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Indirect Green Facades: Exploring the Efficiency of Ornamental Climbers

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ABSTRACT

Background: Urban air pollution and environmental stress can be mitigated by vertical greening systems (VGS), where indirect green facades enhance thermal regulation, air quality, biodiversity and psychological well-being. However, comprehensive screening of ornamental climbers for their morphological, physiological, biochemical and anatomical suitability to indirect green facades is lacking. This study aimed to assess these traits to determine climbers' potential resistance to air pollution and growth performance on indirect green facades.

Methods: Twelve ornamental climbers were screened for indirect green facade adaptation using randomized block design with 3 replications on a 7 ft × 5 ft iron-framed structure. Frame coverage, stem girth, branches per plant, leaves per branch, leaf area, stomatal density, trichome density, total chlorophyll, ascorbic acid, leaf pH, relative water content and air pollution tolerance index (APTI) were recorded at 180 days after planting.

Result: *Clitoria ternatea, Basella alba, Passiflora edulis, Ipomoea purpurea, Thunbergia grandiflora, Antigonon leptopus, Jacquemontia pentanthos* and *Dolichandra unguis-cati* recorded 100% frame coverage, while maximum stem girth occurred in *Basella alba* (3.16 cm). *Ipomoea purpurea* (18.68) and *Antigonon leptopus* (18.21) recorded the highest APTI values (tolerant category), followed by *Passiflora edulis* (17.80, moderately tolerant); remaining climbers fell in the intermediate category. Abaxial stomatal density was highest in *Dolichandra unguis-cati* (61.00 mm^2) and abaxial trichome density was highest in *Clitoria ternatea* (92.00 mm^2). *Ipomoea purpurea, Antigonon leptopus* and *Passiflora edulis* evergreen, simple leaved and fast covering emerged as the most suitable climbers for indirect green facades.

Key words: Air pollution tolerance index (APTI), Ascorbic acid, Indirect green facades, Ornamental climbers, Stomata, Trichome.

INTRODUCTION

Ornamental climbers are frequently favored in urban environments, a preference stemming from their swift growth, visual appeal and capacity to acclimate to diverse environmental factors. On the other hand, there are significant variations among climbing plant species in terms of growth rate, branching patterns, leaf size, canopy density and area coverage. These features have a direct impact on the effectiveness of shade and the degree to which wall temperatures are lowered. Climbing plants are better at concealing sunlight and enhancing thermal performance because they have denser leaves and grow more quickly in both height and width (Köhler, 2008). Despite the growing prevalence of ornamental climbing plants in green facade systems, a comprehensive assessment of their efficacy in controlled environments is lacking. Instead than focusing on the unique performance characteristics of certain species, current research emphasizes the overall advantages of vertical greenery. Even with vertical greening systems becoming more common, the process behind choosing which plants to use hasn't really caught up. Farrokhirad *et al.* (2024) point out that most existing design frameworks skip over a proper species-selection step altogether, defaulting instead to generic approaches that treat all climbers as roughly interchangeable. That assumption doesn't hold up well in practice. Sethupathy *et al.* (2025) found that even common, easily available ornamental climbers can vary quite a bit in how well they actually cool a building. This is exactly the gap the present study sets out to close, through a systematic, multi-parameter comparison of ornamental climbing species for indirect green facade use. Therefore, an assessment of decorative climbers is essential to find species that, when incorporated into indirect green facades, demonstrate quick establishment, ideal coverage and improved cooling benefits

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(Perini *et al.,* 2011). The purpose of this study is to evaluate specific decorative climbing plants' compatibility and performance for indirect green facade systems. The assessment will concentrate on foliar density, coverage extent, branching frequency and essential growth features. As a result, the findings of this study will help choose the best climbing plants, supporting sustainable urban landscaping techniques and improving building thermal management.

MATERIALS AND METHODS

At SRM College of Agricultural Sciences, Chengalpattu, an experiment was carried out to assess ornamental climbers appropriate for indirect green façades during the year 2025-26. The location lies between latitudes 12°23′19.7″N and longitudes 79°44′37.4″E, with an average elevation of 50 m and a relative humidity of 50-70%. The region's average temperature varied between 23°C and 38°C. An iron frame construction with supporting poles on both sides and a frame height of seven feet and width of five feet was used for the experiment (Fig 1). The experiment was laid out in a randomaized block design (RBD) with three replications. The treatment involves twelve ornamental climbers *viz.,* T_1-Butterfly pea (*Clitoria ternatea* L.), T_2-Malabar spinach (*Basella alba* L.), T_3-Passion fruit (*Passiflora edulis* Sims.), T_4-Garlic vine (*Mansoa alliacea* (Lam.) A.H.Gentry), T_5-Morning glory [*Ipomoea tricolor* (L.) Roth], T_6-Blue Trumpet Vine [*Thunbergia grandiflora* (Roxb. ex Rottler) Roxb], T_7-Rangoon creeper [*Quisqualis indica* (L.) DeFilipps], T_8-Coral vine (*Antigonon leptopus* Hook. and Arn.), T_9-Skyblue clustervine [*Jacquemontia pentanthos* (Jacq.) G.Don.], T_{10}-Rock trumpet [*Mandevilla splendens* (Hook.f.) woodson], T_{11}-ornamental Grape vine (*Vitis vinifera* L.), T_{12}-Cat'sclaw vine (*Dolichandra unguis-cati*). The observations were recorded on the botanical (habit, evergreen or deciduous and leaf type), morphological (frame coverage, stem girth, number of branches/plant and number of leaf per branch, leaf area), anatomical (stomatal density and trichome density), biochemical (chlorophyll content, ascorbic acid, leaf pH), physiological (relative water content, APTI value) characteristics. The Air Pollution Tolerance Index was calculated following the method of Singh and Rao (1983).

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

Where,

A = Ascorbic acid content (mg/g).

T= Total chlorophyll content (mg/g).

P= Leaf extract pH.

R= Relative water content (%) of the leaf sample.

ANOVA was performed on the collected data using statistical software RStudio in accordance with the design. The F-test was used to determine whether there were significant changes between treatments and CD was used to compare means at the 5% level.

RESULTS AND DISCUSSION

Botanical characteristics

Among the ornamental climbers studied, *Clitoria ternatea, Basella alba, Antigonon leptopus, Jacquemontia pentanthos* are herbaceous perennial, *Passiflora edulis, Mansoa alliacea, Thunbergia grandiflora, Quisqualis indica, Vitis vinifera*, *Dolichandra unguis-cati* are woody perennials, while *Ipomoea purpurea* is a herbaceous annual climber. *Ipomoea purpurea* and *Vitis vinifera* are deciduous in nature while all the other species are evergreen. The leaf type of *Clitoria ternatea, Mansoa alliacea* and *Dolichandra unguis-cati* are compound while all the other species should bears simple leaf (Table 1).

Morphological parameters

All the morphological parameters showed significant difference among the treatments (Table 2). At 180 days of planting, *Clitoria ternatea, Basella alba, Passiflora edulis, Ipomoea purpurea, Thunbergia grandiflora, Antigonon leptopus, Jacquemontia pentanthos, Dolichandra unguis-cati* species covered 100.00% of the installed iron frame, while *Vitis vinifera* covered 75.00%, *Mansoa alliacea* covered 50.00% and *Quisqualis indica* and *Mandevilla splendens* covered only 25.00% of the frame. The maximum stem girth was recorded in T_2 (3.16 cm), followed by T_3 (2.90 cm), whereas the minimum was found in T_{10} (1.80 cm). The number of branches per plant was highest in T_5 (47.00), followed by T_1 (33.96), whereas the lowest was recorded

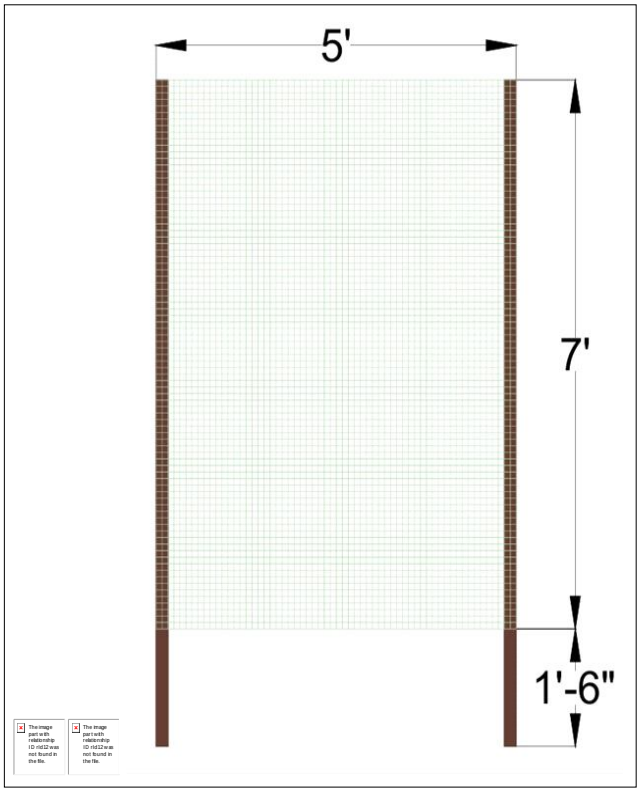


Fig 1: Dimensions of the Iron frame designed for this experiment.

in T_{10} (1.00). The highest number of leaves per branch was observed in T_5 (62.00), followed by T_3 and T_4 (47.00), while the lowest was recorded in T_{11} (5.00).

Physiological and biochemical characteristics

To examine the possible role of physiological and biochemical components influencing air pollution tolerance index were analysed and presented in Table 3. Ascorbic acid content was significantly varied across the 11 species that were studied and it ranges from 14.01 to 6.94 mg/g FW across the species. *Ipomoea purpurea* (14.01 mg/g FW) followed by *Passiflora edulis* (13.99 mg/g FW) and *Antigonon leptopus* (13.99 mg/g FW) recorded the highest ascorbic acid compared to species like *Thunbergia grandiflora* which recorded the least ascorbic acid of 6.94 mg/g FW. It is observed that all the ornamental climbers exhibited a leaf pH towards acidic side from 4.57 to 6.24. Plants like *Mansoa alliacea* recorded the highest pH among them *i.e.,* 6.24 pH, followed by *Basella alba* and *Thunbergia grandiflora* with the pH of 5.94, while *Mandevilla* recorded the lowest pH of 4.57. The relative water content (RWC) varied from 84.75% to 65.70% across the studied species. The relative water content was high in some of the species like *Thunbergia grandiflora* (84.75%), *Passiflora edulis* (83.23%), *Basella alba* (82.45%), *Vitis vinifera* (82.62%) and *Dolichandra unguis-cati* (82.05%) and low in *Mandevilla splendens* (65.70%). Among the studied species total chlorophyll content was found to be highest (1.51 mg/g FW) in *Clitoria ternatea* and *Antigonon leptopus*, followed by *Ipomoea purpurea* (1.28 mg/g FW). The climbers like *Basella alba* showed the lowest total chlorophyll content (0.36 mg/g FW).

Air pollution tolerance index (APTI) value

The APTI value estimated using the four biochemical parameters in plant leaves namely, RWC, total chlorophyll content, leaf pH and ascorbic acid value, can be used as a predictor of air quality.

In the present study, *Ipomoea purpurea* and *Antigonon leptopus* recorded the APTI of 18.68 and 18.21 respectively coming under tolerant category, followed by *Passiflora edulis* (17.80) being moderately tolerant. All the other species falls in intermediate category of APTI response with the values ranging from 10.95 to 13.73.

Anatomical characteristics

The leaf stomatal density was higher on the abaxial surface in the species studied ranging from 61.00 mm^2 in *Dolichandra unguis-cati* to 26.66 mm^2 in *Basella alba* (Table 2). Stomata was absent on the adaxial leaf surface in other species. *Basella alba*recorded the maximum stomatal density (67.33 mm^2) on the adaxial leaf surface, while *Ipomoea purpurea*recorded the minimum stomatal density (5.66 mm^2). *Clitoria ternatea, Passiflora edulis, Thunbergia grandiflora, Quisqualis indica* and *Antigonon leptopus* bears trichomes on both abaxial and adaxial leaf surface. *Jacquemontia pentanthos* bears trichomes only on the adaxial surface while *Vitis vinifera* bears only on the abaxial

Table 1: Botanical characteristics of ornamental climbers.

Treatment	Scientific name	Family	Habit	Origin	Deciduous/ evergreen	Leaf type
T_1	*Clitoria ternatea* L.	Fabaceae	Herbaceous perennial	Tropical Asia	Evergreen	Compound
T_2	*Basella alba* L.	Basellaceae	Herbaceous perennial	Tropical asia	Evergreen	Simple
T_3	*Passiflora edulis* Sims.	Passifloraceae	Woody perennial	South America	Evergreen	Simple
T_4	*Mansoa alliacea* (Lam.) A.H.Gentry	Bignoniaceae	Woody perennial	South America	Evergreen	Compound
T_5	*Ipomoea purpurea* (L.) roth	Convolvulaceae	Herbaceous annual	Central America	Deciduous	Simple
T_6	*Thunbergia grandiflora* (Roxb. ex Rottler) roxb	Acanthaceae	Woody perennial	South East Asia	Evergreen	Simple
T_7	*Quisqualis indica* (L.) DeFilipps	Combretaceae	Woody perennial	Tropical Asia	Evergreen	Simple
T_8	*Antigonon leptopus* Hook. andArn.	Polygonaceae	Herbaceous perennial	Mexico	Evergreen	Simple
T_9	*Jacquemontia pentanthos* (Jacq.) G.Don.	Convolvulaceae	Herbaceous perennial	Tropical America	Evergreen	Simple
T_{10}	*Mandevilla splendens* (Hook.f.) woodson	Apocynaceae	Woody perennial	South America	Evergreen	Compound
T_{11}	Vitis *vinifera* L.	Vitaceae	Woody perennial	Mediterranean region	Deciduous	Simple
T_{12}	*Dolichandra unguis-cati* (L.) L.G. lohmann	Bignoniaceae	Woody perennial	Central and South America	Evergreen	Compound

surface. The trichome density on the adaxial surface was highest in *Passiflora edulis* (69.66 mm^2), followed by *Clitoria ternatea* (41.00 mm^2). The trichome density on the abaxial surface was highest in *Clitoria ternatea* (92.00 mm^2), followed by *Antigonon leptopus* (62.33 mm^2).

Climbing plants have a lot of potential for urban vertical greening since they use unique vertical growth processes. The suitability of ornamental climbers for use in indirect green façades has been tested using an inexpensive iron-framed indirect green façade construction. In green facade systems, frame coverage that influences climbers' capacity to spread also enhances shade effectiveness and helps control the microclimate. In the present study, *Clitoria ternatea, Basella alba, Passiflora edulis, Ipomoea purpurea, Thunbergia grandiflora, Antigonon leptopus, Jacquemontia pentanthos, Dolichandra unguis-cati* exhibited faster growth and covered the frame at 180 days of planting (Fig 2). Azhar *et al.* (2018) revealed similar results regarding frame coverage by *Anemopaegma chamberlaynii, Antigonon leptopus* and *Quisqualis indica*. Because of the pattern of foliage coverage, *Vitis vinifera, Mansoa alliacea, Quisqualis indica* and *Mandevilla splendens* displayed slow frame coverage. According to Azhar *et al.* (2018), *Quisqualis indica*foliage pattern cascades downward and the stem climbs twinning vertically over the supporting structure with less leaf coverage before reaching the highest point of the structure. These findings are consistent with the current study.

Climbing plants' canopy expansion and productivity are significantly influenced by their stem girth, number of branches per plant and leaf output, which indicates the plants' capacity for photosynthetic processes.In the present study, *Passiflora edulis, Ipomoea purpurea, Antigonon leptopus, Thunbergia grandiflora* and *Jacquemontia pentanthos* showed higher values for stem girth, number of branches and number of leaves per plant. These species are evergreen and bears simple leaf. According to earlier research, shoot branching is crucial in defining the overall performance and architecture of plants (Leyser, 2009). Perini *et al.* (2017) found that dense foliage development in climbers enhances thermal regulation and environmental performance of green facade systems, which is corresponding to the current findings on big leaf area in *Vitis vinifera* and *Thunbergia grandiflora*. Better photosynthesis and growth are supported by increased branching, which also increases light interception and plant spread. In general, plants with more leaves have more photosynthetic surface area. Additionally, it helps to increase the density of the canopy. Increased leaf numbers improve photosynthetic capability and growth performance, according to research by Larcher (2003). *Antigonon leptopus* had the lowest number of leaves per plant and the highest number of branches in the current study. This is in accordance with Azhar *et al.* (2018). The leaf has a tendency to expand quickly before experiencing rapid withering and death. As a result, the leaf has a shorter lifespan, which is

Table 2: Morphological and anatomical characteristics of ornamental climbers.

Treatments	Frame coverage (%) (180 days)	Stem girth (cm)	No. of branches/ plant (nos)	No. of leaves/ branch (nos)	Leaf area (cm^2)	Stomatal density/mm^2		Trichome density/mm^2	
						Adaxial	Abaxial	Adaxial	Abaxial
T_1: *Clitoria ternatea*	100.00	2.63	29.96	33.96	38.26	22.66	48.33	41.00	92.00
T_2: *Basella alba*	100.00	3.16	39.00	21.96	17.56	67.33	26.66	0.000	0.00
T_3: *Passiflora edulis*	100.00	2.90	47.00	16.03	29.31	0.00	56.33	69.66	50.33
T_4: *Mansoa alliacea*	50.00	1.96	47.00	2.00	24.58	0.00	36.33	0.00	0.00
T_5: *Ipomoea purpurea*	100.00	2.73	62.00	47.00	29.41	5.66	26.66	0.00	0.00
T_6: *Thunbergia grandiflora*	100.00	2.33	35.00	7.00	53.32	0.00	43.00	39.33	41.66
T_7: *Quisqualis indica*	25.00	2.56	16.96	11.50	9.37	0.00	54.66	9.33	15.00
T_8: *Antigonon leptopus*	100.00	2.60	43.01	19.46	30.65	0.00	41.66	34.33	62.33
T_9: *Jacquemontia pentanthos*	100.00	2.20	26.46	24.50	7.59	0.00	39.00	17.66	0.00
T_{10}: *Mandevilla splendens*	25.00	1.80	5.00	1.00	6.36	0.00	34.33	0.00	0.00
T_{11}: *Vitis vinifera*	75.00	2.10	7.50	8.50	42.47	0.00	36.50	0.00	0.00
T_{12}: *Dolichandra unguis-cati*	100.00	2.07	33.49	5.50	17.32	0.00	61.00	0.00	0.00
SE(d)	1.56	0.05	0.81	0.57	0.18	2.558	0.92	10.19	0.76
CD at 5%	3.24	0.09	1.69	1.18	0.38	5.305	1.92	21.132	1.58

thought to be caused by the fast rate of photosynthetic absorption, particularly in tropical plants.

The water in the plant tissue can be determined using Relative Water Content (RWC). According to Seyyednejad *et al.* (2017), a significant amount of water in plant tissue aids in preserving its physiological equilibrium under stressful circumstances. The relative water content was highest in *Basella alba, Passiflora edulis, Thunbergia grandiflora, Quisqualis indica, Vitis vinifera* and *Dolichandra unguis-cati* ranging from 84.75% to 82.05%. Relative water content, which indicates the water balance and cellular stability of plant tissues, is one of the key physiological activities used to assess plant tolerance to atmospheric contaminants, according to a similar study published by. The plant species' resistance to stress is increased by high RWC (Kumar *et al.,* 2014). According to Joshi *et al.* (2009) and Pavlović *et al.* (2014), total chlorophyll is regarded as a measure of photosynthetic activity, growth and biomass productivity. *Clitoria ternatea* and *Antigonon leptopus* had the greatest total chlorophyll content (1.51 mg/g FW) in the current investigation. The result illustrates how plants' physiological health and photosynthetic efficiency differ. Environmental stressors like air pollution can lower the content of chlorophyll by damaging the architecture of chloroplasts and interfering with the synthesis of pigments. The outcome is similar to that of who discovered that plants exposed to external pollutants frequently exhibit chlorophyll degradation. Higher leaf pH values were recorded by *Mansoa alliacea, Basella alba* and *Thunbergia grandiflora*, indicating their greater resistance to air contaminants. Early research by Chaudhary and Rao (1977) found that leaf pH plays a major influence in influencing a plant's sensitivity to air contaminants. An essential antioxidant molecule in plant defense mechanisms against oxidative stress is ascorbic acid. Because ascorbic acid protects cellular components and photosynthetic pigments from oxidative damage, plants with higher ascorbic acid contents are more resilient to contaminants. Increased ascorbic acid concentration enhances plant resilience to air contaminants, a conclusion corroborated by Keller and Schwager (1977).



A. *Clitoria ternatea* B. *Antigonon leptopus*

Fig 2: Plant coverage on the iron frame.

APTI is an effective method for green belt development, according to studies done by different academics. Plants' degree of tolerance to air pollutants is assessed using the Air Pollution Tolerance Index (APTI). When the APTI value is ≤11, the plant is sensitive; when it is 12-16, it is intermediate; and when it is ≥17, it is tolerant of air pollution (Padmavathi *et al.,* 2013; Shrestha *et al.,* 2021). Higher APTI values in the current study indicate that *Ipomoea purpurea* (18.68) and *Antigonon leptopus* (18.21) are typically thought to be tolerant of contaminated settings. In a similar vein, earlier research by showed that plants with higher APTI values have better physiological defense mechanisms and are appropriate for planting in metropolitan areas that are

Table 3: Biochemical, physiological characteristics and the APTI value of ornamental climbers.

Treatments	Total chlorophyll (mg/g FW)	Ascorbic acid (mg/g FW)	Leaf extract pH	Relative water content (%)	APTI	APTI response
T_1: *Clitoria ternatea*	1.51	6.99	5.50	72.01	11.72	Intermediate
T_2: *Basella alba*	0.36	6.99	5.94	82.45	13.19	Intermediate
T_3: *Passiflora edulis*	0.96	13.99	5.60	83.23	17.80	Moderately tolerant
T_4: *Mansoa alliacea*	1.24	6.99	6.24	75.44	13.73	Intermediate
T_5: *Ipomoea purpurea*	1.28	14.01	5.92	74.02	18.68	Tolerant
T_6: *Thunbergia grandiflora*	0.84	6.94	5.94	84.75	13.42	Intermediate
T_7: *Quisqualis indica*	0.92	6.95	5.43	81.04	12.35	Intermediate
T_8: *Antigonon leptopus*	1.51	13.99	5.38	78.13	18.21	Tolerant
T_9: *Jacquemontia pentanthos*	0.99	6.96	5.28	71.50	11.43	Intermediate
T_{10}: *Mandevilla splendens*	1.22	6.96	4.57	65.70	10.95	Intermediate
T_{11}: Vitis 'Ornamental Grape'	0.91	6.96	4.90	82.62	12.29	Intermediate
T_{12}: *Dolichandra unguis-cati*	1.19	6.95	5.30	82.05	12.89	Intermediate
SE(d)	0.002	0.023	0.23	2.08	0.153	
CD at 5%	0.004	0.048	0.48	4.32	0.318	

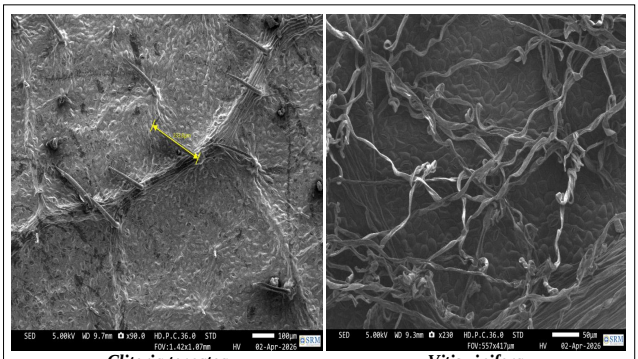


Fig 3: Scanning electron microscopic (SEM) images of trichomes present in the ornamental climbers.

contaminated.This result is consistent with that of Pandey *et al.* (2016), who found that *Ipomoea palmata, Thunbergia grandiflora*, *C. splendens, A. elegans, Q. indica, Petria volubilis* and *Antigonon leptopus* had the highest APTI values and were excellent choices for green façade. Additionally, *Ipomoea purpurea* had the highest APTI value in the current study, which is in line with finding that deciduous species have high APTI. Additionally, *Quisqualis indica* (12.35 ATPI value) in this study indicated an intermediate response, that corresponds to Jim (2015) findings. Similar APTI based screening was conducted by Akilan and Nandhakumar (2016) in Vellore district, Tamil Nadu, where plant species growing in industrial and transportation-heavy zones consistently recorded higher APTI values than those from less polluted college farm sites, reinforcing the reliability of ascorbic acid, chlorophyll, leaf pH and relative water content as robust biochemical indicators for species screening.

In general, plants with dense stomata use water more efficiently and have higher stomatal conductance. On the other hand, because stomatal conductance and transpiration are reduced, a drop in stomatal density may result in a conservative use of water (Dittberner *et al.,* 2018). In the present study, the *Dolichandra unguis-cati* followed by *Quisqualis indica* and *Passiflora edulisrecorded* higher values for stomatal density per mm^2. Hypostomatic leaves were observed in *Thunbergia grandiflora, Quisqualis indica, Antigonon leptopus, Jacquemontia pentanthos, Mandevilla splendens, Vitis vinifera, Dolichandra unguis-cati, Passiflora edulis, Mansoa alliacea.* Because stomata are the main entrance point for gaseous contaminants into leaves, related research by Winner (1981) demonstrates that stomatal features have a substantial impact on plant exposure to air pollutants. The results of Durodola *et al.* (2025) are in line with the stomatal density of *Quisqualis indica* in the current investigation. This trade off pattern between structural traits is consistent with findings by Ramírez-Soto *et al*. (2026), who reported a significant negative correlation between stomatal area and trichome density on both leaf surfaces in Kabuli chickpea cultivars, suggesting that species investing more in trichome development tend to develop smaller, more conservative stomata as part of an adaptive water-use strategy.

Increased trichome density may improve plants' ability to fend off contaminants. The quantity of particulate matter adsorbed on the leaf surface is correlated with the number of trichomes on the leaf surface (Chen *et al.,* 2017). *Clitoria ternatea, Passiflora edulis, Thunbergia grandiflora, Quisqualis indica, Antigonon leptopus, Jacquemontia pentanthos* bears trichomes on the both the abaxial and adaxial surface of the leaf which is one of the selection criteria for pollution control. In the present study, the ultrastructure of the trichomes in *Vitis vinifera* was explored with transmission electron microscopy. On the abaxial surface, the ribbon trichomes are twisted, greatly elongated possessing erect and prostrate trichomes, the prostrate type completely covered the erect form (Fig 3). Domanda *et al.* (2023); Fambrini *et al.* (2021) and Gago *et al.* (2016) have reported similar findings regarding the existence of prostrate and erect trichomes. According to earlier research, trichomes serve as protective structures that lessen environmental harm and increase a plant's resistance to external stress (Werker, 2000). According to Jeong *et al.* (2021) and Hellebaut *et al.* (2022), trichomes on the leaf surface exhibit the highest level of particulate matter reduction. This investigation likewise produced comparable results. This protective function of trichome density aligns with the findings of Satish *et al.* (2023), who demonstrated in pigeonpea that genotypes with higher pod trichome density and length experienced significantly reduced pest damage, indicating that dense trichome coverage functions as a physical barrier against external stressors, whether biotic pests or airborne particulate matter.

CONCLUSION

This study indicated that ornamental climbers exhibit a wide range of morphological, physiological, biochemical and anatomical traits that affect their adaptation to green façades. *Ipomoea purpurea, Antigonon leptopus* and *Passiflora edulis* are among the climbers that are most suited for indirect green façades.

Conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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