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Assessment of indoor plant's performance in banks, offices, hospital and kitchen

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Abstract
The present investigation was conducted during 2017-2019 in which the performance of selected indoor plants were evaluated under different locations. Under this study, five indoor plants *viz. Aglaonema modestum, Scindapsus aureus, Chlorophytum comosum*, *Nephrolepis exaltata* and *Kalanchoe blossfeldian* were selected on the basis of their Air Pollution Tolerance Index and were kept in different locations such as office, bank, hospital, canteen (kitchen area) and control located within the premises of Dr. Y.S Parmar University of Horticulture and Forestry, Nauni, Solan (H. P.) with iso-ecological situation. Different morphological and anatomical parameters of selected indoor plants were evaluated to assess their performance under these locations which contain different types of pollution stresses. Morphological parameter like visual leaf colour grade was found maximum in the plants which were kept in offices (4.769) as compare to other locations. *Scindapsus aureus* and *Aglaonema modestum* showed best visual colour grade under different locations. Further Anatomical parameters like number of stomata and stomatal index were found maximum in *Scindapsus aureus* and *Aglaonema modestum* in all locations. Biochemical parameters like ascorbic acid (0.595 mg/g), relative water content (91.70%) and APTI (9.51) were also found maximum in these indoor plants when were kept at canteen site. From this study, it was concluded that *Aglaonema modestum* and *Scindapsus aureus* having high APTI index and performed best under different locations and these plants can be used for indoor landscaping in urban areas.

Keywords: APTI Index, indoor plants, locations, indoor air pollution

Introduction

Over the years, there has been a continuous increase in human population, transportation, vehicular traffic and industries, which have resulted in increase in the concentration of gaseous and particulate pollutants (Joshi and Swami, 2009) [8]. The substances that pollute the environment are called pollutants, which include gases (sulphur oxides, oxides of nitrogen, carbon monoxide, hydrocarbons, etc.), particulate matters (smoke, dust, fumes, aerosols), radioactive materials and others (Chauhan *et al*., 2004) [3]. The effectiveness of plant species as bio-indicator or tolerance to the air pollution depend upon the air pollution tolerance index (APTI). APTI index is the capability of plants to survive against the air pollution and helps to determine the tolerance and sensitivity of plants against air pollution. Plant's tolerance and sensitivity to air pollutants depends on parameters like chlorophyll content, ascorbic acid content, leaf pH and relative water content. Plants provide sufficient leaf area for absorption and accumulation of air pollutants to reduce the air pollution in the environment (Escobedo *et al.*, 2008) [5], whereas, stomata help to remove the gaseous air pollutants (Kapoor, 2014) [9]. Plants are also initial acceptors of air pollution and act as the scavengers (Mahecha *et al*., 2013) [11]. Indoor plants in urban areas or in home or kitchen play a vital role in reducing the indoor air pollution. Evaluation of plants for their tolerance and sensitivity level to air pollutants is more important because the sensitive plants can serve as bio-indicators and tolerant plants as sink for air pollution in indoor areas. Air pollution tolerance level may vary from species to species depend upon the capacity of plants against air pollution without showing any physical damage. Leaves at various stages of development serve as good indicator of air pollutants. Hence, bio-monitoring of plants has been considered as an important tool to evaluate the impact of air pollution (Rai *et al*., 2014) [13]. Since the 1980s, NASA has been studying house-plants for the purification of space stations. Since then, lots of studies have produced a number of especially capable plants with higher-than-average VOC filtering capacity. At the end of the 1980s, NASA researchers studied the ability of houseplants to purify the air and remove hazardous agents such as benzene (in cement, paint and auto fumes); formaldehyde (in particleboard, paper and carpets); and trichloroethylene (in paint stripper and spot remover). Considering these facts, the present study was conducted on commonly growing indoor plants in mid hills of H.P. to study the APTI and their performance in different environmental conditions.

Material and Methods

Present study was conducted during 2017-2019 in which the performance of selected indoor plants were evaluated under different locations like offices, banks, health centre and canteen which contain different types of pollution stresses. Five indoor plants *viz*. *Aglaonema modestum, Scindapsus aureus*, *Chlorophytum comosum*, *Nephrolepis exaltata* and *Kalanchoe blossfeldian*a were selected on the basis of their Air Pollution Tolerance Index (APTI). The APTI determining various biochemical parameters such as total chlorophyll content (mg/g) as per Hiscox and Israeistam (1979) [6], leaf extract pH as per Barrs and Weatherly (1962) [2], ascorbic acid content (mg/g) as per A.O.A.C., (1980) [1], relative water content (%) as per Singh (1977) [17] were determined from leaves of fully grown plants. Selected indoor plants were kept in different locations such as office, bank, hospital, canteen (kitchen area) and control located within the premises of Dr. Y.S Parmar University of Horticulture and Forestry, Nauni, Solan (H. P.) with iso-ecological situation. Different morphological and anatomical parameters of selected indoor plants *viz*. visual leaf grade as per Henny *et al*. (1983), leaf area (leaf area meter Model - LI – COR – 3100), number of stomata and stomatal index as per nail varnish method and were also determined. Ascorbic acid content, relative water content, leaf pH and total chlorophyll content were also estimated to calculate air pollution tolerance index using following formula;

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

Design of the experiment was factorial Completely Randomized Design (CRD) with 3 number of replications.

Result and Discussion

Visual leaf colour grade

Maximum visual leaf colour grade was observed in *Scindapsus aureus* (4.676), which was followed by *Aglaonema modestum* (4.668). Among different environmental conditions, maximum visual grade point was obtained in the plants which were kept in offices (4.769). *Scindapsus aureus* and *Aglaonema modestum* showed best visual colour grade under different environmental conditions. It shows that these two indoor plants performed good in all sites with dark green and shiny leaves. Regarding different environmental conditions, the plants kept in canteen (kitchen area) showed poor quality leaves of indoor plants. Similar findings were observed by Raina and Sharma (2006) [15], who reported that leaf colour changes from bright green to dull green when plants were grown in polluted site (Table 1.1)

Leaf area

Maximum leaf expansion was recorded in all selected indoor plants which were kept at floricultural farm site (control) as compare to other locations. Whereas minimum leaf area was recorded in plants which were kept in canteen site. The reduced area of leaves at the canteen site may be due to unfavourable conditions particularly in this site like less ventilation due to which there is accumulation of volatiles which may release from kitchen area and more number of visitors. Zang *et al*., 2010 [27] in their studies, reported that CO, CO_2, formaldehyde, PM (Particulate Matter), PAH (Polycyclic aromatic hydrocarbons) and VOC *viz.* benzene, toluene and xylene are common pollutants released from kitchen premises, which resulted in less cell expansion or elongation of leaves. It may be due to less chlorophyll content of leaves at the polluted site (Tiwari *et al*., 2006) [22]. (Table 1.2)

Number of stomata and stomatal index

Maximum number of stomata (42.245) were found in *Aglaonema modestum* when was kept under Floriculture farm (control). More number of stomata (36.083) were observed in all indoor plants kept in floricultural farm as compared to other sites. Whereas, least number of stomata (29.032) were recorded at canteen site. Further, maximum stomatal index (26.393%) was found in *Nephrolepis exaltata* when kept in floricultural farm. Stomatal index (16.450%) of indoor plants was recorded more in plants kept at floricultural farm site followed by office location (15.939%). This may be due to the reason that growing conditions of farm are favourable without any biotic or abiotic stress. Whereas minimum stomatal index (12.655%) was recorded at canteen site. The possible reason of reduced number of stomata and stomatal index in canteen site may be the presence of pollutants like CO_2, CO, NO_X, SO_2, VOC and Particulate matter (Chauhan *et al.*, 2017) [4] in kitchen site. Reduction of the number of stomata and stomatal index is important for controlling the absorption of pollutants (Verma *et al.*, 2006) [26]. The present results are also supported by Lata *et al.* (2010) [10], who reported that air pollutants decreased the number of stomata, stomatal index and stomatal size of the plants. The results are also in line with the reports of Saadabi (2011) [16], who reported decreased number of stomata and stomatal index at the polluted site as compare to control site. (Table 1.3 and 1.4)

Ascorbic acid content (mg/g)

Among five selected indoor plants, maximum ascorbic acid content (0.447 mg/g) was found in *Nephrolepis exaltata*, while minimum ascorbic acid content (0.246 mg/g) was observed in *Scindapsus aureus*. These results are consistent with the findings of Rai *et al*. (2013) [14], who reported that ascorbic acid is a stress-reducing factor and is generally present at higher levels in tolerant plant species. Further, more ascorbic acid content (0.595 mg/g) was analysed in the indoor plants kept at canteen site as compared to control (floricultural farm) with minimum ascorbic acid content (0.258 mg/g). It may indicate that plants were under more stress in canteen site due to the presence air pollutants. (Table 2.1)

Total chlorophyll content (mg/g)

Decreased chlorophyll content of leaves of plants which were kept in canteen site was observed as compared to control. It may be because of accumulation of CO_2 concentration and other gases released from cooking area due to less ventilation in the canteen area which negatively affect plant growth and photosynthetic capacity by reducing leaf chlorophyll content, denaturation of chloroplast and decrease in pigment content due to the replacement of Mg ions with hydrogen atoms in cells. Joshi and Swami (2007) [7] also studied the impact of air pollution on plants and found gradual depletion of chlorophyll and leaf yellowing was directly correlated with a consequent reduction in photosynthesis ability. (Table 2.2)

Leaf pH

The plants which were kept in floricultural farm (control) resulted in maximum leaf pH (6.59), while less pH (5.22) was found in the plants kept at canteen site. The possible reasons may be due to the presence of acidic pollutants such as SO_2, NOx and VOC in ambient air reported by Singh and Verma (2007) [19]; Rai and Panda (2014) [13]. (Table 2.3)

Relative water content (%)

More relative water content (91.70%) of plants was found at canteen site as compared to control site (Floriculture farm) with minimum relative water content (87.45%). Possible reason behind more relative water content in canteen site may be due to prevailing stress conditions to the plants like scarcity of ventilation, kitchen volatiles, more number of visitors in canteen site that resulted in reduced transpiration rate (Rai et al 2013; Verma 2003) [14, 25]. Other findings also revealed more relative water content in polluted sites as plants maintain the physiological balance under stress conditions such as air pollution (Sharma *et al*., 2013) [18]. Tsega and Devi prasad, 2014 [23] and Ogunkunle *et al*., 2015 [12] also observed high relative water content of plants under stress conditions. (Table 2.4)

Air Pollution Tolerance Index (APTI)

Out of selected indoor plants, maximum APTI (9.28) was recorded in *Aglaonema modestum*, which was followed by *Scindapsus aureus* (9.22). Different locations also showed significant variation in APTI of indoor plants species from 8.93-9.51. Maximum APTI (9.51) of indoor plants was found in canteen site, while minimum APTI (8.93) was recorded in the plants grown in floricultural farm (control).

In present studies, higher APTI value of indoor plants was observed in the plants which were kept at the canteen site, which implies that all selected plants have capability to adapt in stress conditions by showing more APTI in canteen site where more stress conditions were prevailing as compared to other sites. These results are in collaborated with the findings of Swami and Chauhan (2015) [20], who observed that the plants having higher APTI value have more capabilities to tolerant against stress conditions such as air pollution. Further, possible reason of high APTI value of *Aglaonema modestum* and *Scindapsus aureus* may be ascribed to their more tendency to acclimatized in different environmental conditions. Tarran *et al.* (2002) [21] also reported in their findings that *Aglaonema modestum* and *Scindapsus aureus* are suitable to grow in stress /polluted sites and further concluded that these plants also have capabilities to remove VOCs and other gases. (Table 3)

Table 1: Effect of different environment on Visual leaf colour, leaf area, leaf stomata distribution and stomatal index of different indoor plants

Table 1.1: Visual leaf colour grade of top 5 selected indoor plant species under different locations

Species / *Locations*	*Aglaonema modestum*	*Scindapsus aureus*	*Chlorophytum comosum*	*Nephrolepis exaltata*	*Kalanchoe blossfeldiana*	*Mean Locations*
Office	4.977	4.91	4.583	4.66	4.713	4.769
Bank premises	4.35	4.633	4.23	4.063	4.05	4.265
Health centre	4.81	4.673	4.42	4.177	4	4.416
Canteen/Mess	4.367	4.327	4.17	3.983	4.037	4.177
Control (floricultural farm)	4.837	4.837	4.5	4.323	4.23	4.545
Mean species	4.668	4.676	4.381	4.241	4.206	
C.D.	Species : 0.132					
	Locations : 0.132					
	Species × Locations : NS					

Table 1.2: Leaf area (cm^2) of top 5 selected indoor plant species under different locations

Species / *Locations*	*Aglaonema modestum*	*Scindapsus aureus*	*Chlorophytum comosum*	*Nephrolepis exaltata*	*Kalanchoe blossfeldiana*	*Mean Locations*
Office	95.1	72.7	33.467	61.567	34.033	59.373
Bank premises	92.3	70.143	31.7	59.767	33	57.382
Health centre	93.793	70.967	31.857	60.8	32.967	58.077
Canteen/Mess	87.007	64.577	28.133	54.277	26	51.999
Control (floricultural farm)	97.167	74	34.533	62.667	35.633	60.8
Mean species	93.073	70.477	31.938	59.815	32.327	
C.D.	Species : 3.169					
	Locations : 3.169					
	Species × Locations : NS					

Table 1.3: Leaf stomata distribution top 5 selected indoor plant species under different locations

Species / *Locations*	*Aglaonema modestum*	*Scindapsus aureus*	*Chlorophytum comosum*	*Nephrolepis exaltata*	*Kalanchoe blossfeldiana*	*Mean Locations*
Office	42.833	35.417	35.417	35.417	22.917	34.4
Bank premises	41.817	33.05	33.667	34.417	24.453	33.481
Health centre	42.083	33.917	37.667	34.25	21.5	33.883
Canteen/Mess	38.658	31.25	29.667	29.083	16.5	29.032
Control (floricultural farm)	45.833	36.167	36.917	36.917	24.583	36.083
Mean species	42.245	33.96	34.667	34.017	21.991	
C.D.	Species : 4.06					

	Locations : 4.06
	Species × Locations : NS

Table 1.4: Stomatal index top 5 selected indoor plant species under different locations

Species Locations	***Aglaonema modestum***	***Scindapsus aureus***	***Chlorophytum comosum***	***Nephrolepis exaltata***	***Kalanchoe blossfeldiana***	***Mean Locations***
Office	16.147	9.63	19.557	28.1	6.263	15.939
Bank premises	15.043	9.3	18.5	26.137	5.667	14.929
Health centre	15.517	9.033	18.8	27.247	5.8	15.279
Canteen/Mess	12.987	7.243	16.04	22.27	4.733	12.655
Control (floricultural farm)	16.72	10.4	20.187	28.213	6.73	16.45
Mean species	15.283	9.121	18.617	26.393	5.839	
C.D.	Species : 0.57					
	Locations : 0.57					
	Species × Locations : 1.27					

Table 2: Effect of different environment on Ascorbic acid content, total chlorophyll content, leaf pH and Relative water content of different indoor plants.

Table 2.1: Ascorbic acid content (mg/g) of top 5 selected indoor plant species under different locations

Species Locations	***Aglaonema modestum***	***Scindapsus aureus***	***Chlorophytum comosum***	***Nephrolepis exaltata***	***Kalanchoe blossfeldiana***	***Mean Locations***
Office	0.187	0.157	0.221	0.414	0.36	0.268
Bank premises	0.262	0.147	0.176	0.456	0.41	0.29
Health centre	0.213	0.125	0.155	0.434	0.393	0.264
Canteen/Mess	0.583	0.655	0.748	0.527	0.462	0.595
Control (floricultural farm)	0.176	0.147	0.215	0.405	0.349	0.258
Mean species	0.284	0.246	0.303	0.447	0.395	
C.D.	Species : 0.013					
	Locations : 0.013					
	Species × Locations : 0.029					

Table 2.2: Total chlorophyll content (mg/g) of top 5 selected indoor plant species under different locations

Species Locations	***Aglaonema modestum***	***Scindapsus aureus***	***Chlorophytum comosum***	***Nephrolepis exaltata***	***Kalanchoe blossfeldiana***	***Mean Locations***
Office	0.47	0.45	0.49	0.73	0.5	0.53
Bank premises	0.56	0.42	0.45	0.73	0.34	0.5
Health centre	0.6	0.39	0.7	0.49	0.45	0.52
Canteen/Mess	0.39	0.42	0.36	0.63	0.31	0.42
Control (floricultural farm)	0.7	0.61	0.73	0.79	0.55	0.67
Mean species	0.54	0.45	0.54	0.67	0.43	
C.D.	Species : 0.026					
	Locations : 0.026					
	Species × Locations : 0.060					

Table 2.3: Leaf pH of top 5 selected indoor plant species under different locations

Species Locations	***Aglaonema modestum***	***Scindapsus aureus***	***Chlorophytum comosum***	***Nephrolepis exaltata***	***Kalanchoe blossfeldiana***	***Mean Locations***
Office	6.76	6.68	6.23	6.61	6.19	6.49
Bank premises	6.48	6.41	5.94	6.1	5.52	6.09
Health centre	6.58	6.28	6.07	6.07	5.61	6.12
Canteen/Mess	5.81	5.43	5.25	5.45	4.15	5.22
Control (floricultural farm)	6.84	6.73	6.4	6.71	6.29	6.59
Mean species	6.49	6.31	5.98	6.19	5.55	
C.D.	Species : 0.094					
	Locations : 0.094					
	Species × Locations : 0.210					

Table 2.4: Relative water content (%) of top 5 selected indoor plant species under different locations

Species *Locations*	*Aglaonema modestum*	*Scindapsus aureus*	*Chlorophytum comosum*	*Nephrolepis exaltata*	*Kalanchoe blossfeldiana*	*Mean Locations*
Office	90.28	90.02	87.42	87.73	87.21	88.53
Bank premises	90.52	90.88	88.72	88.4	87.38	89.18
Health centre	90.66	90.2	88.64	88.02	86.49	88.8
Canteen/Mess	93.94	93.67	91.3	90.56	89.06	91.7
Control (floricultural farm)	89.3	88.53	86.19	86.54	86.7	87.45
Mean species	90.94	90.66	88.45	88.25	87.37	
C.D.	Species : 1.35					
	Locations : 1.35					
	Species × Locations : NS					

Table 3: Air pollution Tolerance Index of top 5 selected indoor plant species under different locations

Species *Locations*	*Aglaonema modestum*	*Scindapsus aureus*	*Chlorophytum comosum*	*Nephrolepis exaltata*	*Kalanchoe blossfeldiana*	*Mean Locations*
Office	9.163	9.110	8.890	9.077	8.963	9.041
Bank premises	9.240	9.193	8.987	9.153	8.977	9.110
Health centre	9.220	9.103	8.970	9.087	8.890	9.054
Canteen/Mess	9.757	9.750	9.553	9.377	9.113	9.510
Control (floricultural farm)	9.063	8.960	8.773	8.957	8.910	8.933
Mean species	9.289	9.223	9.035	9.130	8.971	
$CD_{0.05}$	Species	0.136				
	Locations	0.136				
	Species × Locations	NS				

Conclusions

From these studies, it was concluded that *Aglaonema modestum* and *Scindapsus aureus* having high APTI index and performed best under different locations and these plants can be used for indoor landscaping in urban areas.

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