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Assessment of Air Pollution Tolerance and Physicochemical Alterations of *Alstonia scholaris* (L.) R.Br. along Roadsides of Lahore, Pakistan

Zahid Mehmood[1,4], Ali Hasnain[1], Muhammad Luqman[2], Sohaib Muhammad[1], Narayan Babu Dhital[3], Arooba John[1], Maryam Iqbal[1], Amna Ejaz[1], Matiba Tufail[1], Harma[1], Hsi-Hsien Yang[4*], Muhammad Umer Farooq Awan[1*]

[1] Department of Botany, Government College University Lahore, Pakistan
[2] Department of Environmental Sciences, University of Veterinary & Animal Sciences, Lahore, Pakistan
[3] Department of Environmental Science, Patan Multiple Campus, Tribhuvan University, Nepal
[4] Department of Environmental Engineering and Management, Chaoyang University of Technology, Taiwan

ABSTRACT

Air pollution has become a severe urban environmental and health problem in several countries around the globe. Air pollutants also affect the physiological, morphological and biochemical processes in plants such as stomatal function, photosynthesis, respiration, leaf area, chlorophyll content, amino acid, pH and plant growth. Lahore is the second largest city in Pakistan facing tremendous stress of vehicle emission. This study evaluated the air pollution tolerance potential of *Alstonia scholaris* growing along the busiest roads of Lahore city using air pollution tolerance level and physicochemical alterations. Leaf area, ascorbic acid content (AAC), total chlorophyll (TCh) content, leaf extract pH, relative water content (RWC), and dust accumulation on leaf surface were measured for the roadside plantation and compared with the control plants (at background sites, 20 km away from polluted sites). Average value of AAC, TCh content, leaf extract pH, and RWC of *A. scholaris* in the roadside plantation were, 0.0380 mg g^{-1}, 0.0537 mg g^{-1}, 5.94 and 68.3%, respectively. The average value of dust accumulation on the leaf surface 0.381 mg mm^{-2} and leaf area 1482 mm^2 were higher in roadside than control site. APTI value (0.221) observed for *A. scholaris* in the roadside plantation was significantly higher than that at the control site (0.165). It is concluded that the air pollution tolerance ability of *A. scholaris* was higher along the polluted roads of Lahore than in the background control site. Leaf area, AAC, TCh and APTI decrease as traffic flows increase, indicating that the health of *A. scholaris* was affected by traffic flow.

Keywords: Air pollution, Leaf area, Total chlorophyll, Urbanization

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*** Corresponding Authors:**
Hsi-Hsien Yang
hhyang@cyut.edu.tw
Muhammad Umer Farooq Awan
dr.umerfarooqawan@gcu.edu.pk

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1 INTRODUCTION

Increasing urbanization and industrialization have caused air pollution problems all over the world. In developed countries, vehicle exhaust emissions have been controlled by the maintenance of vehicles and improving fuel quality. However, in developing countries like Pakistan, vehicle emissions have been increasing due to poorly maintained vehicles and the use of poor-quality fuel. Vehicle emissions contain pollutants, such as nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), carbon dioxide (CO_2), hydrocarbons (HCs), particulate matter, and volatile organic compounds (VOCs). Among them (CO) make large composition of the vehicle exhaust and (NO_x) cause smog which affect environmental health adversely (Zamorategui-Molina *et al.*, 2021; Biswas *et al.*, 2021; Liu *et al.*, 2022). Leaves are the part of plants have direct contact with air pollutants than the other parts of the plants, such as stems and roots (Shafiq *et al.*, 2009).

Pollutants emitted by road vehicles enter the leaf and affect the morphological and biochemical processes concerned with leaves (Zhang *et al.*, 2016a). Air pollutants can be absorbed through stomatal openings of leaves of plants growing along the roadside (Zhang *et al.*, 2016b). Air pollutants may affect the anatomical, morphological, and biological functions of plants. They reduce leaf area, flower yield, leaf length, and seed germination, and affect the physiological processes of plants (Iqbal *et al.*, 2019). A study showed that pollutants absorbed by leaf surfaces had a reduced chlorophyll concentration and stomata conductance (Gratani *et al.*, 2000). These pollutants also changed the biochemical properties, such as ascorbic acid content (AAC), total chlorophyll (TCh) content, leaf extract pH, relative water content (RWC), and morphological characters such as leaf size. They also affect respiratory and enzymatic activities, photosynthetic pigments, and water uptake (Abhishek, 2018). Likewise, automobile exhaust can affect the leaf dimensions, and delay in flowering, pause seed germination. On the other hand, vegetation helps maintain the environmental balance and reduce pollution (Iqbal *et al.*, 2019).

The air pollution tolerance index (APTI) is a parameter used to know the tolerance ability of plants under polluted environment (Chauhan, 2010). AAC, TCh content, pH of leaf extract, RWC, and external factors, such as temperature, humidity, and soil chemistry, influence plant susceptibility and tolerance to air pollutants. Different plants show varied levels of tolerance in different environments. Plants grown in contaminated areas shrank their leaves and change in the size of stomata (Panda *et al.*, 2018). APTI assists in monitoring air pollution in a cost-effective way (Satpute and Bhalerao, 2017). The higher content of ascorbic acid in leaves protects the thylakoid membrane from oxidative injury during less water conditions (Tambussi *et al.*, 2000). AAC is responsible for formation of cell wall, survive under stress environment, and growth of new cell. It also helps in the fixation of carbon. Therefore, the AAC factor is used in the calculation of APTI (Nwadinigwe, 2014). TCh helps plants to survive in a polluted atmosphere (Jyothi and Jaya, 2010). Prajapati and Tripathi (2008a) observed more TCh content in plants grown under pollution stress helps to survive under harsh condition. In physiological process of the plant, pH plays an important role to find the rate of photosynthesis, transpiration and provide cooling sensation to plant during drought condition (Zouari *et al.*, 2018). Higher RWC content in plant body maintains the physiological balance during drought condition when exposed to air pollution. High transpiration rate may lead to desiccation, therefore RWC may decide to tolerance towards air pollution (Jyothi and Jaya, 2010).

In Lahore city, the rapid increase in vehicle pollution has, caused environmental problems. WHO confirmed the exceeding level of lead, and primary and secondary air pollutants in Lahore city (Khwaja and Khan, 2005). Lahore is the second biggest city in Pakistan having 11.1 million residents. In Lahore city, vehicular traffic increased remarkably with increases in metro and housing projects (Ashraf *et al.*, 2019). *A. scholaris* is ever green exotic plant planted along road sides due to big canopy cover. It has long stems containing 4 to 10 whorls and dusky green shinning leaves. It has been growing in tropical region in west Bengal and the west coastline forest of south India and is mostly grown in Pakistan as decorative plant (Khare, 2007). *A. scholaris* in the green belt plantation showed tolerance against air pollution (Tiwari and Tiwari, 2006). A significant reduction in leaf development of *A. scholaris* was observed at the roadside of Karachi (Shafiq *et al.*, 2009).

Latwal *et al.* (2023) determined air pollution indices of trees and shrubs for biomonitoring and green belt. Highest APTI value (85.5) was observed for *Ficus religiosa* from Dehradun, India which was helpful for better selection of plant for green belt in urban area. Amin Mir *et al.* (2022) determined APTI of plant species grown near the CCI-Rajban cement factory, Sirmaur. They found that many plants species such as Teak, Sal, Mango, Mallotus and Gauva showed less tolerant, peepal plant species showed intermediate while eucalyptus showed high tolerance to air pollution. Shrestha *et al.* (2021) measured APTI of plants facing the traffic pollution in the Kathmandu Valley of Nepal. They selected nine plant species for biochemical parameters. *Cinnamomum camphora* out of nine species revealed the maximum tolerance against polluted environment whereas other species showed an adequate tolerance behavior against stress environmental condition and *Nerium oleander* has highest dust content. These species were suitable for roadside plantations. Bui *et al.* (2021) determined tolerance ability of 11 plant species planted under the air pollution in South Korea. Particulate matter accumulations on the leaf surface were also measured. Maximum APTI value was observed in *Pinus strobes* while *Cercis chinensis* showed minimum value.

In the present study, four parameters, namely AAC, TCh content, leaf extract pH and RWC of *A. scholars* planted along the different busiest roads of Lahore city were measured with respect to traffic flow. APTI values of plants were determined to help categorize the abilities against hazardous environmental condition. This study also determines the sensitivity, tolerance behavior of plants to survive in air pollution conditions and may contribute to maintain the green belt along the roadsides with high traffic flow.

2 MATERIALS AND METHODS

Physicochemical attributes, namely AAC, TCh content, pH of leaf extract, and RWC, were measured for *A. scholaris* planted along four roadside locations in Lahore city. APTI was determined using the above parameters. In addition, leaf surface area and dust content on leaves surface were examined to check the air pollution effect on *A. scholaris* plant.

2.1 Study Area and Site Selection

Lahore, which is located in Punjab region between latitudes 31°20′–31°50′N and longitudes 74°05′–74°37′E, is the succeeding biggest metropolitan urban area of Pakistan after Karachi. In Lahore, the total length of roads is 2,000 km. Due to the increasing population and expanding road network, the road traffic volume has reached saturation point (Zia *et al.*, 2021). Lahore is facing stresses due to air pollution, and pollutants also affected the human health and plant health (Colbeck *et al.*, 2011). Poor air quality index has been observed along congested roads in Lahore city (Khanum *et al.*, 2017). To investigate the positive behavior of roadside vegetation to air pollution, we selected four high-traffic roads such as (Canal Bank road, Wahdat road, Ferozepur road, and Mall road) and one control site for this study (Fig. 1). The control site, which was located in a traffic-free area, was 20 km away from these busiest roads.

2.2 Sample Collection

The experiment was carried out between April and November 2021. Sampling was done in two days in the morning between 8:00 AM and 11:00 AM. Eight trees were selected from each road for sampling. Seven fresh matured leaves were collected from a tree at a distance of 3–4 m. Therefore, the samples from each contained 21 fresh leaves. These leaves were stored in polythene bags and labeled with name, date, and time (Table 1). The leaf samples were taken to the laboratory and stored in a refrigerator at –4°C for further biochemical analyses.

2.3 Traffic Flow Data

Wahdat road is the junction of Ferozpur road and connected with Punjab University and Karim market observed heavy traffic. Ferozpur road is one of the heavily used road service to connect

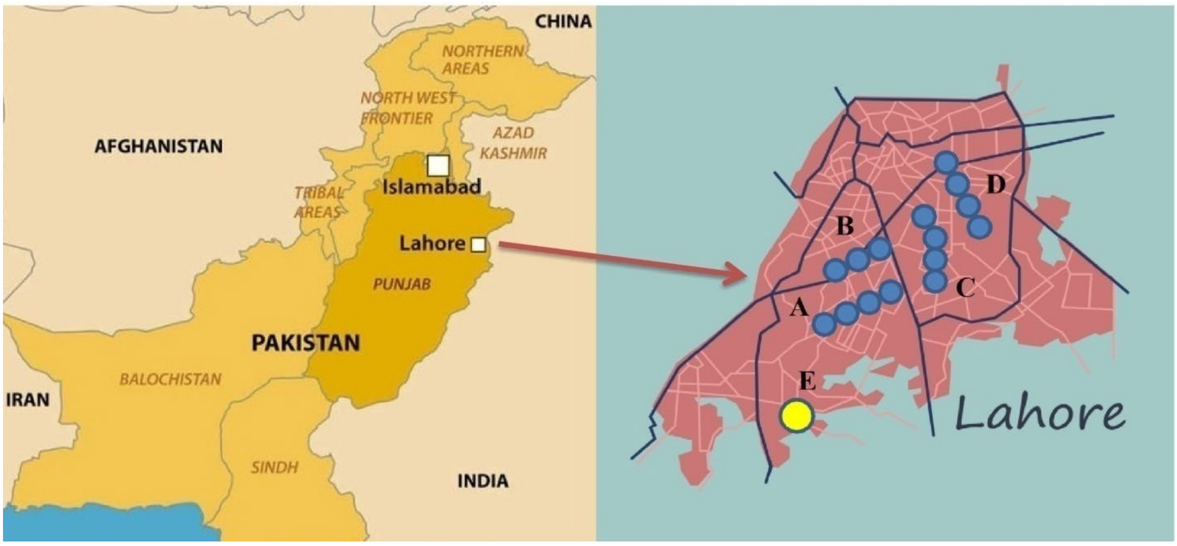

Fig. 1. Map of study roads (A) is Canal Bank road, (B) is Wahdat road, (C) is Ferozepur road, (D) is Mall road, and (E) control site.

Table 1. Experimental design.

Road sides	Number of trees selected	Number of leaves collected (Triplicate)
Canal Bank road	7	21
Wahdat road	7	21
Ferozepur road	7	21
Mall road	7	21
Control	7	21

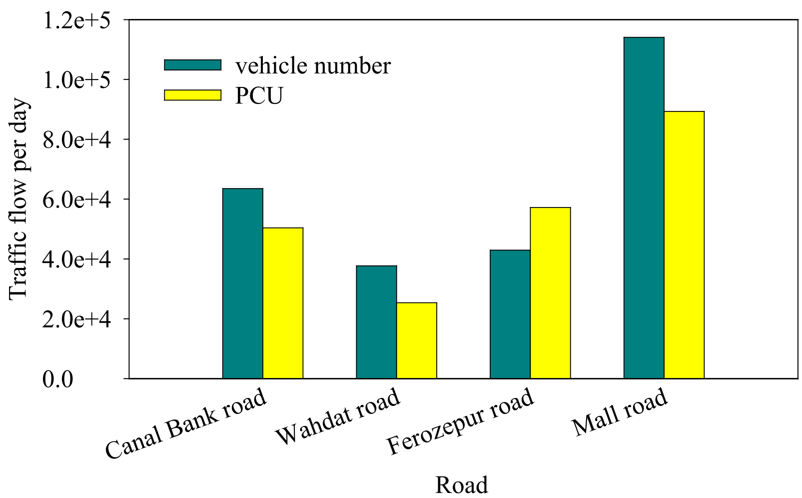

Fig. 2. Traffic flow on different roads.

many residential and commercial area such as Model Town, Qurtaba Chowk, Railway Station, Walton Road, Ichra, Defence, and Kot Lakhpat. According to the Traffic Engineering and Planning Agency Lahore (TEPA), total traffic flow at the junction of Wahdat and Ferozepur road was 80,635 day^{-1}. Total number of vehicles counted from all direction of Wahdat road was 37,689 day^{-1} while on the Ferozpur road was 42,946 day^{-1}.

Mall road and Canal Bank roads are one of the busiest roads of Lahore metropolitan region and traffic flow is high during business and school hours. Canal Bank road has 12 underpasses, which allow continuous flow of traffic from Thokar Niaz Baig to Harbanspura. Mall road has observed heavy traffic because major private public offices, companies and commercial markets on this road. According to the TEPA, total traffic flow at the junction Mall and Canal Bank road are 177,602 day^{-1}. Traffic flow counts on the Mall road of all the directions were 114,075 day^{-1} while on the Canal Bank road 63,527 day^{-1} vehicles were observed. The order of traffic flow on the different roads is Mall road > Canal Bank Road > Ferozepur road > Wahdat road (Fig. 2).

Heterogeneous traffic flow is a big problem in calculating the traffic characteristics, roadway volume, analyze the different traffic facilities and traffic design factors in developing counties. For resolving the traffic heterogeneity, a general factor is used called the passenger car unit (PCU). In this study, PCU was used for determined the heterogeneity volume of traffic in to the simpler equivalent where passenger car unit considers the standard unit but other classes of vehicles taken as in standard car (Bomzon *et al.*, 2021). PCU value was calculated for the Mall road (89,312) which is the highest among all the roads. PCU values for Ferozepur road, Canal Bank road, and Wahdat road were measured 57,187, 50,403, and 37,489 respectively (Fig. 2). The order for the PCU values were the following: Mall road > Ferozepur road > Canal Bank road > Wahdat road.

2.4 Leaf Area and Dust Accumulation

The leaf outline was traced on gridded graph paper, and the leaf area was calculated using the square grid counts inside the leaf outline and the area of a grid. For measuring the dust content on the leaf surface, fresh matured leaves of *A. scholaris* were taken, from polluted and non-polluted sites. First, the fresh leaf weight was measured. Then, dust was removed with a camel hairbrush, and the leaf was washed with distilled water and then dry weighed again. The dust content on leaves was calculated using Eq. (1) (Rai and Panda, 2014).

$$W = \frac{W2 - W1}{A} \quad (1)$$

where
W = Dust content of leaf (mg mm^{-2})
W2 = Weight of fresh leaves (mg)
W1= Initial weight of leaf with dust (mg)
A= area of leaf (mm^2)

2.5 Measurement of Physiological and Biochemical Parameters

2.5.1 Relative water content

The RWC of leaves is a useful tool to find the water status under stress conditions (Seyyednejad *et al.*, 2017). High RWC within the plant body helps to sustain the physiological process during the stressed condition (Innes and Haron, 2000). Initially the fresh weight of leaves (FW) were measured, after that the leaf was placed in distilled water for 24 h to find turgid weight (TW) using a weighing balance. Leaves were oven dried at 75°C for 24 h for determining the dry weight (DW) (Ritchie *et al.*, 1990). RWC was calculated using following Eq. (2).

$$RWC\,\% = FW - DW \times \frac{100}{TW - DW} \quad (2)$$

2.5.2 Leaf extract pH

First, 4 g of the fresh leaf was ground with the help of a pestle and mortar. After that, 40 mL of distilled water was added to the ground leaves. The mixture was centrifuged at 7500 rpm at 20°C for 20 min. The leaf extract pH was measured with the help of a pH meter.

2.5.3 Total chlorophyll content

Fresh leaves (2 g) were grind using pestle and mortar and 80% acetone solution was used for extraction. The solution was filtered with the filter paper and 5 mL of 80% acetone was added to make final volume 15 mL. The solution was transferred to clean centrifuge tube and centrifuged at 1000 rpm for 5 min at 4°C. After that, the absorbance of the extraction solution was measured at 645 and 663 nm on a UV-visible spectrophotometer. The value of photosynthetic pigments i.e., total chlorophyll (mg g^{-1}) can be calculated by Eq. (3).

$$\text{Total chlorophyll} = (A663 \times 8.02 + A645 \times 20.2)V/(1000 \times W) \quad (3)$$

where
A663 = Absorbance at 663 nm
A645 = Absorbance at 645 nm
W = Weight of sample (g)
V = Volume of extract (mL)

2.5.4 Ascorbic acid content

Fresh leaves (2 g) were ground in 20 mL extraction solution (5 g oxalic acid 0.75 EDTA), then the extract was filtered. 1.5 mL of the leaf extract was taken and centrifugation was done for 15 minutes. After that, 1 mL supernatant was taken and mixed with 5 mL 2,6-dichlorophenolindophenol (DCPIP). The color of solution changed into pink, and the value of optical density was measured with the help of spectrophotometer at 520 nm (Et). Optical density for a blank was taken by using 2,6-DCPIP at the same wave length (E_0). 1% AAC was added, and the solution was decolorized. The value of optical density was taken at the same wavelength (E_S) (Fig. 3). AAC (mg g^{-1}) was calculated by using Eq. (4).

$$Ascoric\ acid = \frac{\left[E_0 - \left(E_S - Et\right) \times V\right]}{W} \times V1 \times 100 \tag{4}$$

E_0 = OD of blank solution
E_S = value of absorbance of pink solution
Et = OD value colorless solution
V1 = Volume of the supernatant
V = Final volume of solution
W = Fresh weight of leaf

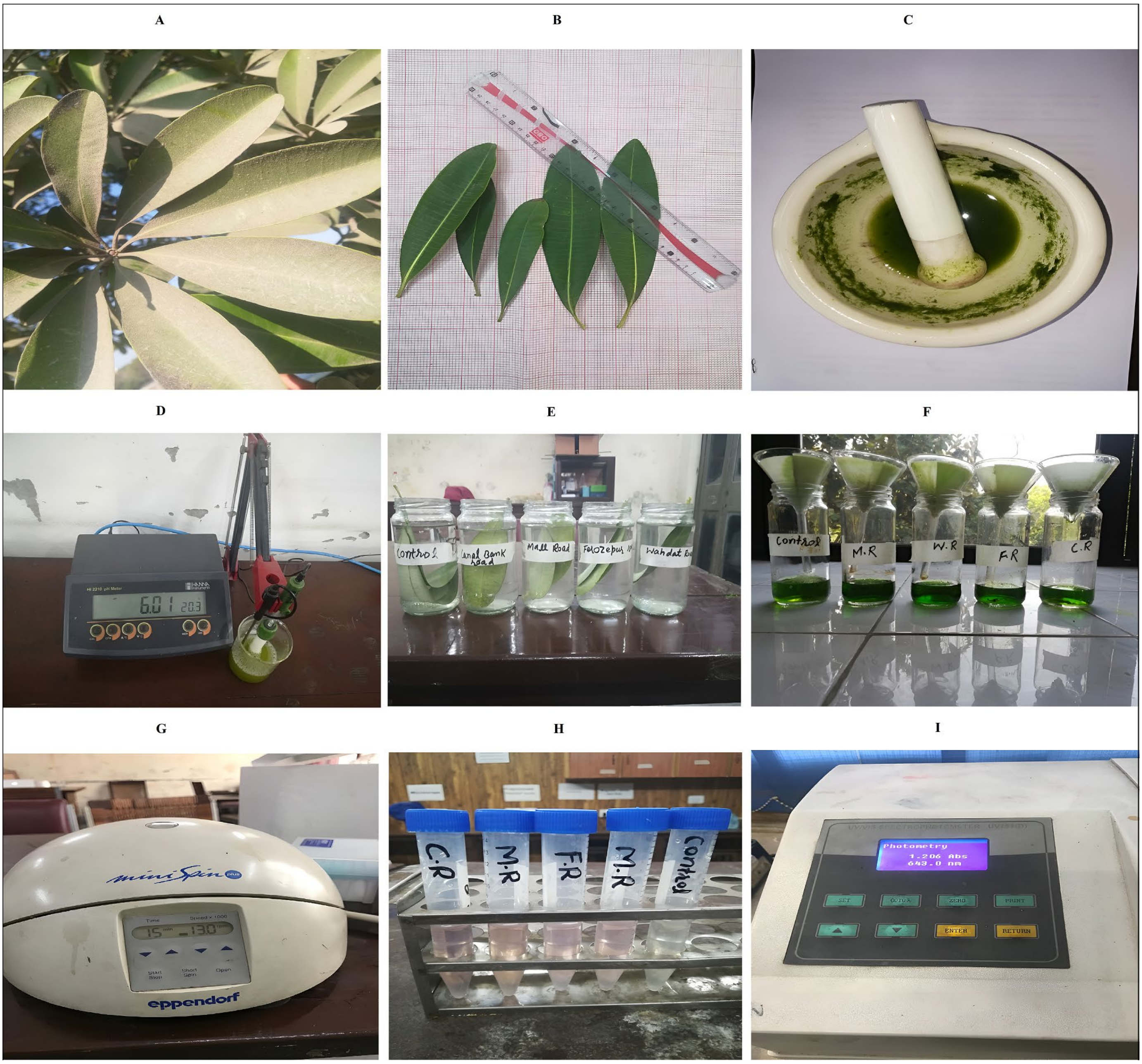

Fig. 3. (A) Dust load on the leaves. (B) Measurement of leaf area. (C) Grinding leaves for measuring biochemical parameters. (D) Measurement of pH. (E) Leaves soaked in water for turgidity measurement. (F) Filtration of leaf extract to determine TCh. (G) Centrifugation of leaf sample. (H) Preparation of leaf sample for spectrophotometer. (I) Observing values of OD for AAC.

2.5.5 Air pollution tolerance index

APTI is an index used to identify the plant species which tolerate to air pollution. APTI value was estimated by using four biochemical parameters including RWC, TCh, AAC and pH using Eq. (5) (Chauhan, 2010).

$$APTI = \frac{\left[A\left(T+P\right)+R\right]}{10} \quad (5)$$

where
A = Ascorbic acid content of leaf (mg g^{-1})
P = pH of leaf extract
T = Total chlorophyll content of leaf (mg g^{-1})
R = Relative water content (%).

3 RESULTS AND DISCUSSION

3.1 Dust Content on the Leaf Surface

The highest dust content was observed for *A. scholaris* leaves collected from Mall road (0.539 ± 0.108 mg mm^{-2}), whereas the lowest dust content was noted in the leaves of control site (0.0116 ± 0.00146 mg mm^{-2}). The sampling sites in terms of leaf surface dust content were in the following order: Mall road > Wahdat road > Ferozepur road > Canal Bank road > control site (Fig. (4a)).

Correlation between dust content and PCU showed that dust content of *A. scholaris* increases as the traffic flow increases on all the roads (Fig. (4b)). Plants grown in the roadside environment change their morphological and physiological attributes by the accumulation of dust on the leaf surface. The pollutants released from automobile exhaust are toxic and can reduce plant growth and affect morphological attributes (Ahmad *et al.*, 2012). Dust on the leaf surface reduces plant growth and development and blocks stomata on the upper surface. Dust deposits also alter the optical properties of leaves (Prajapati and Tripathi, 2008b).

3.2 Leaf Area

Leaf is the most sensitive part of plant to be affected by air pollution and major physiological process such as photosynthesis and respiration are concerned with leaf (Kameswaran *et al.*, 2019). Urban trees play an important role to reduce air pollution due to their large leaf area than other plant of green space (Jim and Chen, 2008). Leaves from the control site had a larger leaf area than the leaves from experimental sites. The leaf area was found in the following order of sampling sites: control sample > Ferozepur road > Canal Bank road > Wahdat road > Mall road (Fig. (5a)). The mean leaf area of *A. scholaris* in the control site was bigger than that in polluted

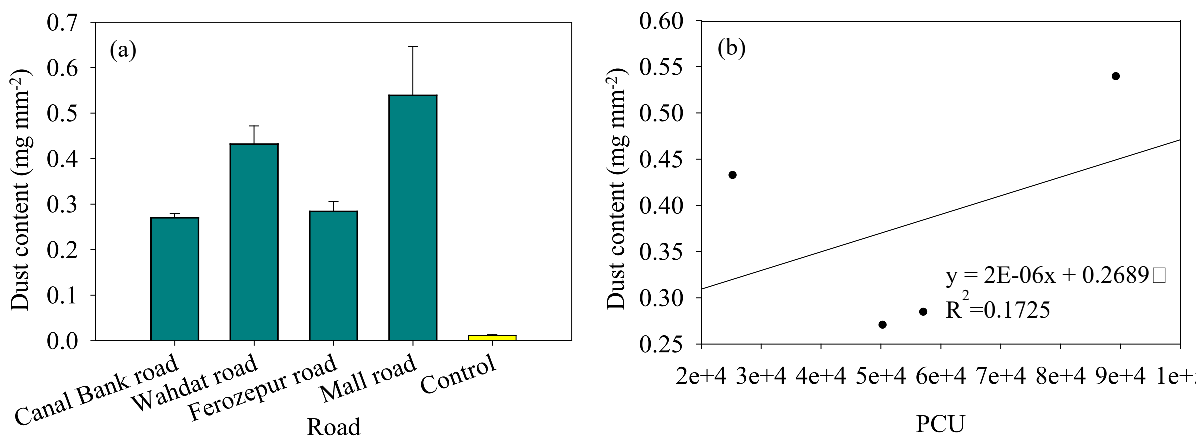

Fig. 4. (a) Dust content on leaves surface of *A. scholaris* and (b) Correlation between dust content of *A. scholaris* and PCU.

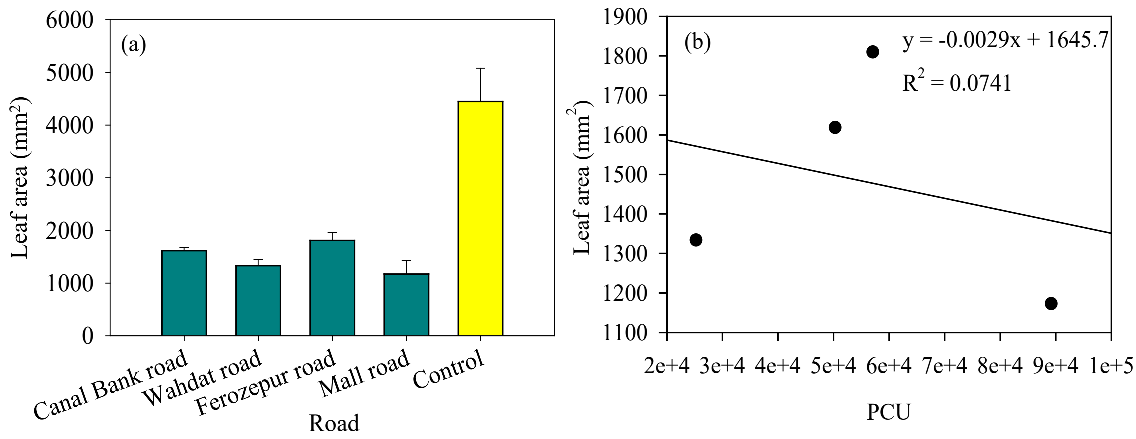

Fig. 5. (a) Leaf area of *A. scholaris* and (b) Correlation between leaf area and PCU.

sites. Correlation between leaf area of *A. scholaris* decreases with increases of traffic flow of different roads (Fig. (5b)). Jahan and Iqbal (1992) who-examined that leaf area, leaf length, leaf width, and petiole length decreased in environment pollution region while increases in pollution free area. Seyyednejad *et al.* (2009) observed a decrease in the leaf area in the plants planting in heavily polluted sites. This is due to disturbance in physiological and biochemical alterations that caused the reduction of leaf area.

3.3. Biochemical Parameters

3.3.1 Ascorbic acid content

Ascorbic acid in the leaves of plants has multiple functions such as cell division, photosynthetic carbon fixation, protect against reactive oxygen species (Sahu *et al.*, 2020) and also help the development of root, shoot, leaf and fruit of woody plants (Bilska *et al.*, 2019). Reactive oxygen species or free radicle produce might be due to low concentration of ascorbic acid in plants when exposed to air pollution (Rai and Panda, 2014). The AAC were 0.0383 (Mall road), 0.0222 (Ferozepur road), 0.0374 (Canal Bank road) and 0.0544 mg g^{-1} (Wahdat road), having the average value 0.0380 mg g^{-1}. The mean ascorbic acid content in the control site was 0.275 mg g^{-1} (Fig. (6a)). The highest AAC content was calculated from Wahdat road where as the lowest content was calculated from Ferozepur road. The AAC was calculated by following order: Wahdat road > Mall road > Canal Bank road > Ferozepur road. Higher AAC means higher tolerance ability to air pollution.

The correlation showed that the ascorbic acid increases with increases the number of vehicles (Fig. (6b)). These results agree with the findings of Deepalakshmi *et al.* (2013) which reported that plant species has higher concentration of AAC were more tolerant of air pollution. AAC is an

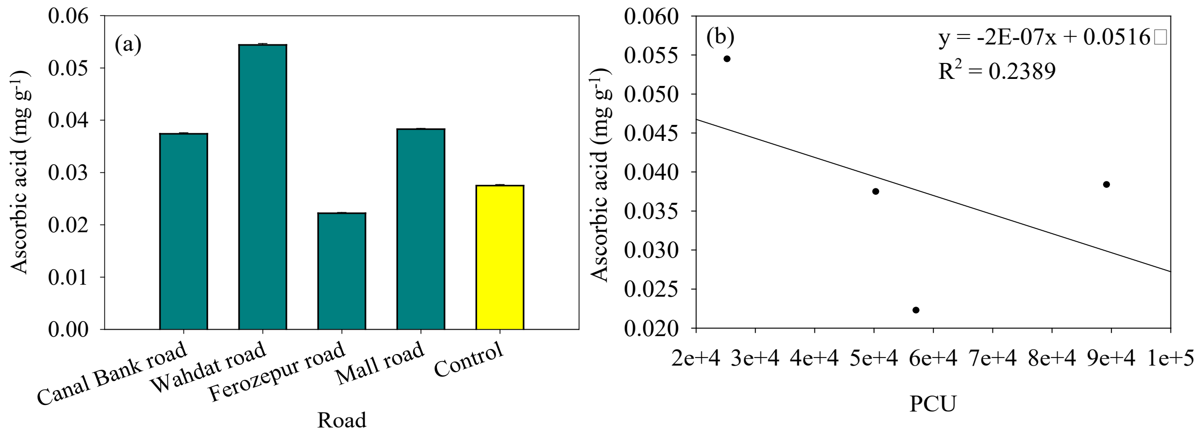

Fig. 6. (a) Ascorbic acid content of *A. scholaris* and (b) Correlation between ascorbic acid content and PCU.

antioxidant which the increases tolerance ability of plants under pollution stress. The maximum concentration of AAC was calculated in the air pollution region as compared to the less pollution area. Tripathi and Gautam (2007) reported that the concentration of AAC increased to air pollution in all plant species, which might be due to the increased production of reactive oxygen species (ROS) during the photo-oxidation process.

3.3.3 Total chlorophyll content

Chlorophyll plays important role in the photosynthetic system, absorbing sunlight, transfer electrons during photosynthesis growth and biological processes of plants (Hu *et al.*, 2021). The average TCh content for *A. scholaris* was 0.0537 mg g^{-1} acquired from different road containing Mall road (0.046 mg g^{-1}), Ferozepur road (0.062 mg g^{-1}), Canal Bank road (0.053 mg g^{-1}) and Wahdat road (0.054 mg g^{-1}). The mean value for the control site sample was (0.052 mg g^{-1}) (Fig. 7(a)). The maximum value of TCh content was detected for the Ferozepur road sample while the least value was detected for the Mall road samples. TCh content calculated in different sites was in the following order: Ferozepur road > Wahdat road > Canal Bank road > Mall road.

Correlation showed that TCh content decreases with increases the traffic flow (Fig. 7(b)). Achakzai *et al.* (2017) observed the minimum TCh content in plants, which grow under stress condition. Degradation of content was used as an indicator of pollution stress. Qadir and Siddiqui (2014) described that plants exposed to air pollution gradually decrease the TCh content and co-occurrence of leaf chlorosis which might be associated with the decrease in photosynthetic activity.

3.3.4 Leaf extract pH

Leaf extract pH values for *A. scholaris* in the polluted region were 5.86 (Mall road), 6.05 (Ferozepur road), 6.02 (Canal bank road) and 5.85 (Wahdat road), while the mean leaf extract pH was 5.94 (Fig. 8(a)). The highest pH was observed for the sample of Ferozepur road while the lowest pH was observed from the sample collected from Wahdat road. The order of leaf extract pH was Ferozepur road > Canal Bank road > Mall road > Wahdat road. The result of the correlation represented that pH decreases with increases the traffic flow on all the roads (Fig. 8(b)). Kumar and Nandini (2013) noted that plants with least leaf extract pH are more vulnerable than those with higher pH, and the plants with leaf extract pH of 7 are tolerant to air pollution stresses. Leaf extract pH plays an important role in physiological processes. Achakzai *et al.* (2017) examined that most of the enzymes involved in biological functions required high pH for their work. Plants with minimum pH values are less tolerable to air pollution. Escobedo *et al.* (2008) reported that the high pH may improve the conversion of hexoses into vitamin C.

3.3.5 Relative water content

The mean RWC values in leave samples collected from Mall road (75.0%), Ferozepur road (67.7%), Canal bank road (59.3%) and Wahdat road (71.3%) are presented in (Fig. 9(a)). The mean

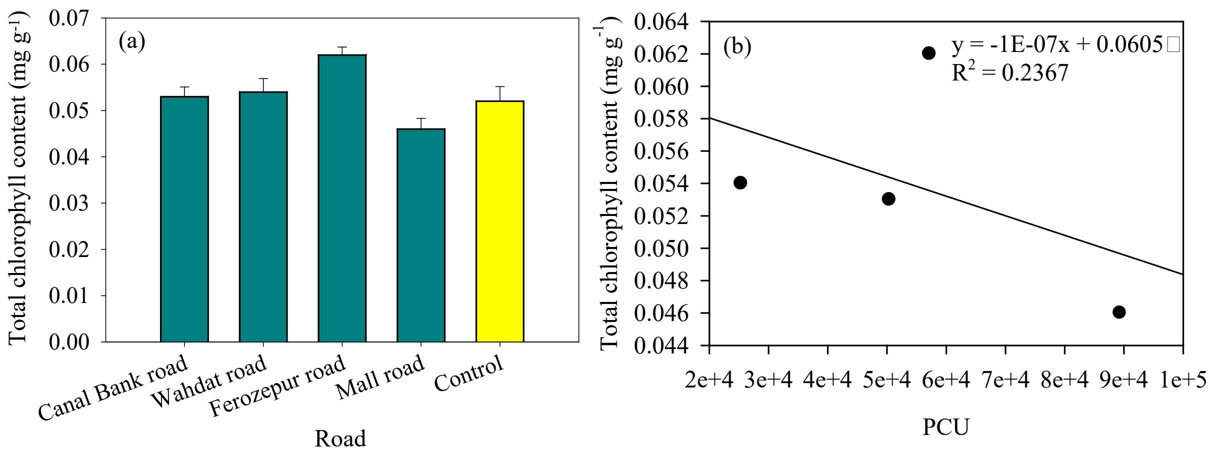

Fig. 7. Total chlorophyll content of *A. scholaris* and (b) Correlation between total chlorophyll content of *A. scholaris* and PCU.

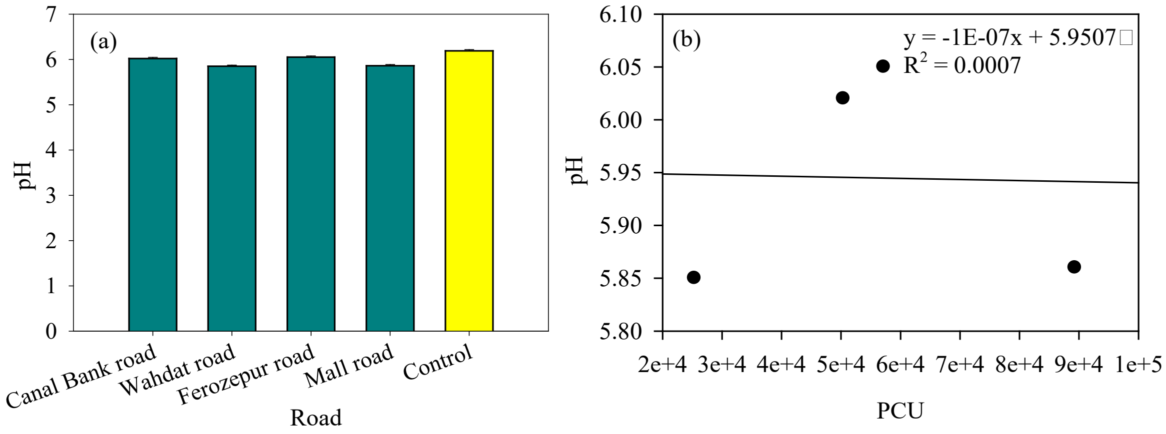

Fig. 8. (a) pH of leaf extracts *A. scholaris* and (b) Correlation between leaf extracts pH of *A. scholaris* and PCU.

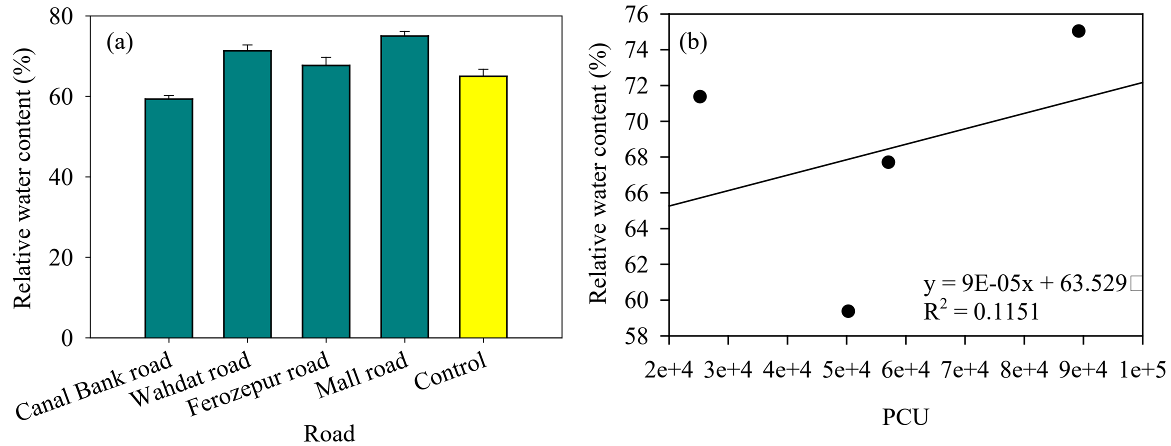

Fig. 9. (a) Relative water content of *A. scholaris* and (b) Correlation between relative water content of *A. scholaris* and PCU.

value from the control site was found to be 65.0%. The maximum value of RWC was calculated from Mall road while the lowest value was examined from Canal Bank road. The order of RWC of different road was Mall road > Wahdat road > Ferozepur road > Canal Bank road.

Correlation between RWC and traffic flow showed that increases the RWC increase with large number of vehicles on the different roads (Fig. 9(b)). The highest RWC value was observed in the highly polluted site where traffic flow was high. Rai and Panda (2014) reported that a maximum RWC under a stressed condition indicates that the plant species are tolerable to that condition. While the plant species have minimum value of RWC, grown under air pollution sites reduced the transpiration rate, and lose its capability to raise water by transpiration pull from root to leaves. Higher RWC in the polluted site signifies the physiological balance and adaptive response toward air pollution (Tsega and Prasad, 2014).

3.4 Air Pollution Tolerance Index

The APTI values determined for *A. scholaris* from different roadsides samples, Mall road (0.231), Ferozepur road (0.222), Canal Bank road (0.107), Wahdat road (0.324) and control site (0.165) are presented in (Fig. 10(a)). The highest value of APTI was observed for the samples collected from Wahdat road, whereas the lowest APTI was observed for the sample collected from Canal Bank road because large number of different plant species planted along roadside absorb air pollutants more efficiently. In this study the correlation between APTI and traffic flow showed that the APTI values for *A. scholaris* decreases with increase the traffic flow on the selected road (Fig. 10(b)). Singh *et al.* (1991) reported that Plants with maximum APTI values shown positive response to

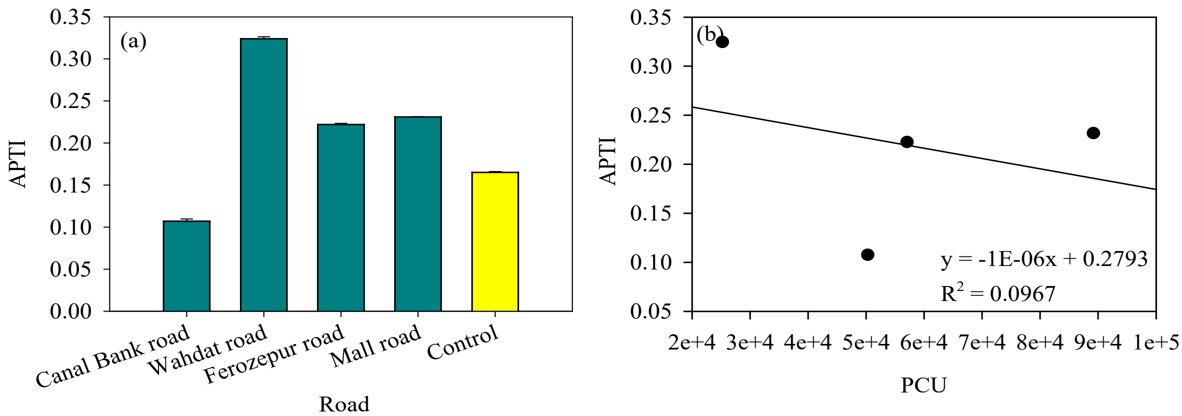

Fig. 10. (a) APTI values of *A. scholaris* and (b) Correlation between APTI values of *A. scholaris* and PCU.

air pollution while those with minimum APTI values are more susceptible to air pollution. Fatima *et al.* (2020) assessed APTI of plants at Anwarul campus of Hyderabad. They evaluated APTI for determining the sensitivity and tolerance of plants used as bio-indicators under pollution stress. Tak and Kakde (2020) examined APTI and air pollution performing index (API) of plant species grown in an industrial zone. Their results showed that *Azadirachta indica*, *Cassia siamea* and *Ficus* were tolerant species based on APTI and API values.

In Pakistan, it is important to screen and control the pollutants with the increase in the number of road vehicles. Ghauri *et al.* (2007) observed PM_{10}, TSP, SO_2, NO_x, and O_3 are more in Lahore city with respect to total suspended particulate (TSP) and coarse particles (PM_{10}) to be 996 and 368 $\mu g\ m^{-3}$, respectively. The maximum of air pollutants and correlation with traffic density were noted near the busiest road. The studies conducted by Pakistan-EPA on ambient air quality at major roads in Punjab city observed that maximum concentration of particulate matter had a substantial association with vehicular traffic on roads. Therefore, APTI values of the roadside plants were higher due to the pollution stresses caused by the highest amount of PM_{10}, TSP, SO_2, NO_x, and O_3 in the air at major roads of Lahore while lowest at the control site. The highest value of APTI indicates that plants possess tolerance against heavy pollution.

4 CONCLUSIONS

Air pollution is a big and serious issue worldwide. In the last couple of decades, the increasing urban population, industrialization, and ever-growing automobile population have led to the degradation of air quality globally. In the present study, *A. scholaris* trees, planted along the polluted roadside of Lahore city had higher dust content (0.381 mg mm^{-2}) loads on leaves than those planted in the control site. Likewise, the AAC (0.0380 mg g^{-1}), RWC (68.3%), and APTI (0.221) of this plant species were higher for the road where traffic flow is high. APTI value in the Canal bank road is lower compared to control site might be large number of plantation along the bank of canal. AAC in the leaves was the most crucial factor providing tolerance to plants. However, the leaf extract pH and leaf area were lowest in the trees planted the roadside of Lahore city as compared to the trees planted in the control site. The TCh content varied more in polluted sites as compared to control site plants. Although it is common for different plant species to have different levels of tolerance to air pollution stress, the results of the present study suggested that a plant species could demonstrate different levels of tolerance according to the degree of air pollution.

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