problem in West Coast Canada. The presence of haze and airborne pollution have strong connections with increased inflammation and disruption of the immune system (Croft et al., 2021). Inhalation of haze by the human body can cause respiratory discomfort and serious symptoms such as shortness of breath, coughing, wheezing, etc. To improve the problem of urban air dust pollution, scientists have been investigating the method of green space dust retention, which is the process of dry deposition of atmospheric particles on the surface of plants. Green space effectively absorbs dust in the air and reduces its impact on people (Ma et al., 2018). Research has shown that green space can reduce the pollutant concentration (NO and NO2) by an average of 49 % (Baik et al., 2012). In Christchurch, New Zealand, and Beijing, China, respectively, Chen et al. found trees removed approximately 300 metric tons and 1,261 metric tons of air pollutants annually (Chen et al., 2017).

Dust retention capacity is often mistaken for dust retention ability. While the former is the amount of dust retained, the latter is the resistance of trees to dust pollution. For example, a tree species with a high dust retention capacity and a low dust retention ability would be negatively affected by dust pollution in terms of its growth and development. Misunderstanding the difference between dust retention capacity and ability can hinder garden designers and landscape designers from choosing species that are conducive to dust retention, to optimize the function of urban vegetation for dust retention. Photosynthesis is the process by which plants use light energy to reduce carbon dioxide (CO2) to sugars, which are subsequently converted to a variety of organic compounds that constitute approximately 95 % of plant dry mass (Chapin & Eviner, 2004). As a significant process of maintaining the trees' health, this project uses dry mass as an indicator of the photosynthesis performance under the effect of dust retention.

At present, many experts and institutions have conducted detailed studies on the dust retention mechanisms of tree species in different cities and have found a lot of patterns (Ma et al., 2018). The dust retention ability and capacity of vegetation depends on several factors including canopy type, leaf and branch densities, and leaf micromorphology (e.g., texture, trichomes, and wax) (Erkebaev et al., 2021). For example, fluff and wrinkles on the surface of a leaf are effective in blocking dust particles from drifting across the surface and retaining them to be washed off by precipitation (Durmushidze, 1977). Conifers are more effective in retaining dust and capturing particulate matter than broadleaved species due to their year-round potential to accumulate pollutants (Chen et al., 2017). Conifers are also ideal for city vegetation designers as they are native to the West Coast, are adaptable to tough conditions, and are evergreen and perennial.

Characteristics of Six Conifer Species

The species of conifers studied in this experiment share different combinations of similar characteristics that may influence dust retention capacity and dust retention ability. Pinus monticola (western white pine) shows a clustered needles structure. Five to six smooth and thin needles converge together at a single point connected to the branch. In contrast, Picea glauca (white spruce) shows a single attachment needles structure with smooth and plumper needles compared to those of pines. Each needle is connected to the stem at alternating angles with approximately 1 mm in spacing and a slight upward tilt. The common Thuja plicata (western red cedar) has a flatter, scale-like leaves structure. Each strand of scales expands outwards with a slight upward tilt. Thuja plicata 'Zebrina' (Zebrina western red cedar) is the variegated form of Thuja plicata, and therefore shows similar traits. A notable difference is that the scales are slightly thinner than that of Thuja plicata and, thereby, it has a flatter branch structure. Another type of pine, Pinus ponderosa (ponderosa pine), has a bundled, long needles structure that points downwards. It secretes a sticky wax. Unlike all the species above that show thin and needle-like leaf characteristics, Taxus chinensis (Chinese yew) has less tilted leaves that are plumper than needle leaves. It has a similar needle structure to Picea glauca in that the needles attach to the branch independently.

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OBJECTIVES

This experiment's objectives are threefold. The first objective is to find a Canadian West Coast native conifer species with a high dust retention capacity and low negative impact of the dust on the species' photosynthesis ability, out of six species. The second objective is to investigate any effect(s) of urban pollution on photosynthesis for the six tree species. The third objective is to observe the species' characteristics that may work for and against dust retention and that allow for ease of the dust to be washed off by rain. These objectives may help determine the most compatible urban green space species to plant in polluted areas in Vancouver.

HYPOTHESES

If I weigh the dust collected on leaf samples of P. ponderosa, P. glauca, T. plicata, T. plicata 'Zebrina', P. monticola, and T. chinensis, T. plicata will have retained the most dust. Its bumpy and fleshy (compared to needle-like) texture of the leaves may be more efficient in capturing dust. Due to the scale-like leaf structure that covers more area, T. plicata may have the highest photosynthesis productivity. Yet, the characteristics of its leaf may make it harder for the dust to be washed away, resulting in a reduction in photosynthesis. Among the other needle-like conifers, T. chinensis will be least impacted by the dust retained due to its smooth and plump leaf structure, and less fuzzy hair on the surface, allowing the dust to be washed away easier.

METHODOLOGY

The controlled variables were the date and time the samples were collected, the collection site, the approximate size of the trees and the samples collected, the observable health condition of the trees, the human input (i.e., I collected all the samples), and the measuring apparatus. The independent variable in this project was the tree species, of which there were six. The dependent variables were the mass of the dust retained from the samples, the samples' dry mass, and the observed microscopic traits of the dust condition on leaf samples.

The experiments were triplicated. The respective day 0 for each trial was January 1st, January 10th, and February 4th, 2021. The processed data for graphing was derived from the averages of all trials and samples for each period for each species.

Sample Collection

The leaves were collected right after the rain (day 0) and every three days (days 3, 6, and 9) after, at Langara Golf Course, Vancouver, BC. Three plants were randomly selected for each tree species as sample trees for the whole experiment. According to the difference in leaf size, I picked five to eight clusters of needles using gardening scissors. I performed uniform sampling from four directions of the canopy and took the samples from the same height (around 170-180 cm) (Wang et al., 2011). I made sure to avoid shaking the trees during the collection process to prevent

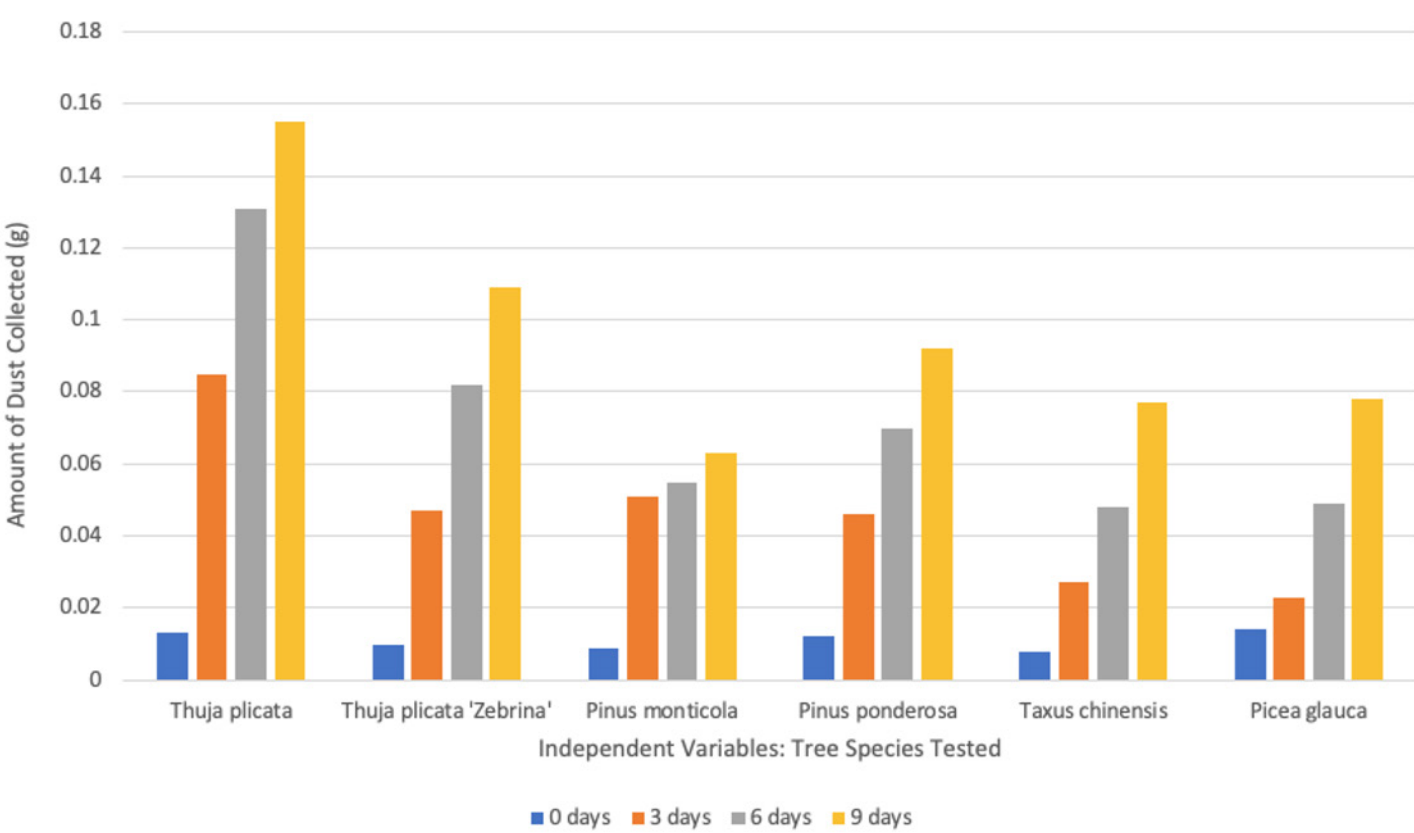

Figure 1: Average Amount of Dust Collected (g) vs. Six Types of Controlled Conifer Trees. Note. The average total mass of dust each species collected in intervals of three days.

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dust from falling off the leaves. The collected samples were carefully stored in separate reusable zipping plastic bags. The collection site is open to the public and no significant harms were imposed on the trees.

Dust Retention Capacity

On each sample collection day, I weighed 25 g of the sample by cutting off the excessive branch. The sample branches were thoroughly washed with the ultrasonic washer for 3 min with 300 g of distilled water. Using the funnel and a double-layered paper filter, I filtered the turbid liquid twice. I then oven-dried all the paper filters at 60 °C for 30 min. Controlling for the mass of an unused filter, I weighed and recorded the mass of each used filter.

Photosynthesis Productivity

On each sample collection day, I performed the same ultrasonic washing process described above to one branch per sample. I then air-dried the excessive water from the clean samples and recorded the mass. I oven-dried the samples at 60 °C for 1 h, then recorded the mass again.

Microscopic Observation

I observed samples from different dates under a dissection microscope at 2x and 4x magnifications. I observed both rinsed and non-rinsed samples. I recorded the observations for the qualitative data. The x-axis in Figure 1 (Pg. 3) shows the six conifer species for each collection day, and the y-axis represents the mass of the dust accumulated. Looking at the total dust accumulation over a nine-day period, T. plicata, the species with the highest result (0.14 g), collected 40 % more dust than the second highest species, T. plicata 'Zebrina', its variegated species. Following them are P. ponderosa (0.08 g), T. chinesis (0.07 g), P. glauca (0.065 g), and P. monticola (0.05 g). Although, P. monticola shows the second highest total after three days, its retaining speed decreases to 0.0025 g every three days, compared to P. ponderosa which maintains a steady accumulation of 0.03 g every three days.

The x-axis in Figure 2 lists the six conifer species, and the y-axis represents the percentage of the dry mass in relation to the washed sample over the nine-day period. T. plicata shows the highest dry mass decrease of 35 %, which is 10 % higher than the species with the lowest reduction, P. ponderosa. After three days, T. plicata's dry mass was reduced by 5 %, by 15 % at day 6, and 15 % at day 9. P. ponderosa's mass was reduced by 5% at day 3, 2 % at day 6, and 3 % at day 9. For the other four species, in order of increasing cumulative reduction are P. glauca (15 %), T. plicata 'Zebrina' (16 %), P. monticola (20 %), and T. chinesis (27 %).

DISCUSSION

Dust Retention Capacity

I found that T. plicata retained the most dust, followed by its variegated Zebrina species, as predicted in my hypothesis. It may be due to the scale-like layers as mentioned in the introduction; it provides additional folds to create a rough surface for the dust to remain. Another key result is that the increasing differences in

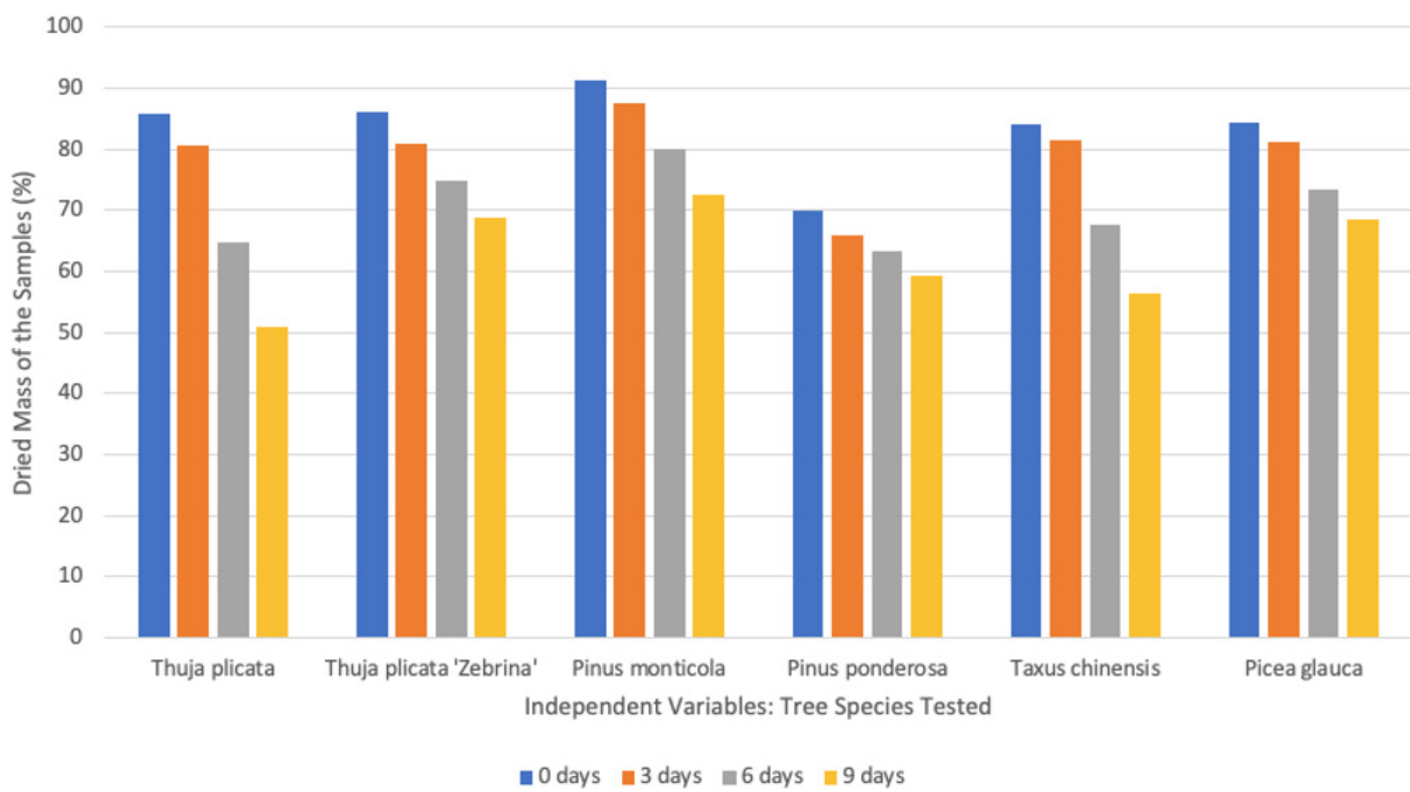

Figure 2: Dried Mass of the Samples (%) vs. Six Types of Controlled Conifer Trees
Note. The dry mass as a percentage of the mass of the washed samples for each species in intervals of three days.

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dust retention gradually get smaller, as the overlaying dust slowly reaches the maximum capacity that the leaf can hold. This is because the dust will be easily blown off by wind when it is in contact with the dry dust particles below instead of the waxy and sticky leaf surface, after a period of retention.

Photosynthesis Productivity

The data were indirectly measured with the dry mass of the samples as an effective method for projecting a trend of photosynthesis performance (Trimble, 2019). The general pattern in the is that the dry mass, representing the photosynthesis product, slowly decreased over time according to Figure 2. As predicted, T. plicata

Figure 3: P. glauca Under a Dissection Microscope (4x mag.) Note. The surface of needle-like leaves has little white, dotted bumps and the texture is fuzzy and frosted. There are short spikes with a waxy liquid in the creases that collect rounder particles.

Figure 4: P. monticola Under a Dissection Microscope (2x mag.) Note. Similar to the needle-like species, the only unique note about western white pine is the endpoint of its clustered needles. Unlike the single needle structure, its multiple needles join at one point of the branch, creating tighter spacing.

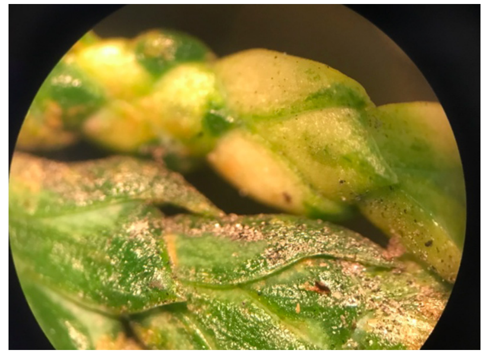

Figure 5: T. plicata Under a Dissection Microscope (4x mag.) Note. The waxy surface of the scales retains dust particles in clusters. The upward openings of the creases between scales also hold a great amount of dust particles. T. plicata 'Zebrina' shows similar traits to the non-Zebrina species.

Figure 6: P. ponderosa Under a Dissection Microscope (2x mag.) Note. The ponderosa pine has a fuzzier surface than white spruce. It has smaller white bumps and serrated edges.

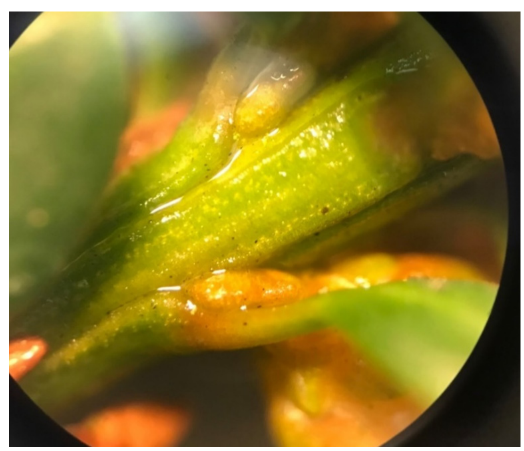

Figure 7: T. chinensis Under a Dissection Microscope (4x mag.) Note. Having the smoothest surface, Chinese yew has the least visible dust particles. However, under closer observation, tiny dust particles are spotted. The branch of Chinese yew has many joints for the leaves, adding more creases for dust to be trapped, compared to other plants.

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shows the most decrease in photosynthesis productivity due to the dust trapping structure of its scale-like leaves. P. ponderosa shows the least decrease which may be due to its better retention ability or its low retention capacity.

Microscopic Observations

Haze-causing dust particles, which can cause serious health issues and have become increasingly problematic, are hardly spotted by the naked eye. As such, the microscopic observation was meant to explore the characteristics of the leaf surface in detail and how they might affect the retention of the dust particles. The general patterns I found are that dust tends to stay on plants in clusters and in the folds or creases of the leaf. Even after a gentle rinse, representing the precipitation, many dust particles remained on the surface.

P. glauca has an overall larger space between needles, being a disadvantage. An advantage of this species is the sticky and waxy liquid it secretes, as this is a good binding substance for rounder dust particles that are harder to adhere to the surface. Its small white dots on the needles provide uneven and fuzzy texture for collecting smaller fuzz. P. monticola has a smooth needle surface without bumps like P. ponderosa. This largely decreases its ability to retain dust compared to other species, yet the connecting point between the branch and the needles creates tight and deep spaces for dust and even larger particles to be trapped. This could also be a disadvantage for the trapped dust to be washed away by drizzle. T. plicata and its Zebrina species have the most complex needle structure. Their uneven and waxy flat surfaces may benefit the ability to collect large clusters of dust, which can be more efficiently washed away by rain. Creases between scales in T. plicata are also great for capturing dust from sideway angles. P. ponderosa has the fuzziest needle texture out of all six species. With white dots covering the whole surface, it is great for collecting lighter and smaller fuzz particles. With a relative amount of fuzz collected, it forms a fuzzy net-like structure to capture heavier and rounder dust particles. Due to its smooth non-waxy surface, T. chinesis does not retain much visible dust.

Sources of Error

There are a few potential sources of error to note for this project. First, human error may have occurred and resulted in minor deviations in the data. However, this is acceptable because the human input was from one individual (myself), thus consistency could be ensured to some extent throughout the project. Another influential factor is the number of samples collected in the experiment. With limited time and resources, I tried to maximize the number of samples collected and trials performed. If I could have included more samples, the data would likely have been more accurate. Though factors like wind and temperature could not be controlled in the natural setting, they were consistent for all species on each collection date. If possible, I would like to collect samples through a wider range of natural settings which can then help me to derive a standard for the calculations of different tree species such that the experiment can be replicated under different conditions.

Future Work

In the past, urban green space planning often emphasized aesthetics and the purpose of providing people with visual enjoyment. With the frequent emergence of urban environmental problems, the planning of urban green space now focuses on their functionality more than their aesthetics. The provincial and municipal governments provide funding for the construction of urban green space every year mainly because of their diverse ecosystem services (Parks Canada, 2021). The present project mainly investigates the impact of dust retention on photosynthesis productivity and sorting individual characteristics that affect the performance of dust retention to make a preliminary analysis of these West Coast native conifer tree species. The ecosystem services of urban green space also include important features like noise reduction and carbon sequestration which tackle other challenges in urban environments. With so many variables, it is far from sufficient to consider only dust retention. A large number of experimental studies and conclusions are needed to comprehensively consider all factors to compare the optimal design plan for urban green space.

CONCLUSIONS

In conclusion, my hypotheses were supported by my experiment showing that T. plicata, while having the highest result in dust retention, also has the most negatively impacted photosynthesis rate over time. With only two major factors tested, my experiment cannot provide a full analysis of which trees should be planted in the city. However, this is still a needed first step to finding the most nature adaptive ways in addressing urban pollution.

Though the goal of the project is not to eliminate dust in urban area, the result shows that urban green space can act as a 'dust net' to minimize the drift of dust in the atmosphere, specifically around the respiratory area. The project provides reason for planting vegetation along busy roads or around residential and public infrastructures to improve respiratory health and bring various benefits. It is a small, yet meaningful, first step for building a city that balances both aesthetics and ecosystem. It is important to take what nature has given us, use it, and protect it well.

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Hi everyone! I am Herong Zhang from Sir Winston Churchill Secondary, Vancouver, BC. I live in a beautiful city that is constantly under poor air quality due to urbanization, industrial pollution, and wildfires. I found a lack of research specifically targeting the dust retention ability of native west coast tree species. Moreover, most of the studies conducted on dust retention neglect the importance of the tree species' health and its performance in photosynthesis. I decided to approach the idea of investigating six common conifer species by focusing on the negative impact of dust on photosynthesis productivity and the micro-morphology of the individual species' leaf surface. I hope the project can inspire more people and contribute to combating environmental challenges with urban pollution.

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