

## Effects of Particle Matters on Plant: A Review

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**Abstract:** The particle matter, particularly the suspended particle matter (PM  $\leq$  2.5) in the air is not only a risk factor for human health, but also affects the survival and physiological features of plants. Plants show advantages in the adsorption of particle matter, while the factors, such as the leaf shape, leaf distribution density and leaf surface microstructure, such as grooves, folds, stomata, flocculent projections, micro-roughness, long fuzz, short pubescence, wax and secretory products, appeared to play an important role determining their absorption capacity. In this paper, the research progress on the capture or adsorption of atmospheric particles was summarized, and the forest vegetation and woody plants were discussed. In addition, special attentions were paid to the effect of haze-fog weather on greenhouse plant, the different responses of plant leaves to dust particles and suspended particles, as well as the effect of suspended particles on morphological change of plants. In the future, research should focus on the mechanism of the influence of particulate matter on plants. More advanced effective and convenient research methods like spectral detection method also need to be developed. This paper may provide reference for future studies on plants' response to haze and particle matter.

**Keywords:** Particle matters; haze; air pollution; PM2.5; leaves; stomata

### 1 Introduction

Haze has been one of the most complicated environmental problems, which caused by air pollution. Inhalable particle matter (PM) in the air is considered to be one of the main components of haze, and an important factor that contributes to air pollution [1]. PM is usually divided into four categories according to the aerodynamic diameter (Dp) of pollutants, which includes total suspended particles (TSP, Dp  $\leq$  100  $\mu$ m), coarse particles (PM2.5-PM10, Dp = 2.5-10  $\mu$ m), fine particles (PM2.5, Dp  $\leq$  2.5  $\mu$ m) and ultrafine particles (UFP, Dp  $\leq$  0.1  $\mu$ m) [2,3]. The visual disturbance caused by aerosols (AOD) such as dust, sulfates, nitrates, metals, and organic hydrocarbons in the atmosphere is a generally considered as the cause of haze [4]. The concentrations of particle matters on haze periods are more than those during clear days. Health studies have shown a significant association between exposure to particle pollution and health risks [5].

Green plants play an irreplaceable role in improving urban air quality and protecting human health [6]. However, the efficiency of capture and clear PMs and their tolerance to particle matter is differed among various plant species. For example, *Agave sisalana* has a strong resistance to haze in northern China in winter [7]. Vegetation in urban areas is conducive to the removal of harmful particle matters from the atmosphere [8,9]. Evergreen conifers are often not suited for roadside in urban areas because they are in general less tolerant of high traffic-related pollution, although they can clear particle matters in the air efficiently [10].

In China, the air quality classification is shown in Tab. 1 [11]. The current air pollution can be determined based on the 24-hour average PM2.5 concentration. Air Quality Index Level (AQL) is based on the Air Quality Index (AQI). For example, in China, if the concentration of PM2.5 is 80  $\mu$ g/m<sup>3</sup>, it

means that the air is favorable, the level of air quality index is the second-class, and the color of the air quality pollution level is indicated by yellow. The standard of air quality classification in China and United States showed remarkable differences. In the United States, the most polluted city has a concentration of PM<sub>2.5</sub> above 35  $\mu\text{g}/\text{m}^3$ , which was considered to be harmful to human health. While the concentration of PM<sub>2.5</sub> up to 75  $\mu\text{g}/\text{m}^3$  indicated a clear environment in China.

**Table 1:** The air quality classification in China

IAQI	Average PM <sub>2.5</sub> in 24h ( $\mu\text{g}/\text{m}^3$ )	AQI	AQL	Category	Color
0	0	0	0	0	0
50	35	0 ~ 50	First-class	excellent	green
100	75	51 ~ 100	Second-class	favorable	yellow
150	115	101 ~ 150	Third-class	'light' pollution	orange
200	150	151 ~ 200	Forth-class	'moderate' pollution	red
300	250	201 ~ 300	Fifth-class	'heavy' pollution	purple
400	350	> 300	Six-class	'ultra-serious' pollution	maroon
500	500	×	×	×	×

When deposited to PM<sub>2.5</sub>, the particle matters may block stomata on the leave of plants and affect their physiological activities. Since the 1930s, extensive studies have been carried out worldwide to explore PM adsorption and deposition on plants. the results showed air pollution may affect PM deposition factors, the leaf adsorption or deposition characteristics on plants. Many researchers have studied leaves deposited PM of urban greening plants for over 50 years. The large amounts of data were analyzed using a meta-analysis method [12]. The PM deposition by vegetation and the main factors affecting PM characteristics vary across different scales, and the variations were caused by different vegetation macrostructure, environmental variables and PM source characteristics. The common method is filtering membrane weighing, but it is a invasive and complicated method. The influence of particle dust on crop reflectance spectrum was studied by Wang using spectrum technology which is a kind of non-invasive testing technique. The primary research indicated that foliar dust may influence the reflectance spectrum [13]. The surface of plant leaves microstructure, particles size, particle distribution and etc. were observed mostly by means of scanning electron microscopy (SEM) [14]. Atomic force microscopy (AFM), confocal laser scanning microscopy (CLSM), gas chromatograph and image analysis method such as image J were also used to analyze the microstructure of leaves and the PM leaves adsorbed [15-18].

## 2 The Impacts of Haze on Plants

Studies have shown that when the AOD (aerosols) increased from 0.05 to 0.5, the scattering of blue light will increase 83%, which may inhibit the photosynthesis of plants. However, if AOD continues to increase, the scattering of green light will increase accordingly. When the atmospheric aerosol concentration reaches a certain level, the effect of the reduction of direct radiation on photosynthesis cannot be compensated by the increase of scattered radiation, and the increase of AOD will be very harmful when the photosynthetic rate decreases. So most of the time, the AOD is harmful [19]. When haze occurs, it will increase the proportion of blue light and green light. Due to the fact that green light is an inefficient light for photosynthesis, which will weaken the photosynthesis of crops and inhibit their growth.

Most of the studies indicated that haze had led to decreased crop production, reduced the quality of agricultural products, environment of agricultural production pollution, and circulation of agricultural products hindering [20-22], among which particle matter is the "culprit", especially PM<sub>2.5</sub>. Different

plants showed different responses to PM<sub>2.5</sub>, which deserved further investigation.

Particle matters among haze will affect the physiology and morphology of plants, including increased cell alkalinity, photosynthetic inhibition, leaf senescence, stomatal damage, and decreased growth and productivity [21,23]. Chameides used the CERES crop model to estimate the relationship between crop yields and the severity of regional haze in China in 1999 and the result showed that parts of China were depressing optimal yields of at least 5-30% of the crops because of haze. If the Chinese government could control the haze pollution effectively, there will be a significant increase in the production of crops, so that the pressure of growing food demand in China will be greatly relieved in the coming decades [24].

In addition, the haze will decrease the rate of photosynthesis by affect the the photosynthetic characteristics of plants. Some plant leaves' net photosynthetic rate, transpiration rate, and stomatal conductance were correlated negatively with PM<sub>2.5</sub> concentration. For example, the content of chlorophyll and the chlorophyll fluorescence parameters (Fv/Fm, Fv/Fo, PS II, qP) in leaves at four experimental sites decreased with the aggravation of pollution, whereas the cell membrane leakage rate and qN increased [25].

The particle matters deposited on leaves may block stomata, and directly affect photosynthetically active radiation (PAR). Thus, photosynthesis and respiration will be affected, as well as physiological processes. The particle matters also function as a carrier for other pollutants, such as sulfates, nitrates, metals, and organic hydrocarbons, which could penetrate deeper into plant tissues. The results showed that foliage accumulated an increasing quantity of particle matters in successive months, but the accumulated amount differed considerably between sites and plant species [26]. However, dynamics deposition, wash-off, and re-suspension cannot be ignored [27,28].

The harm of haze on greenhouse plants has been reported extensively. In haze weather, suspended particle matters increase in the air, and the extinction of particles leads to an insufficient in solar radiation, light intensity and light time. As a consequence of decreases in received energy, the rate of photosynthesis and the output of greenhouse plants also declined. Take strawberries for an example, the haze will not only affect the yield of strawberries, but also the taste. Xi Jinlin investigated the impact of haze on strawberry production in 30 strawberry production bases in Beijing. Their studies found that with the increase IAQI, the photosynthetic active radiation, and the photosynthetic rate decreased obviously, with significantly ( $P < 0.01$ ) negative correlation. They also found that haze can reduce strawberry production about 4500 ~ 15000 kg/hm<sup>2</sup> range. Haze weather can lead to an increased incidence of disease, while the impact of pest incidence is not obvious [29].

Moreover, haze also decreases the accumulation of sugar, protein, and other nutrients in plants, which will decrease the taste and seriously affect the appearance and commodity properties of agricultural products. For example, in haze weather, the upper leaves of eggplant, the edges of cucumber, tomato, and other vegetables turn yellow, which indicating the impaired function of leaves. Tomatoes are hard to stain and cucumbers slow to swell [30].

If the concentration of particle matter in haze exceeds the tolerance point of plants, it will harm the growth and survival of plants. Continuously exposure to suspended dust particles with larger size will directly cause the formation of leaf dust, which obstructing the respiration of plants. Haze causes low temperatures and high humidity on the ground, which is also a primary cause of various diseases and insect pests such as downy mildew, late blight, and grey mold, etc., leading to crop production, and quality decline [31].

Last but not the least, when haze weather occurs, a large number of artificial source aerosols, such as heavy metals, organic pollutants, etc. are floating in the air. The poisonous and harmful substances will slowly penetrate into the soil through atmospheric precipitation over time, especially along with the rain and snow. If plants absorb harmful substances back into the body, they can be very harmful to humans to eat, and also the soil-crop-consumer ecosystem will be damaged.

Not only for plants, the haze will also affect the survival, growth, and development of insects. Tan

studied rearing *Bicyclus anynana* butterflies in two smoke environments. And the results indicated that there was no smoke particle in larvae trachea but presenting in the trichomes covering the spiracles. These unique structures may function as barriers to effectively inhibit particle matter entering the larval body [12].

### 3 Factors of Capturing and Absorbing PM

To reduce the particle matters concentration in air, plants could be used as particle matters biological filters, which accumulating PM on their leaves. However, the capture and clean ability vary with plant species, season, and region, etc. In the case that a height dependent correction in the roughness sub-layer was taken into account, the PM<sub>2.5</sub> sulfate deposited faster. The high deposition velocities observed in the day were associated with larger friction velocities and unstable conditions in the daytime. Moreover, the model of the depositional theory was modified by Matsuda K. and applied to the Japanese deciduous forest [32].

The shrubs and broadleaf trees types possessed the most effective ability to capture and accumulate PM<sub>2.5</sub> from the air during spring and summer. Overall, when there are no leaves in autumn and winter, the conifer and mixed tree types play the most important role in removing the dust [32,33]. The needle-like made conifers more efficient with PM<sub>2.5</sub> accumulation and post-rainfall recapture than broad-leaved species [34]. So, it was a good biological filter compared to broad-leaved species. Many types of research have shown that trees could improve air quality by retarding and absorbing particles. Other studies showed similar results [35-37].

The foliage of arbors, shrubs and herbs, garden plants [38], branches, trunks, barks [39] and certain organs of plants exhibited outstanding ability to capture and accumulate particle matters in the air [15]. Studies showed that plants will develop certain features like increased plant height, largest total surface area and whorled leaf arrangements to enhance PM accumulation. These studies are based on the comparison of leaf shape (linear, lanceolate, obovate, palmate, needle-like, tip-like, broad-leaved or elliptic) and leaf arrangement (opposite, alternate or whorled). As a result, the ability of the plants to capture and accumulate PM differs significantly among foliage with different morphological features [40-45]. But Daresta had different results: the arrangement of leaves had no effect on particle matters adsorption, perhaps because other characteristics of leaves had more significant effects than the leaves arrangement [46]. What's more, the PM<sub>2.5</sub> adsorption amount of some landscape plants unit leaf area and the pollution degree are positively correlated [47].

### 4 Mechanisms and Background Techniques

Different techniques has been used to study the mechanisms of PM capturing and filtering behavior of different types of plants [48,49].

Pine seedlings were sprayed with dry  $(\text{NH}_4)_2\text{SO}_4$  aerosol particles or 50 mM solutions of different salts. The results showed that there was a correlation between wax degradation and particle matters on the surface, and the AOD deposition 'degrades' waxes potentially and decreases pine tree drought tolerance. Also, one of the causes of wax weathering was the increasing thickness of wax tubes [50]. Generally, increased wax degradation was caused by plant age and with the amount of air pollution [51]. Juergen Burkhardt used an aerosol sprayer and wind tunnel to simulate a particular matter environment. And he came to a similar conclusion that air pollution strongly accelerates aging and degradation process. The thickening of wax tubes, formation of plate-like structures, and loss of wax plugs was also caused by air pollution such as haze [52].

These techniques mentioned above, however, may lead to problems in measuring foliar fertilization, as well as wax degradation and chelates [53]. In general, foliar fertilization is usually used to provide micronutrients, nitrogen, phosphorus, and salt for fast improvement of nutrient deficiencies.

Other factors, such as attaching to the surface of plant leaves or gravity may also affect the atmospheric particles form foliar dust. Foliar dust decreases spectral reflectance of plant, affecting plant growth, leaf morphology and photosynthetic efficiency. In a review, the effect of foliar dust on plant leaf reflectance

spectra is believed to be a complex and relatively new field, and that more systematic research is needed to clarify such effect so as to further improve the management and ecological functions of forests [13,54]. The primary research indicated that foliar dust really influenced the reflectance spectrum and nitrogen prediction especially in the complex field conditions [13,55]. Xiao also used the spectrum technology (ASD field spectrometer) to study the reflectivity of vegetation leaves before and after simulating rainfall. But he found a different conclusion which was that the dust couldn't cause the leaves spectrum red edge to move [56]. Sun studied the influence of dust on the spectral characteristics, the inversion of moisture content and pigment concentration of urban plants (camellia, yellow poplar of Phnom Penh, Photinia Redleaf and French Holly), indicating that to some extent, the influence of dust on the reflection spectrum of plants is not a gradual process, but an accumulation before the spectral changed [57].

The ability of plants to capture and adsorb particle matters is related to factors, including the microstructure of leaves surface, the vegetation factors, and wind, temperature and pollution [58]. So, it is important to quantify the amount of particle matters that deposit and accumulate on different plant species [59]. Several studies quantified PM interactions with leaf surface and measured PM fluxes deposited by trees in urban or periurban areas quantitatively [60-62]. Perini's study demonstrated that the season and age of leaves do not influence the amount of particles deposited [54]. In addition, in Liang's study, there was no significant correlation between PM<sub>2.5</sub> deposition and stomatal density and leaf hair branches with leaves which was still unknown if it was related to the simulated gas chamber [63].

Jin developed the attenuation coefficient of PM<sub>2.5</sub> to quantify the decrease of PM<sub>2.5</sub> reduction rate. The mixed-effects model and regression analysis indicated that it was best for tree-planting with the range of canopy density (CD) being 50%-60% and the leaf area index (LAI) being 1.5-2.0 [64].

For further study, in Shao's paper, some common garden plants in Hangzhou, China, were selected as the study objects to observe the microscopic morphological features of the leaf surface using confocal laser scanning microscopy (CLSM). The results revealed that leaves are able to deposit and accumulate particle matters via the synergy of multiple microstructures on the leaf surface, such as grooves, folds, stomata, flocculus projections, micro-roughness, long fuzz, short pubescence, wax and secretory products [15]. The soil elements were measured via inductively coupled plasma optical emission spectrometry (ICP-OES) to locate the possible particle sources [14]. The combination of ICP-OES and CLSM was used to show that retained particles are primarily composed of C, O, Si, Al, Ca, K, Mg, Nb, Fe, Na, and Ti, which were originated from soil dust [14].

Atomic force microscopy (AFM) was used to determine several parameters like the arithmetical mean deviation of the profile, the ten-point height of irregularities, and peak-to-valley value. Then the surface roughness and other microscopic characteristics of leaves could be characterized. And the resuspended matter method was applied to evaluate the adsorptive capacity of the leaf surface [16].

Metadata, derived from the National Aeronautics and Space Administration (NASA) and Socioeconomic Data and Applications Center (SEDAC) demonstrated negative correlation between the production of three grain crops (wheat, rice, and corn) and PM<sub>2.5</sub>. And the results indicated that if the haze pollution could be controlled effectively, there would be a significant increase in the production of grain crops [17].

PM detection equipment and the gas chromatography method were also used to prove that bamboo forests are able to capture and accumulate PM<sub>2.5</sub>. By monitoring the changes of PM<sub>2.5</sub>, PAHs, and VOCs in atmosphere [17,18], Perini found the influence of non-target variables for the first time. Also, he found a negative impact of the synthetic leaf on PM capture. However, there are many inconsistent conclusions: Palmate leaves showed a greater capacity to capture and accumulate particle matters probably due to their larger edge effect. Palmate leaves were mostly "tip-like" leaves, with more turbulent boundary layer and complex leaf shape, so the edge effect was obvious, which was more conducive to the capture and adsorption of particle matters. leaves with waxy substance or rough surfaces had high PM level compared to leaves with a smooth surface [54]. It is worth noting that, referring to Sæbø's and Liu's findings, the epicuticular wax played a negative impact on capturing PM [65,66]. Anyway, the results

may contribute to urban greening by optimizing living walls [54,67]. Fernández Espinosa showed that leaf roughness was not a main factor when choosing a biomonitor species of airborne particles. He analyzed the relationship between PM10 and the trace elements in the leaves of oleander and lantana. Then he pointed out that the content of heavy metals (Cu and Fe) in oleander leaves was significantly positively correlated with the content of PM10 ( $p < 0.05$ ). Oleander was a more useful biomonitor species of Cu and Fe in the air than lantana [10].

The above methods, combined with related theories of botany, may help to the study on the mechanism of leaf adsorption of particle matters. Our team explored the impact of haze on greenhouse crops using spectrum technology and microscopic observation. Also, we made a device to simulate the occurrence of particle matter manually, which can control the concentration of particle matter, and the shed where the plants are located can be used as a greenhouse. The research results will be published in subsequent academic papers.

As mentioned in the previous content, SEM and image analysis methods were used to observe and analyze the surface of plant leaves microstructure, particle size, and particle distribution. The ability of plant leaves to capture and accumulate particle matters from the air is mainly affected by the microstructure of the leaf surface, the secretory products, the shapes, leaf arrangement, the distance from the ground and the environmental pollution [40]. Leaves microstructure characteristics, such as grooves, folds, stomata, flocculus projections, micro-roughness, long fuzz, short pubescence, wax and secretory products, were the main factors. Leonard found that the roughness differs between the adaxial and abaxial surfaces of the same plant leaves, and the microstructures and abilities are also different [15]. For example, Leaves with distinctive grooves, such as stripe, net, corrugated, nodular, or verruca, had the advantage of capturing particle matters and making PM2.5 deposit [63]. *A. sibirica* had grooves around the protrusion to capture more PM2.5 than *P. propinqua* which lacked these grooves. Pointy protrusions were more efficient than flattened at retaining PM2.5 [68].

Zhang found that the number of stomata was one of the main factors for coniferous trees to capture particle matters, which was different from Chen. Also, the properties of the cuticle in different seasons will affect the ability to capture particle matters in some plants [16]. Leonard found lanceolate leaves possess higher PM tolerance compared to needle-like or linear leaves due to the epicuticular wax and leaf hairs [15]. Moreover, the PM deposition level does not depend on the content of wax but on the structure and composition of the wax according to Dzierzanowski K [36]. From a bionic point of view, leaf hairs may help leaves attract charged particles and some metal species by creating surface polarity. Therefore, when the leaves were moving, the leaf hairs made it difficult for particle matters to fall off the leaves [69,70].

Besides, adsorption, leaf surface microstructure, such as rooves, folds, stomata, flocculent projections, micro-roughness, long fuzz, short pubescence, wax and secretory products, appear to play a key role in regulating morphological parameters, such as shape, and size of leaves, contact angle (wettability), leaf order, leaf inclination angle, and canopy shape [53].

Through comparative analysis, it is concluded that the micro-morphological structure with the adsorption of atmospheric particles capacity from high to low is the waxy structure > fluff > groove > protruding strip. It is worth mentioning, the denser these micro-morphological structures are, and the greater the difference in-depth, the more favorable they are for the adsorption of atmospheric particles [71].

In general, different plants have leaves with different morphological characteristics. So, the ability of the leaves to capture and accumulate particle matters differs significantly among plants. And this varies greatly from tree to tree and plant species [72]. Moreover, rougher leaf surfaces, larger differences in the depths of creases, densely ridged grooves, lower stomatal densities, and more waxes are more conducive for the capture and adsorption of particle matters [73-76]. In contrast, the leaf surface is smooth, without obvious fluctuation, and there are wide gullies, well-arranged pores, and shallow and sparse grooves, which has relatively weak particle retention and absorption abilities [40]. That is to say, tree species for urban greening should be selected with this characteristic in the plant leaves, including densely ridged grooves, waxy mucus and long villi flocculent protrusions. Leonard quantified particle matters loads in 16

species along Sydney roadsides. Then he found that tree species with leaf hairs accumulated significantly more matters, besides, metals associated with vehicle use including copper, chromium and manganese in collected matters [77].

### 5 Measures to Deal with Haze for Greenhouse

Haze days can also affect the plants in the greenhouse, so measures are needed to reduce the harm when necessary.

In the first place, it is necessary to develop and promote LED lighting systems for the greenhouse. Certain lighting can meet the needs of plant to grow during haze days [78].

Secondly, when the haze day comes, it will cause the light to weaken and the temperature to drop. At this time, we should take measures to increase the temperature in the greenhouse and reduce the work of irrigation and pruning. If irrigation is really needed, we should also adopt drip irrigation. After several haze days, if the weather turns sunny, we should pay attention to not irrigate and fertilize suddenly. We can spray some plant growth regulators to enhance the stress resistance of plants [79].

Lastly, People found that the fine and ultrafine particle matters couldn't be washed away from some kinds of leaves by rain. And most of the particle matters which were removed by rain were large [80,81]. So, if the leaves are dusty, we can wash them manually to remove the large matters accumulated on leaves.

### 6 Discussion and Suggestion

To sum up, the haze, especially particle matters, has different effects on plants. On the other hand, plants have developed different resistance mechanisms to alleviate potential damage caused by exposure to PM. However, quantitative research in this filed is still lacking. The potential reason include the occurrence time of natural haze and dust weather is not fixed, the test variables are difficult to control, the test period is long and unstable, and the repeatability rate of the test is low [82].

Without solving the problem of artificial simulation of haze environment in the laboratory, many types of researches cannot be carried out. Therefore, in addition to natural haze weather, environmental simulation of particle matter is very important. In Hwang's study, the soot particles were generated from the diffusion flame burner using acetylene as the fuel [34]. And the removal of submicron ( $< 1 \mu\text{m}$ ) and ultrafine ( $< 0.1 \mu\text{m}$ ) soot particles by five kinds of tree leaves were quantitatively compared in terms of deposition velocity through TEM image.

Also, previous studies always focused on forests, green belts, field crops and so on. For plants in a greenhouse, the occurrence of haze also affects their growth, but there isn't so much research about the relationship between greenhouse plants and haze. In the research on the harm of haze to greenhouse plants, the methods are relatively simple and backward, and most of the existing researches is qualitative analysis. In the future, reasonable artificial simulation of haze environment in the laboratory should be used to study the impact of haze on greenhouse plants. Quantitative and qualitative methods, combined with spectral technology and micro-analysis technology and so on, also need to be used to research air purification and cultivation.

There is one more thing to remind: The particle matters in the air are mainly composed of sulfates, nitrates, sodium chloride, metals, organic hydrocarbons ammonia, dust, and water. The PM<sub>2.5</sub> ionic components were the main  $\text{SO}_4^{2-}$ ,  $\text{Na}^+$ ,  $\text{NO}_3^-$  and  $\text{NH}_4^+$ . In different pollution areas, PM<sub>2.5</sub> pollution was due to certain source pollution at different pollution levels. The composition of PM varies by region, season, cause of formation, etc. [83]. Therefore, in future studies, all the researches involved in particle matters should be indicated to facilitate reference and comparison by scholars.

Studies on the effects of haze on plants are inseparable from the analysis of plant microstructure. Particle matter is adsorbed to the leaf surface by the plant, and then enters the interior of the leaf. The particle matter perhaps in the vicinity of the structure of grooves, folds, fuzz, wax, etc., or block the stomata. Thus, the particle matter will make a negative role in respiration and photosynthesis and weaken the quality of the plant. If the concentration of particle matter is too large, it will cause plant poisoning,

wilting and even death. It is important to note: Plants may have developed adaptations to particle matters input or deposition in the process of evolution. So, there are still many more questions that deserve further study. In the future, research work should focus on the analysis of the mechanism of the influence of particulate matter on plants. The plant physiology, poisoning principles and principles of light environment should also be studied.

## 7 Conclusion

The effect of particle matters on plant leaf is complex. This field needs to be researched systematically. In this paper, the research progress on the capture or adsorption of particle matters was summarized. And the impact of PM on plants was also introduced. Advanced new methods need to be adopted to improve the management of environment and the ecological functions of plants.

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