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Assessing of Air Pollution Tolerance Index of Plant Species in Aliero
Local Government Area, Kebbi State North-Western Nigeria

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ABSTRACT

Green plants along roads can provide eco-friendly effective structure to improve air quality and to reduce human exposure to air pollutants. However, the plants used for the development of green vegetation must be tolerant to air pollutants. The present study compares the air pollution tolerance index (APTI) of different plant species found in the vegetation traffic barriers in the Aliero area, Kebbi State. Biochemical and physiological parameters (relative water content, leaf extract pH, total chlorophyll and ascorbic acid) were analyzed. The finding revealed that, *Azadirachta indica* had the highest ($p < 0.05$) content of Ascorbic acid (9.60 ± 1.0), Relative water contents (88.8 ± 3.1), and pH (7.53 ± 0.2) but low ($p < 0.05$) chlorophyll contained (18.48 ± 0.6) when compared with other plant species at the experimental site (polluted site). All the plant species at experimental site demonstrated tolerance to air pollution based on APTI index. Highest APTI value ($p < 0.05$) was observed in *Azadirachta indica* (33.85 ± 0.2) followed by *Mangifera indica* (23.57 ± 0.5). *Azadirachta indica* was expected as an excellent tolerant plant to air pollution on the basis of APTI value. Higher levels of ascorbic acid content, high pH value and low chlorophyll content observed at polluted site as compared to control site, were sign of stress condition. Plant species with highest APTI value could be used in cost effective green vegetation management for reducing the levels of atmospheric pollution.

Keywords: air pollution, apti, green plants, ascorbic acid, chlorophyll

1.0 INTRODUCTION

Air pollution is the introduction of foreign particles (chemicals, particulate matter, biological substance) originated from natural processes or human activities (Karmakar and Padhy, 2019) into the atmosphere that causes diseases, discomfort to living organisms and damage the environment (Lohe, *et al.*, 2015). Air pollution is one of the common environmental problems facing the world population today (Tanee and Albert, 2013), and is getting worse with growing population due to loss of natural vegetation, increased in transportation and high industrial activities (Gulia *et al.*, 2015; Karmakar and Padhy, 2019). Industries and transportation are major causes of urban air pollution worldwide (Shrestha *et al.*, 2021). Air pollution has significant impact on climate change, public and individual health (Manisalidis *et al.*, 2020) and it's one of leading causes of diseases in developed and developing countries (Shrestha *et*

al., 2021). Developed countries are experiencing heavy air pollution due to an increase use of automobile transportation, industrial activities, expansion of human settlements and decreasing of green vegetation day by day due to natural phenomena and human activities.

Green plants play a significant role in decreasing the effect of air pollution (Pandey, 2015) thus, they can be utilized for mitigation the impact of air pollution on climate change and public health. Green plants are classified into sensitive, intermediate and tolerance to air pollution (Bharti *et al.*, 2018). Sensitive plants to air pollution experienced physiological and morphological changes when exposed to air pollutants (Liu and Ding, 2008). Hence, sensitive plant species are the effective bio-monitor of air pollution because plants are the initial acceptors and susceptible to air pollutants present in the atmosphere (Tanee and Albert, 2013). Air pollutants causes stomatal and leaf injury, decreases plant photosynthesis by

decreasing chlorophyll contents and reduced growth as well as plant's yield (Tiwari *et al.*, 2006). The ability of the plants to tolerate air pollutants depends on their biochemical, physiological and morphological characteristics (Tanee and Albert, 2013). Air pollution tolerance index (APTI) describes the inherent ability of the plants to resist the impact of air pollution (Shrestha *et al.*, 2021). APTI value is based on two biochemical parameters total chlorophyll content (Molnar *et al.*, 2020) and ascorbic acid content (Tanee and Albert, 2013) and two physiological parameters pH (Klumpp *et al.*, 2000) and relative water content (Rao, 2006). Total chlorophyll, relative water content (RWC), ascorbic acid and the pH of leaf extract are the biochemical and physiological parameters for describing the APTI index of a specific plant species (Molnar *et al.*, 2020). These parameters dependent on each other and are sensitive to air pollutants (Kanwar *et al.*, 2016). APTI value is the most important biochemical tool for classifying plants based on their tolerances or sensitivity levels to air pollution. APTI value was categorized into three groups; 1-11 (sensitive), 12-16 (intermediate) and ≥ 17 tolerant (Bharti *et al.*, 2018; Ogunkunle *et al.*, 2015). Based on APTI value, plants with low APTI value (sensitive plant species) can be used in low pollution areas as bio-monitors, while plants with high APTI value (tolerant plant species) can be used in highly polluted areas to mitigate air pollution. Several researches were conducted on the type of plant species to be used in urban green vegetation. Some of these studies were conducted in Nigeria (Tanee and Albert, 2013; Agbaire and Esiefarienrhe, 2009). However, the conclusions of these studies cannot be generalized over different regions in Nigeria because of the differences in geographic and climatic conditions. In this paper an attempt has been made to study the biomonitoring and tolerance potential of some common terrestrial plant species; *Annona muricata*, *Adansonia digitata*, *Azadirachta indica*, *Mangifera indica* and *Ficus polita* of Kalli, Kwanar Kashin Zama, Gidan Taya and Shiyar Chediya (experimental site) and Aliero State University (control site) all in Aliero Local Government, Kebbi State.

2.0 MATERIALS AND METHODS

2.1 Study Area

The area for study is Aliero Local Government area of Kebbi State Northern Nigeria.

2.2 Plants Sampling

For experimental purpose, a total of five dominant tree species i.e., *Annona muricata*, *Adansonia digitata*, *Azadirachta indica*, *Mangifera indica* and *Ficus polita* were selected because of their presence at both the control and experimental sites. For investigation, leaves from top, middle and base canopy of plants were collected in the morning between 07: 00 A.M and 10: 00 A.M. from the experimental site and the control site, the sampling was done in triplicate. Collected samples were put in a labelled polyethene bags and brought to the laboratory in an icebox for analysis. The samples of each plant species obtained from the same site were mixed to make a composite sample for each site. Thus, there were ten composite samples, each corresponding to one of the plant samples obtained from experimental site and control site respectively. Three replicate analyses were done for each composite samples. Care was taken to ensure all plants undergoing investigation had isoecological conditions with respect to light water, soil and pollutant exposure.

2.2 Methodology

The following physiological and biochemical parameters were analyzed: leaf Relative water contents (RWC), ascorbic acid content (AAC), total leaf chlorophyll content (TLC) and pH of leaf extract. These were used to compute the APTI values for both the experimental and control site.

2.2.1 Determination of Relative Water Content

Three different weights of the leaves (fresh weight taken immediately after collecting leaves, turgid weight after immersing in water overnight and the dry weight after drying in hot air oven at 70 °C overnight) were used for calculating the RWC of leaves (Singh and Rao, 1983).

$$RWC = \frac{\text{Fresh Weight (FW)} - \text{Dry Weight (DW)}}{\text{Turgid Weight (TW)} - \text{Dry Weight (DW)}} \times 100$$

2.2.2 Total chlorophyll

A crushed leaf sample (5 g) was taken, and 10 mL of 80% acetone was added to it. Then, the sample was left aside for 15 min for thorough extraction. The leaf extract so obtained was decanted into

centrifuge tubes and was centrifuged at 2500 rpm for 10 min. Then, the absorbance was taken at 645 nm and 663 nm using a spectrophotometer. The total chlorophyll content was calculated using equation below (Arnon, 1946)

$$Tch = (20.2(A_{645}) + 8.02(A_{663})) \times \left(\frac{V}{1000 \times W}\right)$$

2.2.3 Ascorbic acid

A part of fresh leaf tissue (1 g) was crushed and put in a test-tube. Then, 4 mL oxalic-ethylenediaminetetraacetic acid extracting solution was added to the test-tube followed by 1 mL orthophosphoric acid, 1 mL of sulphuric acid (5%), 2 mL ammonium molybdate (5%) and 3 mL distilled water. The solution was allowed to stand for 15 min and the absorbance was measured at 760 nm with a spectrophotometer. The concentration of ascorbic acid was obtained from the standard curve of ascorbic acid in mg mL⁻¹ and converted to ascorbic acid content per gram dry weight (Singh *et al.*, 1991).

2.2.4 Leaf-extract pH

3. 0 RESULT AND DISCUSSION

3.1 Relative Water content

Relative water content is the balance between water uptake and its release by the plants. Air pollution increases protoplasmic permeability of the cells, causes loss of water and nutrients leading to early senescence of the leaves (Karmakar and Padhy, 2019). RWC of the chosen plant species varies between 57.84±.46 to 88.80±.25 % (Fig. 1). RWC of all the plant species in experimental site (ES) were significantly (p<0.05) higher than those in the control site (CS) (Fig. 1) with the exception of *Annona muricata* and *Ficus polita*. *Azadirachta indica* from the experimental site had the highest RWC (88.8±.25 %), followed by *Adansonia digitata* (84.88±.76), *Mangifera indica* (83.83±.24) and *Ficus polita* (64.64±.25) while *Annona muricata* (57.84±.39) had the lowest RWC. This is

Leaf sample (5 g) was crushed and homogenized in 50 mL deionized distilled water. The sample was filtered and the pH of leaf suspension was measured using a pH meter (Singh *et al.*, 1991).

2.2.5 Determination of APTI

The method of Singh *et al.* (1991) was used in the calculation of APTI.

$$APTI = \frac{A(T+P)+R}{10}$$

Where, A = ascorbic acid content (mg/g); T = total chlorophyll content (mg/g); P = pH of leaf extract and; R= relative leaf water content (%).

2.3 Statistical analysis

All the statistical analyses were carried out by using Microsoft Excel 2013 and SPSS statistical software version 21.0. All the analyses were performed in triplicate for each sample and expressed as mean ± SE. The significant difference in four parameters (total chlorophyll content, pH, ascorbic acid content and relative water were tested by one-way analysis of variance (ANOVA).

an indication that, plants species survive at the polluted area retain more water than those at less polluted area. The present finding agrees with the previous finding of Tanee and Albert (2013), Shrestha *et al.* (2021) and that of Zhang *et al.* (2015) whose reported higher RWC in plants obtained from polluted site. High RWC might be the possible adaptive feature that help the plants to survive in polluted area (Rai and Panda, 2014). RCW control and balance the physiological activities of the plant (Tanee and Albert, 2013) and is associated with the plant tolerance against air pollution (Achakzai *et al.*, 2017). Air pollutants decreases RWC in sensitive plant species which in turn lower stomatal CO₂ assimilation by the plant. Hence, decreases photosynthetic ability of plant (Lawlor, 2002).

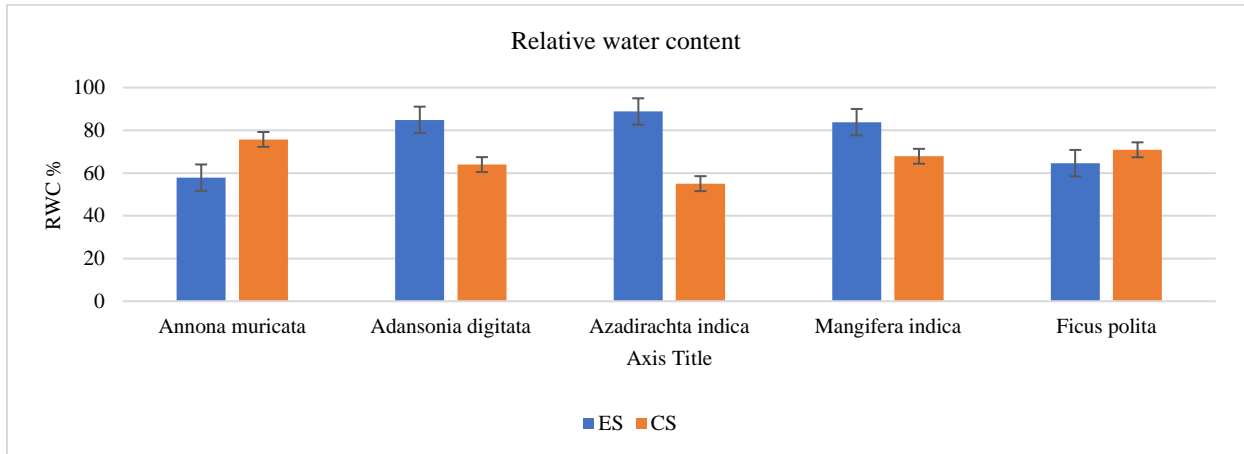


Fig. 1 Average relative water content of the selected plant species; error bars represent the standard deviation (n = 3).

3.2 Total chlorophyll

Chlorophyll is the principal photoreceptor pigment in photosynthetic plant and also act an indicator of plant's growth and productivity (Pavlovic *et al.*, 2014). The chlorophyll content of plants differs from species to species; age of leaf and also with the level of pollution as well as with other biotic and abiotic factors (temperature, drought, light intensity, salt stress) (Katiyar and Dubey, 2001). The total chlorophyll content of the selected plants was found between range from 30.20 ± 0.03 mg/g to 15.58 ± 0.19 mg/g from the control site while the range of 19.04 ± 0.08 mg/g to 12.48 ± 0.12 total chlorophyll content was found in the experimental site (Fig. 2). *Adansonia digitata* contained the lowest chlorophyll contain from the both sites i.e., control (15.58 ± 0.19) and experimental site (12.48 ± 0.12). In the present study, it has been

observed that plant species from the control site with exception *Azadirachta indica* contained higher chlorophyll content ($p < 0.05$) when compared to those plants from the experimental site. There was no significant different ($p > 0.05$) in chlorophyll content of *Azadirachta indica* obtained from the experimental site (18.48 ± 0.06) and that of control site (19.61 ± 0.06). The significant reduction of total chlorophyll content observed in experimental site when compared with control site could be as result of chlorophyll degradation caused by an increase of chlorophyllase enzyme activity (Kumar *et al.*, 2017) due to the impact of air pollution. The present finding is in line with finding Joshi and Swami (2007) and Taneer and Albert, (2013) who reported that, the most common effects of air pollution were the significant decreased of chlorophyll content and leaf chlorosis.

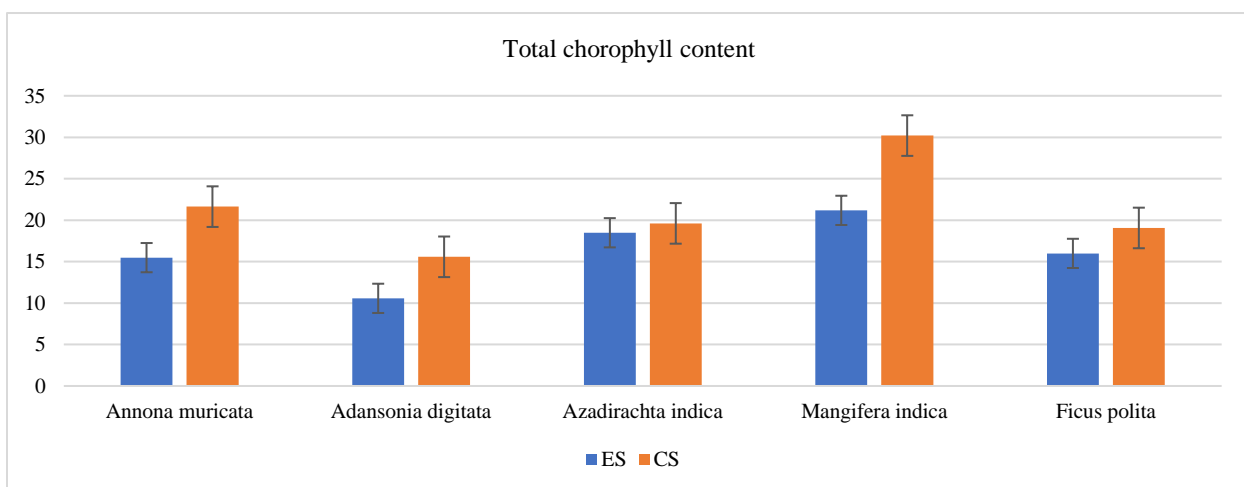


Fig. 2: Total chlorophyll content in different tree species at control and experimental site: error bars represent the standard deviation (n = 3)

Entering of air pollutants such as SO_2 , and NO_2 through the stomata of the plant cause partial denaturation of the green pigment which in turn leads to significant reduction of total chlorophyll content in the polluted leaves (Rai, 2016). Jyothi and Jaya (2010) reported that, high levels of automobile pollution decrease chlorophyll content in higher plants near roadsides. Also, Woo and Je (2006) that reported that sensitive plant species found in polluted area experience low chlorophyll content.

3.3 Ascorbic Acid Content

AAC is a strong reductant and antioxidant agent that provides resistance to chloroplast in a stressed condition against reactive oxygen species (ROS) (SO_2 , H_2O_2 , O_2 and OH) accumulation. It's usually found mostly in all growing parts of plants. Air pollutants increases the production of reactive

oxygen species which in turn increases the ascorbic acid content in the plant parts (Rai, 2016). The AAC in the leaves of the selected plant species at experiment site and control site were presented in the (fig 3). The result of the study revealed that *Azadirachta indica* has the highest ascorbic acid content (9.60 ± 0.10) at the experimental site, while *Annona muricata* has the highest content (6.11 ± 1.9) at the control site. The least content of ascorbic acid at both the sites was shown by *Ficus polita* (3.2 ± 1.2) and (1.47 ± 1.2). According to Nadgorska-Socha *et al* (2017) higher content of ascorbic acid in leaves of plant increases the tolerance of the plant species against air pollution and other environmental stresses (biotic and abiotic factors). Tolerant plants contain higher content of ascorbic acids while sensitive plants contain lower amount of ascorbic acid.

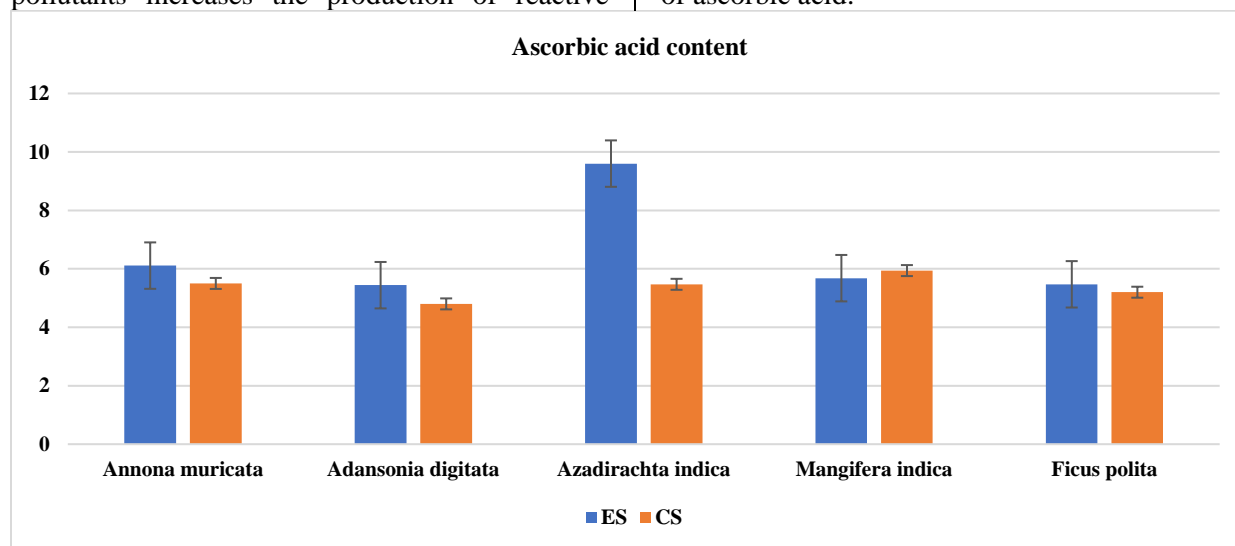


Fig. 3: Ascorbic acid content in different tree species at control and experimental site: error bars represent the standard deviation (n = 3)

3.4 pH of leaf extract

Plants with lower pH are more susceptible to air pollution than those with pH around or above 7 (Alkaline) (Lohe *et al.*, 2015). The pH of the leaf extract of the selected plant species ranges from 5.5 to 7.5 The highest pH value was observed from *Azadirachta indica* (7.53 ± 0.02) while the least pH was found in *Mangifera indica* (5.56 ± 0.02) at the experimental site. In the present study, the pH value *Azadirachta indica* (7.53 ± 0.02) was significant ($p < 0.05$) higher in experimental site as compared to the pH of other plant species at the same site. The present finding agrees with finding of Rai and

Panda (2014) who reported that, higher level of pH increases the tolerance level of plant species to air pollutants by converting hexose sugar to ascorbic acid in foliar tissue of plants. However, the present result contradicts the finding of Joshi and Bora (2011) whose reported that, air pollutants (nitric oxide (NO_x) and sulphuric oxide (SO_x)) in atmospheric air lowered the pH of the leaf extract. The higher pH observed in *Azadirachta indica* might be correlated with high ascorbic acid contain found in *Azadirachta indica* at the experimental site. The activity of ascorbic acid is also pH-dependent which is high at higher pH and low at

lower pH. Therefore, high leaf extract pH makes plants more tolerant to air pollution, low pH also reduces the photosynthetic efficacy of the plant

species by decreasing chlorophyll content (Bharti *et al.*, 2018; Shrestha *et al.*, 2021; Lohe *et al.*, 2015).

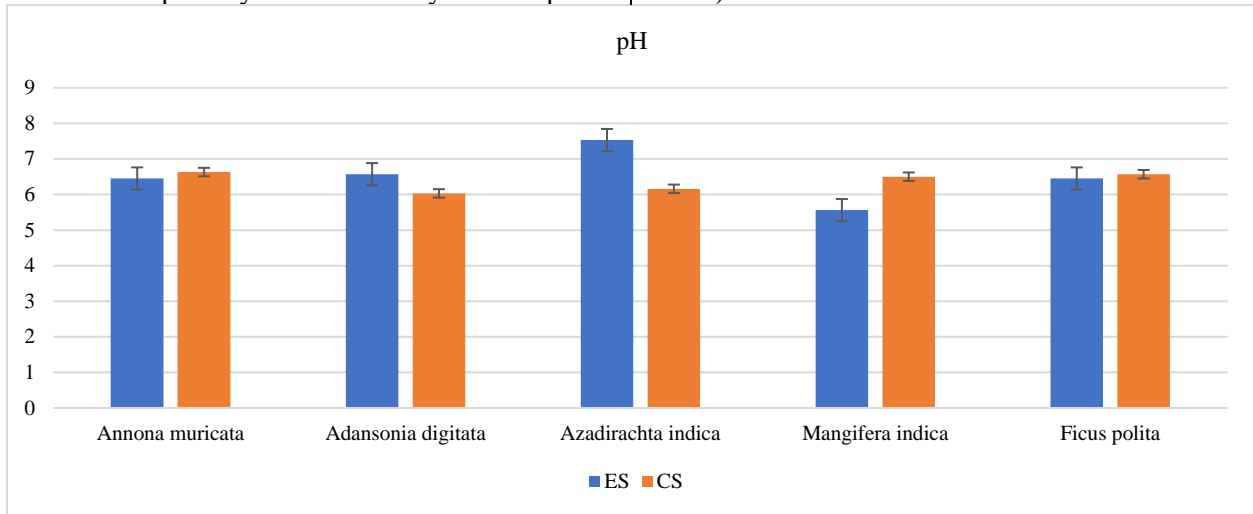


Fig. 4: pH of leaf extract in different tree species at control and experimental site: error bars represent the standard deviation (n = 3)

3.4 APTI

In the present study, the result of APTI demonstrated that *Azadirachta indica* and *Mangifera indica* growing in the experimental site had higher APTI values than those at the control site. Maximum APTI value was observed in *Azadirachta indica* (33.85 ± 0.2) at the experimental site. Plant species with higher APTI value are considered as a tolerant species to air pollution and can be used for decreasing the levels

of air pollution. The increased of APTI values of the selected plant species was in the order; *Azadirachta indica* > *Mangifera indica* > *Annona muricata* > *Ficus polita* > *Adansonia digitata*. The difference of the APTI value observed in different plant species can be attributed to the variation in any of the four physiological factors (RWC, pH, AAC and Total Chlorophyll) which governs the computation of the APTI index.

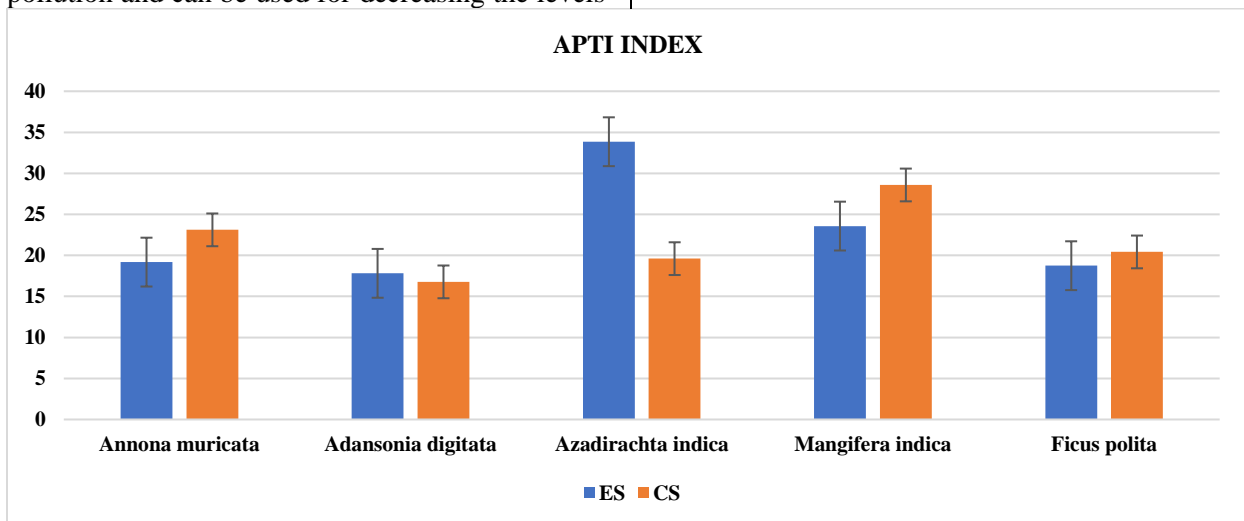


Fig. 5: APTI index of different tree species at control and experimental site: error bars represent the standard deviation (n = 3)

4.0 CONCLUSION

The tolerant plant species (*Azadirachta indica* and *Mangifera indica*) identified in the present study could be used in urban green belts

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