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Environmental Assessment of Dust-Holding and Oxygen-Producing Productivity of Hawthorns in Kazakhstan

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Abstract: The research aimed to study the oxygen production and the dynamics of the leaf blade dust-collecting ability of hawthorns growing in contrasting ecological and climatic areas. Hawthorns in urban green spaces are a fairly common tree species and play an important hygienic role in purifying the atmospheric air from dust and harmful impurities and have sufficient oxygen productivity. Hawthorn trunks ensure 70% of all oxygen productivity and gas absorption. Meteorological conditions of the ecological regions under study have a huge impact on the amount of dust adsorbed on the tree surface. The dust-holding capacity of hawthorns, which, according to research, have rough lamina, increases towards the end of the growing season. The maximum dust deposition is observed in July, with the least amount of precipitation. Hawthorns that grow along highways experience the greatest environmental pressure. The difference is on average 1.8-1.9 times in comparison with the reference area. The maximum dust accumulation was found within the near-highway plantations characterized by an average density and vertical structure, as well as ventilation capacity. Two regions selected for research represent the technogenic environment of a large city. Therefore, to improve the quality of life and contribute to the improvement of the environmental situation, it is necessary to plant sustainable trees and shrubs within the city boundaries, which serve as a protective barrier to the deteriorating environmental situation.

Keywords: Hawthorn, Fruits, Lamina, Environmental Stability, Dust-Holding Capacity

Introduction

The air basin state is the most important indicator of the environmental situation. Polluted atmospheric air in the modern world has become a serious environmental factor in the life of plants. Woody plants and brushwood have the unique property of being the only natural element of the urbanized environment serving as an effective means of environmental protection for cities, preserving and improving their quality. Being green filters, they purify the atmosphere from dust, gases, and harmful toxic substances of transport and industry and reduce city noise and bacterial air pollution.

Unlike the root-regulated nutrient absorption from the soil by plants, they are unable or very limitedly able to regulate harmful substance absorption by assimilation organs from the air. As a result, harmful gases and dust accumulate in leaf cells and on their surface. This has a positive aspect (the role of plants in atmospheric air purification). On the other hand, harmful compounds cause serious disturbances in the life processes of plants, affecting their stability in the technogenic urban environment.

The urgent issues of urban pollution and selecting sustainable woody plants and brushwood species for landscaping were studied.

The research aimed to study the oxygen production and the dynamics of the leaf blade dust-collecting ability of hawthorns growing in contrasting ecological and climatic areas.

Materials and Methods

Research Objects

The objects of the research are four hawthorn species (*Crataegus* L.) of different geographic origins, most often found in the plantings of the studied ecological and climatic regions: Central Asian species-*C. altaica* Lge., *C. sanguinea* Pall.; Far Eastern species-*C. dahurica* Koehne; North American species-*C. douglasii* Lindl.

The hawthorn (*Crataegus*) genus under study is the largest genus of the apple (*Maloideae* Focke) subfamily, the *Rosaceae* (*Rosaceae* Juss) family. It was described by (Linnaeus, 1753) and is a phylogenetically ancient genus formed in relatively high latitudes of Eurasia under mesophytic climatic conditions. The life span of hawthorns under favorable conditions is 200-300 years (300-400 years) (Solovieva and Kotelova, 1986), in single cases up to 1,000 years (Boboreko, 1974). Since the beginning of the last century, scientists have described more than 1,100 new species and variations of the *Crataegus* L. genus (Nazhand *et al*., 2020), according to other data-1,250 (Boboreko, 1974) and 1,500 species (Tsinovskis, 1971), whereas 1,125 species grow in North America (Tsinovskis, 1971).

Seven wild-growing species grow in Kazakhstan: *C. almaatensis* Pojark., *C. pontica* Koch, *C. turkestanica* Pojark., *C. sanguinea* Pall., *C. altaica* Lge., *C. transkaspica* Pojark., *C. songarica* Koch (Kentbayev and Kentbayeva, 2020). The range of arboretums in Kazakhstan includes up to 50 hawthorn species. Natural hawthorn thickets are also found in the mountains of the Northern Tien Shan (Zailiyskiy, Dzhungarskiy, and Kungey Alatau) among fruit species: *C.almaatensis* Pojark., *C. sanguinea* Pall., *C. turkestanica* Pojark., *C. altaica* Lge, *C. songarica* C. Koch. In the Western Tien Shan mountains, the hawthorn thickets are located on the eastern and western slopes with a steepness of 15-30°, at an altitude of 800 to 1,200 m above sea level on dark gray and mountain forest soils. Pure hawthorn stands (*C. altaica* Lge) grow in the Tyulkubassky and Boraldaisky forestry enterprises with an area of 749 and 745 ha, respectively. *C. turkestanica* Pojark and *C. altaica* Lge predominantly grow in the Brich-Mullinsky forestry enterprise (63.5 ha) and the Chirchinsky forestry enterprise (995.2 ha) (Dong *et al*., 2021).

Hawthorn grew in both the Old and New Worlds, as evidenced by the fossil leaves and fruits of *Crataegus* L. found in various deposits of the earth's crust. According to paleobotanical data, hawthorn was found on Earth even in the Cretaceous period of the Mesozoic era (Taylor *et al*., 2009). Studies of the Upper Cretaceous flora of North Asia and the Gilyak flora of Sakhalin are very interesting, where prints of 101 tree species were found, including *Crataegus* L. In the Tertiary period, imprints of *C. kornerupii* Heer leaves from the flora of the Balatamskaya stratum of Turgay were found. In the Quaternary period, many woody plants and brushwood, including hawthorns, died out due to a sharp change in climate (German *et al*., 2019). In the Sarmatian flora, the leaves of *C. sarmatika* Krysht., *C. praemonogyna* Krysht. and *C. oxyacantnoides* Geep was found among a large number of leaf imprints. It should be noted that the leaf fragment of *C. sarmatika* Krysht. resembles *C. sanguinea* Pall. The Sarmatian flora of Moldova is characterized by thermophilic species; in particular, leaf fragments of *C. oxyacantnoides* Geep were found there (Baranov, 1959). Imprints of *C. praemonogyna* Krysht. and *C. carpamaeotika* Krysht were found in the Miocene flora of southern Ukraine. The Miocene flora of the Western Urals in Bashkiria resembles the Oligocene Kazakh flora and the Ukrainian Miocene flora and the leaves of *C. fominii* Krysht were also found there. According to Shaparenko and Baykovskaya (1956), starting from the Upper Oligocene, *Rosaceae* are found quite often in all Tertiary deposits of Europe, Asia, and North America. Typically, leaf imprints can be found but occasionally one can also find the remains of seeds and fruits. The hawthorn distribution throughout the world evidences its environmental plasticity.

In our research, we considered three areas contrasting from the environmental and climatic standpoint. The increased negative impact of the technogenic environment, deteriorated composition of the atmospheric air, oppression of vegetation, and deteriorated soil and climatic conditions can be observed from the suburbs to the urban center. That is why we studied the plants growing in the city downtown as the most susceptible to negative impacts.

Ecological and climatic region No. 1 - Semey, we studied the intra-quarter and near-highway plantations of the city downtown.

Ecological and climatic region No. 2 - Almaty, we studied the intra-quarter and near-highway plantations of the city downtown.

Ecological and climatic region No. 3 - references hawthorn plantations acting as a control region in our case. The hawthorns under study grow on the same level ecological background in the arboretum of the Issyk State Dendrological Park, located in the foothill zone 50 km from Almaty.

In anthropogenic urban conditions which include the first two experimental regions, the main environmental factors (soil, hydrological, light, and temperature regimes) affecting the urban vegetation are specific and diverse. They have a strong effect on the entire vegetation of urban plantations:

- Light mode: Reduction of solar radiation due to dust and smoke contamination; a change in the light quality and a lower UV ray content and photosynthetically active radiation; street lighting influencing the photoperiodic processes of plants
- Temperature regime: The daily temperature variation is not pronounced; easing frost; lengthening the period with a positive air temperature; cooling the soil in winter when clearing from snow; daytime heating of asphalt, concrete walls of buildings and higher thermal radiation from them at night

- Hydrological regime: Limited water supply to the soil due to asphalt pavements, most of the moisture is lost entering the sewer system; increased air dryness and overheating of dusty leaves complicates water regime of urban plants; trees growing in isolation (especially near-highway plantations) in urban conditions suffer from the leaf surface overheating and water loss by transpiration
- Soil factors: Asphalt and concrete pavement of large urban areas; deteriorated soil aeration (change in water, gas, and thermal conditions) negatively affecting the root system development; when cleaning and burning foliage (litter), vegetation is deprived of natural nutrients, which also increases the soil freezing depth; the impact of the urban technogenic environment in the form of pollution with heavy metals, salts, gases, dust, etc.

The first ecological and climatic region, the city of Semey, is considered the most radioactive in Kazakhstan. The landfill site and the surrounding areas are still heavily polluted, which negatively affects the health of residents and woody plants/brushwood. The concentration of hazardous substances generated near highways is twice the norm. Unique pine forests of the Priirtyshye (a region near the Irtysh) are preserved around Semey. They act as the main protectors and play an important environmental role in the region. The southern side of the forest has woody plants and brushwood that look like spots throughout the area. The main trees there are pines, which play a protective role, holding back sandstorms. Birches, aspens, poplars, hawthorn, and other deciduous trees grow in the forest besides pines. This region has a moderately cold climatic background as it is located in a deeply continental zone. A long distance from the ocean causes high-temperature amplitudes, on average 4.3°C. It reaches -48°C in winter and 44°C in summer. The average wind speed is 2.3 m/s. The annual level of precipitation is quite high in Semey, with abundant precipitation in July. January is a rainless month (MPAAR, 2014).

The second and third ecological and climatic regions are located in the southeast of Kazakhstan, where the climate is continental and arid. In the plain part of the region, it is mainly determined by geographic location, while the climate of mountainous regions is determined by the law of vertical zoning. A characteristic feature of the southeastern regions of Kazakhstan is the abundance of solar heat and light.

The second ecological and climatic region is Almaty, which is a large metropolis in the southeast of the Republic of Kazakhstan, at the foot of the Tien Shan mountain range, located in the foothills of the northern slope of the Trans-Ili Alatau ridge. The mountains stretch in a latitudinal direction from west to east. Until recently, it was considered one of the most landscaped large cities, but the increased anthropogenic load, population, construction, and economic growth began to have a strong impact on the environmental situation. The green protective belt has decreased in recent years and is being replaced by new urbanization elements. Air pollution in Almaty is an acute environmental problem complicated by physical-geographical and natural-climatic conditions. The average annual air temperature in Almaty is 9.0°C. The absolute minimum on February 26, 1951 was-37.7°C. The hottest month is July; the average monthly air temperature is 23.5°C and the absolute maximum temperature was observed on July 31, 1983 (+43.4ºC). Frosts start on October 14 on average and end on April 18. Stable frosts last for an average of 67 days, from December 19 to February 23. Weather with temperatures over 30°C is observed on average 36 days a year. Like any large city, the Almaty center has a “heat island” -the contrast of the average daily temperature between the northern and southern city outskirts is 3.8 and 0.8°C. Therefore, frosts in the city center begin on average seven days later and end three days earlier than in the northern outskirts. On average, 600-650 mm of precipitation falls annually; the principal maximum is in April-May and the secondary maximum is in October-November. The rainless season is in August (MPAAR, 2014).

The third ecological and climatic region, the Issyk State Dendrological Park, is a control option for research. It is located at an altitude of 750 m above sea level in the foothills of the Trans-Ili Alatau and belongs to the IVth arid foothill region. The arboretum area is a sloping, undulating plain with low hilly elevations and shallow ravines. The annual amount of precipitation in the Issyk State Dendrological Park ranges from 198 to 250 mm (Shelek village). A characteristic feature of the southeastern part regions is that a large amount of precipitation falls in the first half of the warm season, namely in the spring-summer period (MPAAR, 2014).

The choice of the hawthorns from the Issyk arboretum as control is quite justified. It should be noted that the plant growth conditions in the Issyk State Dendrological Park differ significantly from other ecological and climatic regions under study. Firstly, the arboretum territory is less polluted environmentally. Secondly, it is located far from the urbanized city areas, which affects the climatic conditions and air purity. Thirdly, the environmental climate in the arboretum is close to natural ecosystems (forest environment). Fourthly, the plants here experience less anthropogenic impact due to the remoteness from the main highways and limited visits. Fifthly, plant care creates favorable conditions for growth and development. The above-listed factors became decisive for the selection of this particular site as reference and control.

Urban plantations (highway landscaping objects, intra-quarter territories) of the studied ecological and climatic regions require an examination of their environmental state. The range of trees and shrubs calls for a thorough analysis and comprehensive assessment of decorativeness and resistance to urban conditions. Street hawthorn plantations occupy a special place in the landscaping system due to the massive planting of this genus in cities, high decorativeness, and the huge role they play (Kulagin, 1974).

The hawthorn has barely been studied in terms of the resistance of certain species to atmospheric air pollution conditions. The influence of environmental factors on the gas-absorbing and dust-holding capacity of hawthorn in urban ecosystems has not been studied. Nevertheless, scientists from different countries have studied other woody and shrub species widespread in the urbanized city environment.

Urban plants play an increasingly important role in improving the urban atmospheric environment, as noted by Chinese scientists (Qiu *et al*., 2009). In 2013, the dust-holding capacity of four urban tree species (Ficus virens var. Sublanceolata, Ficus microcarpa, Bauhinia blakeana, and Mangifera indica Linn.) was studied in Guangzhou at different pollution intensities and for different seasons (Qiu *et al*., 2009).

In Shanghai, China (Liu *et al*., 2012), in 2020, five representative plant species were selected. It was proven by the example that the dust-holding capacity of their leaves was influenced by various factors. The study showed a certain pattern that can provide a scientific basis for the configuration of urban green plant species (Liu *et al*., 2012).

Green spaces purify urban air from dust and gases. Polluted air flows slow down meeting a green massif on their way, causing 60-70% of the dust contained in the air to settle on trees and shrubs under gravity. A certain amount of dust precipitates from the air stream, bumping into trunks, branches, and leaves. A significant amount of dust settles on the surface of leaves, needles, branches, and trunks. When it rains, this dust is washed off to the ground. Due to the temperature difference, downdrafts of air occur under the green spaces which also carry dust to the ground. Air dustiness in green spaces is 2-3 times less than in open urban areas. Tree plantations reduce air dustiness even in the absence of deciduous cover. For example, dust content decreases 2.5 times in the depths of a green massif at a distance of 250 m from its edge (Shilov, 2019).

Research Methods

We assessed the ability of various plant species to filter out dust-like particles from the air according to generally accepted methods (Supuka, 1997; Medvedev, 2004). The degree of the lamina surface relief and dust particle deposition was established using images from the JSM-6510LA analytical scanning electron microscope (Jeol, Japan) in the "Electron Microscopy" engineering nanolaboratory of the Kazakh National Agrarian Research University. The duration of observations to study the lamina dust-holding capacity covered three seasons, where May, July, and September were chosen as the months of observation.

When determining quantitative values for predicting oxygen productivity and absorption of carbon dioxide by hawthorns, we used the technique developed by S.V. Belov (1964) and methods of biochemical plant analysis (Polevoy and Maksimov, 1978). To determine the quantitative mass of the structural hawthorn components, we used both our data and the existing standards (NFIK, 2016). Hawthorn *C. sanguinea* Pall. acted as the object of research in this field. We selected hawthorn models of different ages based on the available documentation and determined their quantitative volumes according to the generally accepted technique (Katmakov *et al*., 2019; Usoltsev *et al*., 2019). The content of chemical elements in the leaves was determined in the "Electron Microscopy" engineering nano laboratory of the Kazakh National Agrarian Research University using the JSM-6510LA analytical scanning electron microscope (Jeol, Japan).

Digital information was processed using the methods of mathematical statistics (Katmakov *et al*., 2019; Usoltsev *et al*., 2019; Kentbayeva, 2020).

Results

Meteorological factors can have a significant impact on particles deposited on the lamina of woody plants. Soil and climatic conditions of Almaty and Semey contribute to a weak manifestation of dust storms, which affects the number of suspended particles. The maximum number of days with dust storms is observed in the dry summer months in all three ecological and climatic regions. At the same time, the prevailing wind speed is 6-9 m/s, with a short-term increase up to 15-17 m/s. The lowest amount of precipitation falls in the third ecological and climatic region-the reference one. The maximum amount of precipitation occurred in region No. 3; precipitation in this area is not less than in the zone of sufficient moisture but its peculiar distribution and high-temperature background of the warm period create aridity conditions, while significant precipitation more often falls in liquid form in the daytime (74%). The second ecological and climatic area occupies the middle position-465 mm (MPAAR, 2014; MPEKR, 2014).

When determining the dust-holding capacity of experimental urban hawthorns, we visually estimated the crown density, its width, height, internal structure, planting density, location depending on ecological regions, categories of plantations (near-highway, intra-quarter), and months of observations.

We studied the dust-holding capacity of hawthorn lamina in all three ecological and climatic regions at two heights from the ground level (1.5 and 3.0 m), due to the low average height of hawthorns. The study of the lamina to determine the dust-holding capacity of plants is justified given the large area of dust deposition and the expansion of planting and landscaping in cities. This is also confirmed by the studies of the dust-collecting capacity of forested plants in Guangzhou, South China (Liu *et al*. 2013). It was also proven in Shanghai in 2019 and 2020 by different scientists, that the deciduous surface of plants is an important receptor for atmospheric pollutants, therefore, the selection of suitable plant species for the urban environment is very important (Liu *et al*., 2013; Lin *et al*., 2019; Sun *et al*., 2021).

Due to the rough branches and trunks of trees and shrubs, the deposition of dust on them is several times higher than on the leaf surface, but the total amount of precipitated particles is mainly determined by the foliage absorption. This is consistent with the studies of Beckett *et al*. (1998), who note that due to their large leaf area relative to the ground on which they stand and the physical properties of their surface, trees can act as biological filters, removing large amounts of particles in the air and therefore improving air quality in a polluted environment. The paper considers the role of vegetation and urban forested areas in reducing the impact of particulate matter pollution. It also illustrates the improvement in urban air quality achieved by planting more trees in cities (Brack, 2002).

The effect of precipitation on the dust-holding capacity was proven by the studies of seasonal variability in dust accumulation on leaves and pigment content in the leaves of six plant species (Sambalpur, Odisha, India). The plants *Pongamia pinnata, Tabernaemontana divaricata, Ipomea carnea, Ficus relogiosa, Ficus benghalensis*, and *Quisqualis indica* were selected for the study. The result showed a significant (negative) correlation between dust load and pigment content in the summer and rainy seasons (Wang, 2011; Holl and Zahawi, 2014).

The moisture content of the plant leaf surface is a frequent meteorological phenomenon that has complex sources. Leaf surface moisture is an important source of water in urban systems. In addition, the characteristic values of stable isotopes of hydrogen and oxygen of urban dew are supplemented, as well as the transformation reveals atmospheric vapor, rainwater, groundwater, and dew water (Dong *et al*., 2021).

At the first site under study, soil properties underwent significant changes as a result of anthropogenic activity. The soil profile is so disturbed that their properties changed and the classification of the soils under study as light and dark chestnut is legitimate only in genesis terms. Most soils are characterized by a slightly alkaline and alkaline reaction, their pH values range from 7.65 to 8.36 (MPEKR, 2014).

The second ecological region comprises chestnut soils, which are the area of detrital cones, mainly dark chestnut soil (the main soils of the city). The entire area of detrital cones is composed of thick proluvial boulder-pebble sediments, mostly with coarse sand filler. The boulder-pebble strata are covered by a layer of dusty loessial soil of extremely variable thickness (usually from 20-30 cm to 2-3m) (MPAAR, 2014).

The soils of the Issyk State Dendrological Park's arboretum have a fully developed profile and bubble up from the surface. The transition from one horizon to another is very gradual. The humus horizon thickness is 50-55 cm. At a depth of 50-60 cm, carbonate effusions in the form of mycelium can be found. The soil-forming rock is loessial loams (MPAAR, 2014).

The amount of deposited dust is of course dependent on the types of soils. In terms of mechanical composition, these soils are quite dusty in three regions.

In our experiments, we took leaf samples not immediately after rain, but 7-10 days after the onset of sunny weather. The maximum amount of precipitation falls on the second ecological and climatic region-Almaty, then the first ecoregion followed by the Issyk arboretum-the control area. This is quite consistent with our research. We can say that a greater amount of precipitation in the first ecological and climatic region had a positive effect on the dust-retadust-holding capacity of plants. Consequently, it affected the purity of the atmospheric air at the research site.

Consider the results of dust-holding capacity by months of observations (Table 1). As mentioned above, we chose three months of observations-summer months as the most susceptible to the manifestation of dust storms. In terms of descending precipitation, these months are arranged in the following order: May-July-September. The amount of precipitation that falls in the spring is higher compared to other periods. The summer and fall months are characterized by less rainfall across all three research areas. Therefore, the minimum dust-holding capacity of hawthorns (according to tabular data) can be attributed to May and the maximum – to July (the hottest month).

Concerning the experimental data on the dust-holding capacity for the hawthorn species under study, they can be arranged in the following order: *C. sanguinea* Pall.– *C. altaica* Lge.– *C. dahurica* Koehne – *C. Douglasii* Lindl. *C. altaica* Lge. and *C. dahurica* Koehne change position, giving way to each other, only in rare cases. The relief and roughness of *C. sanguinea* Pall., as seen in the photo at x1, 500 zoom, explains the maximum dust-holding capacity of this species (Fig. 1). However, high pubescence and relief are associated with a higher dust-holding capacity. This is confirmed by the fourth position of *C. Douglasii* Lindl. in the descending series. *C. Douglasii* Lindl. also has minimum capacity against the background of the rest, i.e., we can say that both the maxima and the minimums of the parameter under study belong to the North American species.

The dust-holding capacity of *C. sanguinea* Pall., according to 2021 observations, varies per month within the following limits for all areas and categories of plantations: May-0.92-1.80, July - 2.02-4.74, and September-1.62-3.95 g/m^2. The species with minimal dust-holding capacity (*C. Douglasii* Lindl.) has the following values: May – 0.82-1.69, July – 2.04-4.53, and September – 1.75-4.03 g/m^2. The influence of the studied factor has no significant distinctions and strong fluctuations in the first two ecological areas. In comparison with the reference area (Issyk State Dendrological Park), the difference is on average 1.8-1.9 times, i.e., the amount of dust settled on the hawthorn lamina in Almaty is much less. The annual precipitation in the city with the plantations under study is almost 1.5 times higher than in the first area – plantations in Semey (Table 1, Fig. 2).

Dust-holding capacity in the control area 1.5 m high from the ground surface per month for all three ecoregions was: May - 0.82, July - 2.04, and September- 1.75 g/m^2 for *C. Douglasii* Lindl.; 0.92; 2.02 and 1.62 g/m^2 for *C. sanguinea* Pall., respectively. The same trend persisted per season and per species under study. We can also note the absolute impact in the categories of plantations for two ecoregions. Motor transport has a huge impact on near-highway plantations. The minimum dust accumulation in the driest summer month (July) varies in the following range: Near-highway – 3.96-4.72 g/m^2, intra-quarter – 2.54-3.84 g/m^2. The difference between the maximum values is x1.2 and x1.6 between the minimum values (Fig. 2).

The degree of hawthorn dust-holding capacity variability for all three experimental sites on S.A. Mamaev's scale of variation coefficients variability is estimated as very low and low. The experiment accuracy does not exceed the 5% level in all observations. When considering the limit parameter values, we should note that the maximum refers to *C. sanguinea* Pall. (local species) and the minimum refers to *C. Douglasii* Lindl. (North American species). This trend can be traced in almost all fields of research.

The above high dust-holding capacity at a height of 1.5 m from the ground surface of low trees and shrubs, including hawthorn, is associated with the fact that the greatest amount of dust particles usually falls at a low height (1.5-2.0 m) except for days with dust storms.

The first ecological and climatic region, as an industrial city and an area with an elevated radioactive background, showed higher dust deposition on the hawthorn lamina surface. This is consistent with research by Ma *et al*. (2020) and Trivedi *et al*. (2009). According to them, increased excavation, open-pit mining, and road traffic suggest that dust deposition on plants may increase. Dust can affect photosynthesis, respiration, and transpiration and allow the entry of phytotoxic gaseous pollutants, according to a review paper (Trivedi *et al*., 2009; Ma *et al*., 2020).

An assessment of the atmospheric dust impact on foliage pigments and resistance to pollution of plants grown near coal-fired power plants was also published in 2018 by Hariram *et al*. (2018). Plant species grown near Thermal Power Plants (TPPs) are one of the fixed substrates for absorbing most of the pollutants emitted from TPP chimneys. The constant exposure of these plants to toxic pollutants can affect their persistence and the concentration of key biochemicals. Our studies provide evidence for evaluating the combined effects and resistance of plants to pollution for long-term environmental management around industrial enterprises. The two ecological regions we studied (1 and 2) belong to the industrial zone.

One of the most important functions of plants is the enrichment of atmospheric air with oxygen and carbon dioxide absorption. Humans and animals breathe in oxygen and breathe out carbon dioxide. This provides the balance of the oxygen and carbon dioxide constancy in the air basin of our planet. The need for oxygen is determined by the energy consumption of the body for movement, functioning of internal organs, and meeting the needs of each cell. Oxygen is the waste in the formation of primary organic substances. This element is necessary for human life, industrial needs, as well as for the life of animals and plants.

Carbon dioxide is of exceptional importance for green chlorophyll-bearing plants since all organic substances of plants are built through the assimilation of CO_2 in the process of photosynthesis. In nature, it proceeds due to solar energy and only in light. Carbon dioxide is contained in the air in negligible amounts (0.03%, or 0.57 mg/L of air), but its consumption by plants in the process of photosynthesis per year is about 1/35 of the total carbon dioxide supply in the atmosphere (about 2,100 billion kg), i.e., the entire CO_2 reserve would have been consumed by plants in just 35 years, if there were no sources of such reserve recovery.

The sources of CO_2 reserve recovery are combustion, respiration of animals and plants, emission of CO_2 in sources during volcanic eruptions, and the activity of soil organisms. The CO_2 content in the air is not constant, it is subject to very significant fluctuations, thereby playing the role of the environmental factor. Oxygen makes up about 21% of the total volume of atmospheric gases. The main source of oxygen is plants and especially forest plantations. The oxygen mass over one ha of forest in the column is about 24 thousand tons. The global oxygen demand is about 400 billion tons per year. There for, releasing oxygen, the flora maintains the atmospheric gas balance.

We want to emphasize one of the most important functions of green spaces, namely their role in enriching the air with oxygen and absorbing carbon dioxide, by the example of hawthorns. The relevance of this research is justified and confirmed by scientific studies.

According to Brown, measuring forest carbon is gaining increasing global attention as countries strive to comply with agreements under the United Nations Framework Convention on Climate Change. There are well-established methods for measuring forest carbon and they are best based on permanent sample areas located in a statistically sound setting. Tree-based measurements at these sites can be easily converted to above-ground biomass using biomass expansion factors. Future measurements of forest carbon stock may rely more heavily on remote sensing data and new remote sensing technologies are being developed now (Brown, 2002).

In the early 1900 s, the Canberra Plain was mainly treeless, according to Brack. With the selection of Canberra as the site for Australia's new capital, extensive tree planting began in 1911. These trees have brought several benefits, including aesthetic value and improved climatic extremes. However, more recently, it has been thought that benefits could extend to pollution mitigation and carbon sequestration (Brack, 2002).

Forests are expanding and play an important role in the global carbon cycle. Soil carbon did not change significantly with any treatment during the study period. The results show that tree planting significantly increases biomass accumulation during the first few years of reforestation of former agricultural land and that grazing land use has a strong influence on the biomass accumulation rate. Holl and Zahawi (2014) recommend small-scale planting trials to quickly assess potential biomass accumulation and determine the priorities of sites for Carbon (C) sequestration. The chemical composition of wood plants consists mainly of three elements: Hydrogen, carbon, and oxygen, which count on average 96.7% of the total mass of organic matter.

Chemical analysis of the 2021 results, in general, confirms that the actual main content in plant organs is carbon (C 45.5%), oxygen (O_2 41.9%), and hydrogen (H 6.3%) (Table 2).

The average total volume of carbon, oxygen, and hydrogen in our example is 93.70 to 93.75% by region, i.e., the bulk of the chemical elements contained in the dried leaves of hawthorns account for these three elements and the remaining mass is nitrogen, fluorine, etc. Among the four species under study, *C. sanguinea* Pall. has a relative maximum total mass per three elements (94-94.2%) and the minimum accounts for *C. altaica* Lge. (93.3-93.6%). Looking at these data, we can make an unambiguous conclusion that the content of carbon, oxygen, and hydrogen in various hawthorn species varies insignificantly and changes in tenths. Therefore, for further research, it is sufficient to select one species that will characterize the entire hawthorn genus. *C. sanguinea* Pall. was chosen as a reference experimental species. This is a local species, the most widespread in Central Asia. In addition, it contains carbon, oxygen, and hydrogen in total equal to the average value per four species and three areas of research. Figure 3 is a diagram of the main chemical elements (C, O, H, F) in the leaves of *C. sanguinea* Pall. growing in the first ecological region.

Figure 4 shows the results of biochemical determination of chemical elements (C, O, H, F), identified in 2021 with the JSM-6510LA analytical scanning electron microscope (Jeol, Japan). In the course of the analysis, we studied compositions of many points on a sheet surface, combined into a single line. Attempts were also made to take samples at a single point (spot sampling), but the results were identical and we settled on the first option. The figures show the lamina surfaces, magnified ×1,500.

The method for quantifying oxygen evolution and carbon dioxide absorption by plants proposed by Belov (1964), does not require taking into account dissimilation, since this is an intermediate process that ensures a certain increase in organic matter by the end of the growing season. We determined oxygen evolution, carbon dioxide, and water absorption in the form of the net final result.

Table 3 shows the averaged materials of 2021 for determining the absolutely dry mass of the hawthorn phytomass elements, carbon dioxide, and water absorption, as well as oxygen evolution during the formation of 1 ton of organic matter. Hawthorns absorb a fairly large amount of CO_2 and H_2O. At the same time, CO_2 is absorbed by the tree bark in greater quantities (1,842 kg) than by leaves (1,652 kg). Leaves absorb more water (585 kg) than wood and bark (558 kg). More oxygen enters the plant organism through wood and bark (1,836 kg) compared to leaves (1,722 kg). The released oxygen also evolves sequentially - 1,412 kg through wood and 1,302 kg through the foliage.

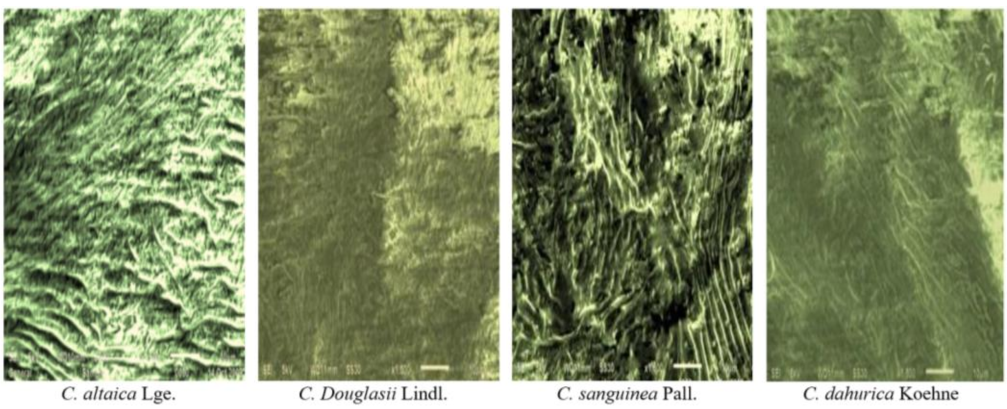

Fig. 1: Relief of the hawthorn lamina surface

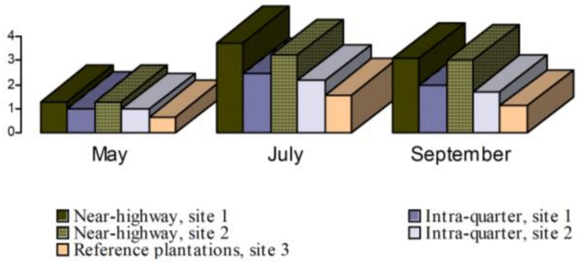

Fig. 2: *C. sanguinea* Pall. hawthorn dust-holding capacity variability (g/m^2) by month of observation

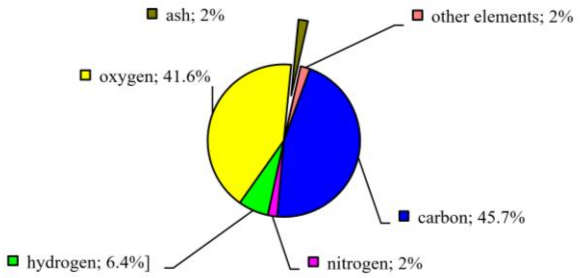

Fig. 3: Distribution of chemical elements In *C. sanguinea* Pall. Leaves

In 2011, Chinese scientists studied carbon sequestration and leaf dust retention by wood plants in green spaces along two main Taiwan highways. Among all the species, Bischofia javanica, Acacia confusa, Swietenia macrophylla, and Alstonia scholaris showed optimal carbon sequestration in trunks and branches with corresponding levels of carbon accumulation (Wang, 2011).

The 2021 research of Dong *et al*. (2021) aimed at studying the effect of three altitudes (below 1,800, 1,800-2,000, and above 2,000 m) on the physical and biometric properties of hawthorn trunk wood and branches, the relationship between wood density in the dry and wet states.

The distribution of chemical elements in individual plant parts is uneven and, therefore, further calculations require establishing quantitative phytomass parameters for certain hawthorn elements. The hawthorn trunk plant mass per 1 m^3 stem wood increases with age and the weight of branches and leaves, on the contrary, decreases, which is a general pattern (Table 3).

In general, the trunk mass grows faster and its share in the total plant mass turns out to be greater than the rest of the structural elements. For example, in age class I (10 years), the trunk mass is 627.5 kg; increasing in age class III (30 years), it reaches 6,408 kg. The lamina phytomass in the same age dynamics varies from 123.7 kg (10 years) to 114.6 kg (30 years). Knowing the general regularity of structural element moisture, utilizing appropriate calculations, we determined quantitative parameters of the mass values for the photo elements under study in an absolutely dry state. The calculations are also summarized in Table 4. From this, it can be seen that the total phytomass of the above-ground hawthorn part is 466.1 kg/m^3 (10 years). The same parameter decreases with age and reaches 451.4 kg/m^3 (30 years).

We determined the wood mass stock in terms of 1ha according to the existing standards. The data of the above-ground hawthorn phytomass in an absolutely dry state, expressed in tons per ha, are given. Because timber is not harvested in urban plantations, the total productivity was calculated as a whole, i.e., without division into selected and remaining wood, as is customary in forestry.

Thus, in our case, it turned out that the wood stock of hawthorns at the age of 10 was 30, at 20 years – 40, and 30 years – 45 m^3/ha.

Knowing the total stock of plantations and using the data in Table 5 is enough to calculate the plant mass for each hawthorn structural element. To do this, the element mass in the absolutely dry state (kg) is multiplied by the corresponding stock (m3/ha); thus, we find the desired value expressed in kg. Then we convert this value by dividing it by 1,000 tons per unit area. Summing up the found quotient masses, we find the total productivity in tons per ha. For example, in age class I, the total productivity is 13.98, in age class II – 18.32, and age class III – 20.32 t/ha.

When forming 1 ton of stem and bark organic matter, 1,412 kg of oxygen is released. When the same amount of foliage mass is formed, 1,302 tons of oxygen are released.

The stem mass releases 13.82 tons of oxygen from 1 ha into the atmosphere. With age, hawthorns increase oxygen productivity. At 10 years, oxygen productivity is 19.53, at 20 years-25.61, and 30 years-28.41 t/ha (Table 6).

Thus, we can say that hawthorns contribute to improving the environmental condition of the ecological regions under study, releasing a significant amount of oxygen into the atmosphere. In conditions of low ventilation in the city, this is a reliable source of oxygen supply to the urban population along with other plants.

With the basic and necessary tabular information, it is quite easy to calculate the amount of carbon dioxide absorbed by hawthorns, which is especially important for large cities (a large number of people, vehicles, enterprises, etc. -producers of carbon dioxide). Wood and bark absorb 1,842 kg of carbon dioxide and foliage-165 kg forming 1 ton of organic mass. Structural and plant masses of hawthorn in an absolutely dry state are expressed in tons per 1 ha. The product of the phytoelement mass by its volume of gas absorption, respectively, provides the required value, i.e., the quantitative mass of the absorbed carbon dioxide.

Table 1: Hawthorn lamina dust-holding capacity (g/m^2)

		Height from the ground surface 1.5 m			Height from the ground surface 3.0 m		
Region	Species	May	July	September	May	July	September
No. 1	*Near-highway plantations*						
	C. altaica Lge.	1.57±0.03	4.29±0.04	3.48±0.07	1.46±0.04	3.52±0.05	3.34±0.06
	C. sanguinea Pall.	1.80±0.04	4.74±0.07	3.60±0.09	1.63±0.04	3.97±0.08	3.67±0.08
	C. dahurica Koehne	1.50±0.03	4.22±0.04	3.47±0.06	1.43±0.03	3.48±0.05	3.48±0.05
	C. Douglasii Lindl.	1.60±0.04	4.53±0.07	3.52±0.07	1.57±0.04	3.87±0.04	3.62±0.06
	Intra-quarter plantations						
	C. altaica Lge.	1.21±0.03	2.92±0.04	1.90±0.05	1.09±0.03	2.35±0.04	1.80±0.04
	C. sanguinea Pall.	1.23±0.03	3.85±0.06	2.18±0.04	1.13±0.03	2.92±0.04	2.08±0.04
	C. dahurica Koehne	1.15±0.02	3.52±0.07	1.93±0.04	1.08±0.03	2.48±0.03	1.85±0.04
	C. Douglasii Lindl.	1.19±0.02	3.63±0.05	2.07±0.05	1.15±0.02	2.89±0.05	1.97±0.05
No. 2	*Near-highway plantations*						
	C. altaica Lge.	1.64±0.03	4.17±0.04	3.87±0.07	1.40±0.03	3.88±0.05	3.62±0.06
	C. sanguinea Pall.	1.76±1.66	4.62±0.06	3.95±0.04	1.67±0.04	4.52±0.08	3.72±0.08
	C. dahurica Koehne	1.67±0.03	4.37±0.09	3.89±0.04	1.43±0.04	3.94±0.05	3.54±0.06
	C. Douglasii Lindl.	1.69±0.04	4.49±0.07	4.03±0.05	1.58±0.04	4.45±0.07	3.71±0.05
	Intra-quarter plantations						
	C. altaica Lge.	1.19±0.03	3.05±0.05	2.12±0.04	1.11±0.03	2.84±0.04	2.03±0.05
	C. sanguinea Pall.	1.33±0.04	3.77±0.05	2.28±0.04	1.22±0.03	3.12±0.05	2.12±0.03
	C. dahurica Koehne	1.25±0.03	3.45±0.04	2.06±0.05	1.09±0.03	2.84±0.04	1.98±0.05
	C. Douglasii Lindl.	1.22±0.03	3.53±0.04	2.32±0.04	1.17±0.03	3.07±0.05	2.10±0.06
No. 3	*Reference plantations*						
	C. altaica Lge.	0.85±0.02	1.94±0.03	1.46±0.04	0.72±0.02	1.67±0.05	1.23±0.03
	C. sanguinea Pall.	0.92±0.02	2.22±0.05	1.62±0.04	0.85±0.02	1.73±0.03	1.36±0.03
	C. dahurica Koehne	0.87±0.02	1.84±0.03	1.49±0.04	0.76±0.02	1.60±0.03	1.19±0.03
	C. *Douglasii* Lindl.	0.82±0.02	2.04±0.04	1.75±0.03	0.80±0.05	1.81±0.04	1.30±0.03

Table 2: Chemical composition of hawthorn leaves in terms of absolute dry weight

			Compounds of chemical elements, %				
Pos. No.	Species	Total volume C, O, H	C	O	H	N	Ash
Ecological and climatic region No. 1							
2	*C. altaica* Lge.	93.30	45.30	41.80	6.20	2.10	2.10
3	*C. sanguinea* Pall.	94.00	45.40	42.30	6.30	2.20	2.20
4	*C. dahurica* Koehne	93.90	45.60	41.80	6.50	2.40	2.40
5	*C. Douglasii* Lindl.	93.60	45.50	42.00	6.10	2.30	2.30
	Average	93.70	45.45	41.98	6.28	2.25	2.25
Ecological and climatic region No. 2							
2	*C. altaica* Lge.	93.60	45.80	42.80	6.20	2.30	2.20
3	*C. sanguinea* Pall.	94.10	45.40	42.30	6.40	2.20	2.10
4	*C. dahurica* Koehne	93.70	45.30	41.90	6.40	2.30	2.30
5	*C. Douglasii* Lindl.	93.40	45.70	42.10	6.50	2.40	2.20
	Average	93.70	45.55	42.20	6.38	2.30	2.20
Ecological and climatic region No. 3 – Reference site							
2	*C. altaica* Lge.	93.50	45.40	41.80	6.20	2.20	2.20
3	*C. sanguinea* Pall.	94.20	45.50	42.50	6.50	2.40	2.30
4	*C. dahurica* Koehne	93.50	45.50	41.50	6.30	2.50	2.50
5	*C. Douglasii* Lindl.	93.80	45.70	42.40	6.40	2.40	2.40
	Average	93.75	45.53	42.05	6.35	2.38	2.35

Table 3: Determination of oxygen evolution during the formation of 1 ton of organic matter (*C. sanguinea* Pall.)

	Basic chemical elements in 1 ton of absolutely dry matter, kg					Absorption, kg		
Phytomass	C	H	O_2	Total	O_2 evolution from CO_2 and H_2O, kg	CO_2	H_2O	Release into the atmosphere O_2, kg
Wood	502	62	424	988	1,836	1,842	558	1,412
Bark	502	62	424	988	1,836	1,842	558	1,412
Foliage	450	65	420	935	1,722	1,652	585	1,302

Table 4: Parameters of hawthorn phytomass elements per 1 m^3 stem wood, kg (*C. sanguinea* Pall.)

	Moisture state				Absolutely dry state			
Age	Trunk	Branches	Foliage	Total	Trunk	Branches	Foliage	Total
10	627.5	158.1	123.7	909.3	326.3	79.2	60.6	466.1
20	635.0	139.4	118.4	892.8	330.2	70.0	58.0	458.2
30	640.8	123.9	114.6	114.6	332.6	62.6	56.2	451.4

Table 5: Calculation of above-ground hawthorn phytomass in an absolutely dry state, t/ha (*C. sanguinea* Pall.)

Age	Trunk	Branches	Foliage	Wood stock m^3/ha	Total mass of structural elements
10	9.79	2.37	1.82	30	13.98
20	13.20	2.80	2.32	40	18.32
30	14.97	2.82	2.53	45	20.32

Table 6: Oxygen productivity and carbon dioxide absorption by various hawthorn phytomass elements (*C. sanguinea* Pall.), t/ha/year

	Phytomass structural elements							
	Trunk		Branches		Foliage			
Age	Oxygen productivity	Carbon dioxide absorption	Oxygen productivity	Carbon dioxide absorption	Oxygen productivity	Carbon dioxide absorption	Total oxygen productivity	Total CO_2 absorption volume
10	13.82	18.03	3.34	4.36	2.37	3.01	19.53	25.40
20	18.64	24.31	3.95	5.16	3.02	3.83	25.61	33.30
30	21.14	27.57	3.98	5.19	3.29	4.18	28.41	36.94

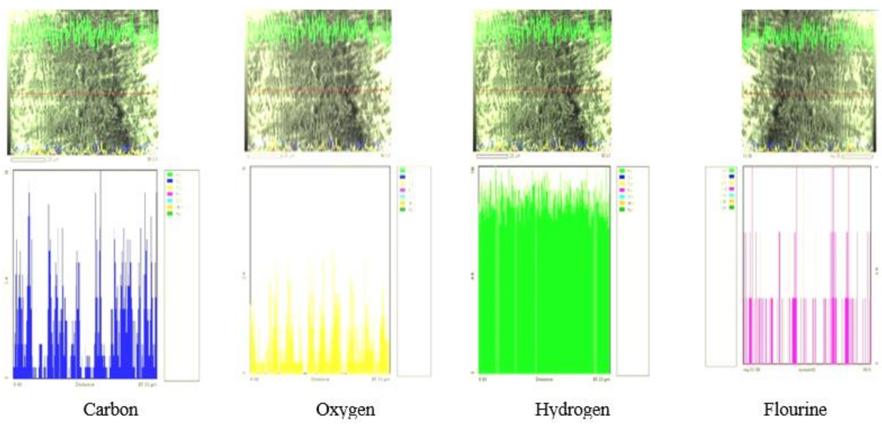

Fig. 4: The content of chemical elements in the *C. sanguinea* Pall. Leaves

Discussion

The trunk part of trees has the greatest gas-absorbing capacity the absorption capacity, while branches and leaves, on the contrary, decrease it., which accounts for about 73% of the absorbed carbon dioxide. Branches and foliage account for 16 and 11%, respectively. The gas-absorbing capacity of hawthorns increases with age, but based on the dynamics of distribution, we can conclude that with each age class, the total volume of absorption will increase to a lesser extent than at a young age. With the age of plantations, their trunk part increases the resulting sanitary and hygienic role of hawthorns, based on their high dust-holding capacity and good oxygen productivity, makes it possible to include these species in the list of plants for landscaping urban areas. Hawthorns in green spaces is a fairly common tree species, they are the most numerous representatives of the *Rosaceae* family, which play a large hygienic and environmental role. It should be noted that trees of different ages produce oxygen more evenly, which increases their hygienic role. With age, hawthorns increase their oxygen productivity and gas absorption capacity. Quantitative volumes of oxygen productivity and carbon dioxide absorption were established experimentally. We found that 1 ha of hawthorns in the process of photosynthesis releases 195,300-28,410 kg of oxygen into the atmosphere and absorbs 25,400-36,940 kg of carbon dioxide per year. The main producing element of hawthorn biomass is the stem which accounts for up to 70% of all oxygen productivity and gas absorption.

The phytomass largely determines carbon sequestration, according to Rozlomiy *et al*. (2021), and makes a great contribution to the overall carbon and nitrogen cycle in the forest ecosystem.

All the studied hawthorn species have rough lamina, but the indigenous species *C. sanguinea* Pall. turned out to be the leader. The dust-holding capacity of hawthorns increases towards the end of the growing season. Maximum deposition of dust on the lamina surface was noted in the driest month of observations-July. Hawthorns that grow along highways experience the greatest environmental pressure. The above data are in complete agreement with studies in Coimbatore, India, where 24 sample sites were selected along two major roads and divided into urban and suburban ones (Subpiramaniyam *et al*., 2021).

Conclusion

The influence of the studied factor has no significant distinctions and strong fluctuations in the first two ecological areas. In comparison with the reference area, the difference is on average 1.8-1.9 times, i.e., the amount of dust settled on the lamina of hawthorn plantings in the second region is much less. The above high dust-holding capacity of low trees and shrubs, including hawthorn, is associated with the fact that the greatest amount of dust particles usually falls at a low height (1.5...2.0 m) except for days with dust storms. It should be borne in mind that for urban plants when determining the deposition of dust on the lamina, one should assess both the crown area and physiological state of the tree.

To improve the quality of life and contribute to the improvement of the environmental situation in the studied areas, it is necessary to plant sustainable trees and shrubs within the city boundaries, which serve as a protective barrier in the deteriorating environmental situation. The results of monitoring green spaces in urban conditions, taking into account the principle of environmental zoning, should become the determining criterion for selecting the types of the basic range of tree species to create an efficiently functioning system of green spaces and a differentiated system of measures to care for urban tree plantations.

Author’s Contributions

All authors equally contributed to this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues are involved.

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