

FOLIAGES VERSUS SUCCULENTS: IMPACT OF HOUSEPLANTS ON INDOOR AIR QUALITY

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Abstract: Flora is the nature's most precious gift to man. In ancient times, regard and love for flora was so great that this kindred relationship was extended even to houseplants. Man is destroying and ravaging that greenery, which is so essential for mental, physical and moral health and spiritual sublimation of man. Nature has been unable to keep pace with and compensate for the huge loss, which is being continuously inflicted by exploitation of vegetation and greenery by urban people.

The objective of this investigation was to standardize the utilization of houseplants and study their impact on several parameters of indoor environmental status in residences. Results enunciated that among the houseplants selected, it was found that both the selected plants were efficient in improving Room Temperature, Relative Humidity, Air Flow Rate of the air quality.

Keywords: Houseplants, Foliages, Succulents, IAQ, IES.

An Overview:

Now-a-days people live without thinking that there is not any greenery in and around their homes. The residences near the industrial and highway areas demand more vegetation, as they block the pollutants to come inside the homes as well as they generate fresh air to breathe. The things and furniture in the homes themselves generate several pollutants which can be harmful for general living conditions. Several studies of NASA and foreign countries proves the efficiency of plants in air tight glass chambers but the researcher wanted to find out the actual effectiveness of the houseplants in residences with natural living conditions.

It has been known from Vedic times that nature and human kind (i.e., Prakriti and Purusha) form an inseparable part of the life support system, which has panchbhutas of air, water, land, flora and fauna; are interconnected, interrelated, interdependent and have co-evolved and co-adapted. Deterioration in one, inevitably affects the other four. The developmental activities of the day involving modern and advanced technology without any consideration of man and

his environment are proving ecologically destructive and there is no doubt that such developmental networks have presented various problems of environmental management.

MATERIALS & METHODS

The zone selected as sample for the purpose of the present study falls under the polluted zone as per the U.I.T, Udaipur. Firstly, because a number of industries are there and many more are upcoming resulting into lot of pollutant in the air through emission of smoke. Secondly, the National Highway- 8 passing from Udaipur is a busy highway having hardly any plantation on both the sides of the road, hence the vehicular pollution further accelerates the presence of pollutant in the air. Thirdly, this area is also a residential area where as many as 500 houses are constructed and occupied. Thus, this polluted zone was purposively selected to study the impact of houseplants on IES of residences. In this polluted zone, there were 15 west facing houses along with the National Highway- 8 in Udaipur. These houses were constructed by Rajasthan Housing Board. All the 15 houses were falling into MIG category. Out of these houses, 10 houses were selected purposively for conducting all the experiments due to the following reasons:

- In these ten houses the house owner gave the consent to conduct all the experiments for stipulated period of time.
- The constructional and architectural features and external environment of these residences were found to be very similar during the visit made by the researcher.
- Since there were a large number of experiments to be conducted which required lot of equipments and transportation of potted plants in the selected houses, a small number of residences (10) were selected assuming that the findings of these experiments will be generalized and applied to other houses situated in other polluted zone also.

The two most common types of houseplants, i.e., foliage and succulent plants. Indoor Air Quality in the drawing rooms of the 10 west facing residential buildings along with the National Highway- 8 in polluted zone, was analyzed through its several characteristics, viz., Room temperature, Relative humidity and Air flow rate. To measure Room Temperature, RH and Air Flow Rate, the equipment 4 in 1 Environment Tester was used. In order to be precise in measuring the impact of houseplants on IAQ all of the above mentioned parameters were observed in residences considering the following **sub parameters**, viz., Variation in houseplants, Placement of houseplants, Variation in days, Variation in habits.

The data was processed, tabulated, classified and analyzed for statistical treatments in the light of the objectives of the study. To study the role of houseplants in improving the indoor

environmental status Arithmetic Mean and to analyze the role of different attributes of houseplants in judging the various parameters of the environmental status ANOVA test was used.

RESULTS & DISCUSSION

Problems arise when fluctuations occur such as sudden blasts of cold air. Plants underscore the interconnectedness of life, while adding beauty and health. Creating a more natural and inspirational setting allows people to feel a sense of balance, enjoy their working environment. Experiments were conducted to achieve the objective of the study, that is, to standardize the utilization of houseplants and study their impact on indoor environmental status in residential buildings.

Impact of Houseplants on Room Temperature

Among the subparameters selected first was to judge the difference between the selected foliage and succulent houseplants and their impact on IAQ with special reference to room temperature.

Table 1: Comparative Mean Room Temperature (in ° C) in Drawing Room According to Habits and Number of House Plants

Foliage houseplants									
No.of plants	1 Foliage Plant			2 Foliage Plants			4 Foliage Plants		
Days→	1	2	3	1	2	3	1	2	3
Habits↓									
Opened Windows	29.14	26.31 ↓2.83	28.82 ↑2.51	28.81	22.60 ↓6.21	27.50 ↑5.00	29.10	22.59 ↓6.51	27.81 ↑5.22
Closed Windows	31.11	26.40 ↓4.71	29.63 ↑3.23	31.11	25.72 ↓5.39	30.14 ↑4.42	32.68	25.85 ↓6.83	30.90 ↑5.05
Fan "ON"	29.08	24.36 ↓4.72	28.67 ↑4.31	28.62	24.70 ↓3.92	28.04 ↑3.34	28.59	24.00 ↓4.59	27.87 ↑3.87
Fan "OFF"	29.14	25.91 ↓3.23	28.82 ↑2.91	29.10	23.60 ↓5.50	27.31 ↑3.71	29.71	22.59 ↓7.12	27.64 ↑4.95
Succulent houseplants									
No.of plants	1 Succulent Plant			2 Succulent Plants			4 Succulent Plants		
Days→	1	2	3	1	2	3	1	2	3
Habits↓									
Opened Windows	32.52	27.70 ↓4.82	30.42 ↑2.72	33.45	27.64 ↓5.81	32.27 ↑4.63	31.61	23.11 ↓8.50	30.20 ↑7.09
Closed Windows	32.30	27.54 ↓4.76	31.40 ↑3.86	30.34	24.74 ↓5.60	29.83 ↑5.09	31.35	23.00 ↓8.35	30.65 ↑7.65
Fan "ON"	30.53	26.63 ↓3.90	29.61 ↑2.98	31.56	26.42 ↓5.14	30.20 ↑3.78	30.04	23.80 ↓6.24	28.54 ↑4.74
Fan "OFF"	31.07	25.94 ↓5.13	30.32 ↑4.38	33.47	26.72 ↓6.75	32.40 ↑5.68	32.52	24.56 ↓7.96	31.26 ↑6.70

* Note : Last in Abbreviations

Room Temperature measurement is often collected as part of an IAQ investigation because this parameter affects the perception of comfort in an indoor environment. This parameter of thermal comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments and body temperature. The ideal room temperature for human beings recommended by ASHARE ranges between 22° C- 24° C.

It is apparent from the data presented in table 1 that the succulent plants were found to be more effective under all the selected variations, as compared to the foliage plants. Under the condition of keeping four succulent plants in drawing room with opened windows have shown that the average room temperature decreased from 31.61°C to 23.11°C which means a fall in temperature was recorded to be 8.50° C. Whereas, on comparison with four foliage plants under the same condition there was a difference in room temperature from 29.10°C to 22.59°C resulting into a fall in average room temperature up to 6.51°C. The room temperature recorded during the experimentation after keeping houseplants was found to be much closer to the ideal range of room temperature (22° C- 24° C).

Likewise it can also be extrapolated from the data presented in table that on day three (after removal of houseplant/s), the room temperature started rising (from 23.11° C- 30.20° C) and after the duration of 5 hours was reached almost similar to the average room temperature recorded on day 1, i.e., without keeping any houseplant in the room. Thus, it further emphasizes that the presence of houseplants help in maintaining the ideal range of room temperature for comfort.

Table 2: ANOVA values of Room Temperature (in ° C) in Drawing Room According to Habits and Number of Houseplants

Foliage Houseplants			
No.of Houseplants	1 Foliage Plant	2 Foliage Plants	4 Foliage Plants
Habits			
Opened windows	15. 91*	49. 26*	161.65*
Closed windows	35. 53*	39. 16*	50.60*
Fan ON	46. 71*	37. 62*	33.41*
Fan OFF	32. 01*	132. 04*	66.75*
Succulent Houseplants			
No.of Houseplants	1 Succulent Plant	2 Succulent Plants	4 Succulent Plants
Habits			
Opened windows	25.67*	52.01*	90.05*
Closed windows	35.94*	53.87*	127.92*
Fan ON	30.09*	27.76*	29.10*
Fan OFF	35.15*	54.57*	53.03*
* Significant difference was found.			

Though the foliage plants also helped in regulating the room temperature as per the standards for thermal comfort but the performance was observed to be more significant in case of succulent plants. Overall, it can be concluded that one, two or four succulent plants were more efficient as compared to foliage plants to regulate the room temperature. Hence, it can be recommended that both types of houseplants could be kept indoors especially during summers for thermal comfort.

The differences in ANOVA values of impact of houseplants among all the subparameters (viz. types of houseplants, number and placements of houseplants, selected rooms and different habits), further it justifies that the houseplants were found to be efficient enough in reducing the room temperature.

Impact of Houseplants in regulating Relative Humidity

According to the table 3, the foliage plants were found to be more efficient in regulating the relative humidity in the selected areas of the residential buildings. Whereas on comparison with four succulent plants under the same condition shows a difference in relative humidity from 71.68 percent to 64.43 percent resulting into a fall in average relative humidity up to 7.25 percent. Relative humidity recorded during the experiments after keeping the houseplants was found to be much closer to the ideal range (40 % to 60 %) of relative humidity. On the other hand, the increment in relative humidity was 8.46 percent on day three after removing the houseplants from 65.89 percent (on day 2) to 74.35 percent (on day 3). After removal of four foliage plants under the same circumstances as mentioned above, which was almost similar to the average relative humidity recorded on day one, i.e., without keeping any houseplants. Thus it further emphasizes that the presence of houseplants helps in maintaining the ideal range of relative humidity for comfort.

Though the succulent plants also helped in regulating the relative humidity under various conditions selected for experiments in table 3 as per the standards given, but the performance was observed to be more significant in case of foliage plants. Hence, it can be said that both types of houseplants could be kept indoor especially in hot and humid climate. Results also allow suggesting that the succulent plants would be better in hot and dry climate as they absorb little less RH as compared to the foliage plants by maintaining natural RH in environment for comfortable living.

Table 3: Comparative Mean Relative Humidity (in %) in Drawing Room According to Habits and Number of House Plants

Foliage houseplants									
No.of plants	1 Foliage Plant			2 Foliage Plants			4 Foliage Plants		
Days→	1	2	3	1	2	3	1	2	3
Habits↓									
Opened Windows	70.88	67.50 ↓3.38	70.55 ↑3.05	72.50	65.35 ↓7.48	71.75 ↑6.73	76.43	68.92 ↓7.51	75.29 ↑6.37
Closed Windows	72.71	67.85 ↓4.86	71.13 ↑3.28	74.85	70.06 ↓4.79	73.73 ↑3.67	76.30	69.79 ↓6.51	74.35 ↑4.56
Fan "ON"	77.03	72.32 ↓4.71	76.21 ↑3.89	77.59	71.92 ↓5.67	76.25 ↑4.33	78.39	72.50 ↓5.89	77.13 ↑4.63
Fan "OFF"	70.88	66.92 ↓3.96	70.55 ↑3.63	72.30	67.52 ↓4.78	71.56 ↑4.04	77.47	70.75 ↓6.72	75.18 ↑4.43
Succulent houseplants									
No.of plants	1 Succulent Plant			2 Succulent Plants			4 Succulent Plants		
Days→	1	2	3	1	2	3	1	2	3
Habits↓									
Opened Windows	71.57	67.19 ↓4.38	69.99 ↑2.80	72.68	66.62 ↓6.06	71.07 ↑4.45	74.19	66.27 ↓7.92	72.34 ↑6.07
Closed Windows	73.49	68.73 ↓4.73	72.51 ↑3.78	71.92	66.87 ↓5.05	71.22 ↑4.35	72.69	65.53 ↓7.16	71.82 ↑6.29
Fan "ON"	77.09	71.14 ↓5.95	74.98 ↑3.84	76.46	71.77 ↓4.69	75.67 ↑3.90	80.31	74.59 ↓5.72	78.77 ↑4.18
Fan "OFF"	72.19	69.32 ↓2.87	71.44 ↑2.12	71.57	67.09 ↓4.48	69.99 ↑2.90	74.19	65.47 ↓8.72	72.33 ↑6.86
* Note : Last in Abbreviations									

The ideal relative humidity recommended by ASHARE ranges between 40-60 percent and by SIAQG is 70 percent. The reason behind absorbing less of RH by succulent plants as compared to the foliage plants may be that succulent plants have fleshy leaves with already having higher water content due to which their capacity to absorb the moisture from the environment reduces. On the other hand, foliage plants have thin and broad leaves with more capacity to absorb moisture from the atmosphere.

There was significant difference in ANOVA values of impact of houseplants on relative humidity with their subparameters (viz. types of houseplants, number and placements of houseplants, selected rooms and different habits). It justifies the efficiency of houseplants in regulating the RH to a comfortable level (40-60 %) and improves the quality of indoor air.

Table4: ANOVA values of Relative Humidity (in %) in Drawing Room According to Habits and Number of Houseplants

Foliage Houseplants			
No.of Houseplants	1 Foliage Plant	2 Foliage Plants	4 Foliage Plants
Habits			
Opened windows	14.62*	21.62*	23.94*
Closed windows	17.05*	19.84*	20.83*
Fan ON	19.79*	24.73*	17.99*
Fan OFF	14.94*	16.83*	20.14*
Succulent Houseplants			
No.of Houseplants	1 Succulent Plant	2 Succulent Plants	4 Succulent Plants
Habits			
Opened windows	15.61*	17.31*	17.43*
Closed windows	16.66*	15.76*	20.61*
Fan ON	17.96*	15.09*	17.81*
Fan OFF	13.98*	15.58*	18.18*

* Significant difference was found.

Impact of Houseplants on Air Flow rate

Air removal is as important as air supply. To maintain air movement, the pressure inside the building is greater than that outside and there is a tendency for air to move outwards. If the air-conditioning system is faulty and the building is under negative pressure, the efficiency of exhaust fans will be reduced and outside air will infiltrate anywhere it can, perhaps 'rushing in' when windows are opened. The effect of this is that pollutants will not be ventilated out of the building. Balancing is often carried out inadequately. So the air handling should be balanced by keeping plants, as it ensure the delivering and returning the air in the way it is natured.

It is squeezed out from the table 5, that the foliage plants were found to be more effective in improving the air flow rate of selected areas of the residential buildings. As cited under the condition of keeping one foliage plant in drawing room with fan OFF condition, average air flow rate went up from 0.09 m/s to 0.18 m/s which mean an increment in air flow rate was recorded to be 0.09 m/s. While, with one succulent plant under the same circumstances portrayed a difference in air flow rate from 0.05 m/s to 0.07 m/s resulting into a rise in average air flow rate up to 0.02 m/s.

The air flow rate recorded during the experiments after keeping the houseplants was found to be more than the ideal range of air flow rate. Hence, only one houseplant is sufficient for improving the air speed indoors. But after removing the one foliage plant on day three under the similar situation, air flow rate reduced from 0.18 m/s to 0.09 m/s, which was similar to

the average air flow rate recorded on day one, i.e., without keeping houseplant. Thus, it can be further extracted that the houseplants are the gift of nature to furnish the comfortable range of air flow rate. Significance for the same can be seen in table 6.

Table 5: Comparative Mean Air Flow Rate (in m/s) in Drawing Room According to Habits and Number of House Plants

Foliage houseplants									
No. of plants	1 Foliage Plant			2 Foliage Plants			4 Foliage Plants		
Days→	1	2	3	1	2	3	1	2	3
Habits↓									
Opened Windows	0.04	0.12 ↑0.08	0.04 ↓0.08	0.10	0.18 ↑0.08	0.10 ↓0.08	0.07	0.25 ↑0.18	0.10 ↓0.15
Closed Windows	0	0	0	0	0	0	0	0	0
Fan "ON"	0.96	1.15 ↑0.19	0.96 ↓0.19	0.96	1.20 ↑0.24	0.99 ↓0.21	0.88	1.18 ↑0.3	1.07 ↓0.11
Fan "OFF"	0.09	0.18 ↑0.09	0.09 ↓0.09	0.07	0.16 ↑0.09	0.07 ↓0.09	0.04	0.14 ↑0.1	0.04 ↓0.1
Succulent houseplants									
No. of plants	1 Succulent Plant			2 Succulent Plants			4 Succulent Plants		
Days→	1	2	3	1	2	3	1	2	3
Habits↓									
Opened Windows	0.01	0.06 ↑0.05	0 ↓0.06	0.03	0.11 ↑0.07	0.02 ↓0.09	0.01	0.04 ↑0.03	0.01 ↓0.03
Closed Windows	0	0	0	0	0	0	0	0	0
Fan "ON"	0.79	0.95 ↑0.16	0.78 ↓0.17	0.8	1.00 ↑0.2	0.99 ↓0.01	0.87	1.18 ↑0.31	1.11 ↓0.07
Fan "OFF"	0.05	0.07 ↑0.02	0.04 ↓0.03	0.07	0.10 ↑0.03	0.03 ↓0.07	0.12	0.21 ↑0.09	0.12 ↓0.09
* Note : Last in Abbreviations									

There was significant difference in ANOVA values, except only the difference in ANOVA values under the closed windows and few in other variations was negligible and non significant. So, it can be inferred that the plants themselves cannot generate air movement and needs natural air flow rate through doors and windows or cross ventilation for their better results. ANOVA values indicates that houseplants have a great impact in maintaining the desired level of air flow rate. Further they are proved to be most effective in regulating the air flow rate in extremes of humid summers.

Hence, it can be surmised that houseplants could be kept indoors especially in the climate with high room temperature and relative humidity, to make the indoor environment comfortable.

Table 6: ANOVA values of Air Flow Rate (in m/s) in Drawing Room According to Habits and Number of House Plants

Foliage Houseplants			
No.of Houseplants	1 Foliage Plant	2 Foliage Plants	4 Foliage Plants
Habits			
Opened windows	3.16 ^{NS}	0.423 ^{NS}	0.516 ^{NS}
Closed windows	0 ^{NS}	0 ^{NS}	0 ^{NS}
Fan ON	0.39 ^{NS}	13.05*	8.65*
Fan OFF	0.158 ^{NS}	1.16 ^{NS}	4.27*
Succulent Houseplants			
No.of Houseplants	1 Succulent Plant	2 Succulent Plants	4 Succulent Plants
Habits			
Opened windows	2.46 ^{NS}	4.08*	5.59*
Closed windows	0 ^{NS}	0 ^{NS}	0 ^{NS}
Fan ON	3.46*	3.26 ^{NS}	8.96*
Fan OFF	0.325 ^{NS}	19.84*	1.35 ^{NS}
^{NS} - Non Significant.			
* Significant at 5 % Level of Significance.			

SUMMARY & CONCLUSION

Today's tightly sealed and energy efficient homes save money and are better for the environment but most are not properly equipped to filter and purify the constantly recirculated air. Even "leaky" older homes can accumulate high concentrations of pollutants, as well as exhibit other indoor air quality problems such as dampness, dryness etc. In a comfortable environment there are no noticeable fluctuations in temperature, no stuffiness, draughts, sound level, etc.

Outcome of the results state that the succulent plants are advisable to reduce the greater Room temperatures. On the other hand, the foliage plants are advisable to regulate the required level of relative humidity and to maintain required Air flow rate.

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Abbreviations used:

1. RH - Relative Humidity
2. m/s - meter per second (Unit of measuring Air Flow Rate)
3. IAQ - Indoor Air Quality
4. IES - Indoor Environmental Status
5. EPA - Environmental Protection Agency
6. ASHARE - American Society of Heating, Air conditioning and Refrigeration Engineers, U.S.
7. SIAQG - Singapore Indoor Air Quality Guidelines
8. U.I.T. - Urban Improvement Trust
9. MIG - Middle Income Group

10. *** Note:**

Days-

Day 1- Existing Reading without any Houseplant.

Day 2- Reading after keeping the Houseplant/s.

Day 3- Reading after removal of the Houseplant/s.

Arrows-

↓- denotes decrease in reading (Reading of Day 2 was subtracted from Day 1).

↑- denotes increase in reading (Reading of Day 3 was subtracted from Day 2).