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Potential Use of Chilean Native Species in Vertical Greening Systems

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Abstract: Vertical greening systems (VGSs), i.e., living walls (LWs) and green façades (GFs), are considered a promising technology to diminish the negative effects of urbanisation. Plant selection for these systems is challenging due to the narrow spectrum of species available, and the required adaptation to specific climate conditions. Considering Chile's rich plant biodiversity, this study aims to analyse the potential of Chilean native species to be introduced in VGSs. A total of 109 potentially usable species from the north (n = 25), centre (n = 32), south (n = 31) and the Andes Mountains (n = 21) were selected for VGSs, showing a high level of endemism (43.1%). According to the filters applied, 39 and 70 species were selected for GFs and LWs, respectively. To evaluate appreciation of Chilean native plants and their potential use in VGSs, an online questionnaire was responded by 428 individuals. Most participants agreed or strongly agreed with the use of LWs and/or GFs inside their house/apartment (75.5%) and in their garden/balcony (90.0%). Most of the participants agreed or strongly agreed with the use of Chilean native plants inside their house/apartment (75.0%) and in their garden/balcony (84.4%). Further empirical studies are still required to confirm the use of Chilean native species in LWs and GFs.

Keywords: living walls; green façades; vertical greening systems; native species; urban biodiversity; ornamental plants; demographic research

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1. Introduction

Green infrastructures, such as vertical greening systems (VGSs), are considered essential innovative tools to decrease the negative effects of urbanisation in densely built cities where the extreme lack of green spaces dominates [1]. The urban population of Chile reaches 87.82% of the total population, a percentage in constant increase from 2011 to 2021 (87.13% to 87.82%) [2]. VGSs could be an alternative solution to the problem of the complete absence of suitable terrestrial open spaces, due to the increased urbanisation levels, where various "horizontal" green infrastructures could be installed. To face this necessity, there are various commercial living wall systems around the world and companies' R&D departments testing and improving their "vertical" products including green façade technology [3–5]. However, most of the botanical plant selections by companies are based on common commercial supply without taking native biodiversity ("the variety and variability among living organisms and the ecological complexes in which they occur") [6] into consideration, thus repeating a similar "palette" of plants in VGSs. The VGS technology (also called vertical greenery systems) includes two main common classification categories denominated living walls (LWs), also referred to as green walls or vertical gardens, and green façades (GFs) [7,8].

Referred to as LWs, we focus on the advanced systems that surround buildings and cover walls or façades (slightly inclined or not) indoors or outdoors characterised by vegetation (a wide combination of evergreen or deciduous plant species) with the root system integrated into the vertical system [8–10]. According to the world commercial offer based on the application method, LWs are classified into continuous (light layers with adaptable dimensions, e.g., geotextile, polyamide, planted in situ) or modular (heavier elements with specific or adaptable dimensions, pre-planted or planted in situ) connected to the buildings' walls (indoors or outdoors), or concrete elements, wood or metal frames or even structural steel elements, by means of a substructure (e.g., galvanised stainless steel, timber) or even directly fixed. They are further divided into two main categories based on the material used, namely felt or cloth systems (flexible multilayer, hydroponic) and boxes or panels (pots, rockwool blocks, coco fibre blocks, rock fibre, sphagnum blocks) planted in situ or frequently pre-planted. Fertigation is mainly applied, and hydroponics (hydroponic or semi-hydroponic systems) is the principal technique used to maintain plant growth and development, as most of the systems use balanced water-based nutrient solutions rather than soil or other growing media [11]. However, commercially there are several subcategories less sophisticated and promoted as LWs [12].

On the other hand, GFs are defined as the green infrastructures that spread mostly outdoors on building façades and walls, columns, enclosures and optical divisions, when vegetation cover is formed by climbing (trailing) or hanging plants (cascading groundcover) growing upwards or downwards, respectively. Plant selection is principally based on a single evergreen or deciduous plant species depending on the desired result throughout the seasons and it is rooted in the ground or in planters. The GF consists of the presence or absence of specially designed supporting structures (stainless/coated/galvanised steel cables, wire mesh, flexible trellis systems, wooden, plastic, or aluminium systems) to guide epiphytic vegetation development through the vertical surface [7,8,13,14]. Regarding irrigation, automatic drip irrigation systems are generally used, and manual application of granular or dilute liquid fertiliser promotes and favours GF development [15].

Nowadays, VGSs constitute an integral infrastructure of urban greening and landscape architecture, promoting "biophilic" urban designs [16,17]. According to the world commercial offer, typical modular LW systems have the capacity to house up to 49 plants per square metre, which gives the possibility of introducing diverse plant types and increasing species number in a few vertical square metres. However, when applying GF technology, few plant species are planted but some have the capacity to climb and cover a vertical surface of at least 25 m [11,14,18]. These different characteristics of the systems should be taken into consideration to achieve the goal of conserving and improving urban biodiversity through landscape designing as the number of plants and the green coverage is of paramount importance [19].

Nevertheless, there are limited studies focused on the optimum selection of plant species in VGSs and even fewer analysing the introduction of native plants, in different climates, which could potentially increase urban biodiversity [12,20,21]. No commonly accepted protocols have been generated indicating principles, restrictions and specifying concrete steps for the selection of commercial or native species. For instance, the utilised plant lists for LWs, in different countries, consist primarily of commercial (non-native) evergreens in combination with few deciduous plant types such as low and robust shrubs, small herbaceous species, partial or full shade ferns and grasses without vigorous root system, which are mainly proposed for their adaptability to LW technology (e.g., *Begonia* spp., *Heuchera* spp., *Carex* spp., *Nephrolepis* spp., *Lonicera* spp., *Armeria maritima*, *Pachysandra terminalis* and *Soleirolia soleirolii*, *Sarcococca confusa*, among others) [7]. Regarding the plant selection for GFs, a narrower commercial spectrum is presented consisting of a list repeated during the last decades limited to specific plant species (e.g., *Hedera helix*, *Lonicera japonica*, *Jasminum* spp., *Dipladenia splendens*, *Wisteria sinensis*, *Parthenocissus quinquefolia*, *Rosa* spp. and *Bignonia radicans*, among others). However, there is a growing interest in plant selection and there are new vertical greening projects on the LW market with improved planting designs that present successful results through a sustainable approach that tend to require less maintenance, but with scarce introduction of native plant species.

This increasing necessity for sustainable solutions, due to the global trend of urban growth, incrementally attracts scientific community attention on native plants. Native flora is constantly threatened and displaced by urbanisation, yet the majority of published papers still refer to crops due to the commercial demand [22–26].

Admittedly, the introduction of native plant species in VGSs is a challenging process due to the previous study required, the limited commercial availability and the initial elevated risk due to the lack of experience. Undoubtedly, landscape architects and professionals who design VGSs are confronted with complex aesthetic (subjective factor) and practical criteria and various scientific and ethical considerations that should be considered during the plant selection and design [27,28]. However, the introduction of native plants in VGSs is an encouraging goal due to the abundant benefits they offer in urban life, such as urban biodiversity conservation, life cycle reduced carbon footprint, phytoremediation potentials, plant adaptability to local biotic and abiotic parameters, people's willingness to use native plant species and low maintenance cost among others [27,29–32].

The complexity of the selection of plants and design of VGSs increases with the particularities of the territory, climate and plant biodiversity, as in the case of Chile. According to the official information provided by the Government of Chile, the country is defined as a tricontinental and currently divided into three geographical zones (Continental Chile, Insular Chile, Chilean Antarctic Territory) [33]. Precisely, Continental Chile borders Peru to the north, Bolivia to the northeast, Argentina to the east and the Drake Passage to the south, whereas Insular Chile corresponds to a group of islands of volcanic origin in the south Pacific Ocean and Chilean Antarctic Territory is an area of the Antarctic extending its southern limit to the South Pole [33]. The Chilean territory is also subdivided into 16 regions: Region of Arica and Parinacota, Region of Tarapacá, Region of Antofagasta, Region of Atacama, Region of Coquimbo, Region of Valparaíso, Metropolitan Region of Santiago, Region of Libertador General Bernardo O'Higgins, Region of Maule, Region of Ñuble, Region of Biobío, Region of Araucanía, Region of Los Ríos, Region of Los Lagos, Region of Aysén del General Carlos Ibáñez del Campo and Region of Magallanes y de la Antártica Chilena [33,34].

As for the Chilean territory, it has an exceptional physical geography that dramatically affects the vascular flora and its biogeographical patterns. Chilean east and west natural boundaries are the Andes Mountains and the Pacific Ocean, respectively, which provoke a biogeographic isolation. The country presents a long latitudinal extent (4337 km) but in width scarcely broadens more than 200 km and a minimum of 90 km. Chile has been described by Subercaseaux [35] as "a geographic extravaganza" due to its remarkable geographical variations (e.g., the Atacama desert, a wide coastline of 6435 km in length, inland ice fields, active and non-active volcanoes, the Andes Mountains, etc.) and has been considered a biogeographic island by Pañitrur-De la Fuente et al. [36], due to its aforementioned natural barriers. Simultaneously, the difference in altitude from western to eastern Chile, meaning sea level coast to the Andes Mountains reaching 6893 m above sea level, generates a wide range of bioclimatic variations in its altitude profile. These variations in combination with the natural boundaries and the climatic latitudinal gradient, create diverse geographic conditions, and different unique phenomena are expressed, such as the "Flowering Desert", the "Bolivian Winter" and "El Niño", which profoundly affect the Chilean flora [33,36–42].

According to Sarricolea et al. [43], based on the updated Köppen–Geiger climate classification there are 25 climatic types occurring in continental Chile that are distributed from north to south as essentially arid, temperate and polar and the predominant climates are high tundra and Mediterranean. Regarding latitude, the climates of northern Chile are arid (Atacama Desert), and those of southern Chile are temperate, ranging from the Mediterranean to the western marine coast [43,44]. The plant hardiness zone map (PHZM) of Chile indicates the broad variety of the climatic areas as well, ranging from 1a (-51.1 °C to -48.38 °C) to 12a (10 °C to 12.8 °C) when the global PHZM ranges from 1a to 13b (18.3 °C to -21.1 °C) [45,46]. Therefore, highly heterogeneous biodiversity mosaics are expressed in the Chilean territory and different landscapes and ecosystems house a wide range of endemic and non-endemic plant species that range from the Atacama Desert to Patagonia.

Chile possesses a unique world heritage, recognized among the 34 global biodiversity hotspots ("regions that contain exceptional concentrations of native species but are experiencing rapid loss of their natural habitat") [36,47] of vascular flora by the Global 200 initiative of the Word Wide Fund for Nature and the World Bank, and its flora includes the second highest percentage of endemicity in South America [36,47]. In accordance with the taxonomic, geographic information and the catalogue of the vascular plants growing in continental and insular Chile presented by Rodriguez et al. [48], the Chilean flora includes 186 families, 1121 genera and 5471 species, 4655 of which are native, 2145 of these are endemic to Chile and 816 species are introduced [48]. According to most recent updates by Moreira-Muñoz [49], "the Chilean flora is composed of 56 orders, 171 families, 837 genera, and about 4295 species" (46% growing exclusively in its territory) including "4 endemic families, 84 endemic genera, and 1936 species endemic to the Chilean continental and oceanic territory". Asteraceae, Poaceae, Fabaceae, and Solanaceae families constitute the richest families in genera and species numbers, while *Senecio*, *Adesmia*, *Viola*, and *Carex* are the richest genera [49,50]. It should be mentioned that *Senecio* spp. and *Carex* spp. are commonly presented in different commercial LW projects worldwide, giving the Chilean native species potential adaptability to LW systems.

Native flora is adapted to local climatic and microclimatic conditions and frequently presents high tolerance levels to extreme climatic conditions [47]. This is a beneficial characteristic for VGSs, since its appropriate utilisation under the correct climatic conditions leads to a sustainable performance due to the reduced maintenance needs and native biodiversity conservation [50]. Within this frame of reference, there are no studies regarding the evaluation of the adaptability of native Chilean plant species in VGSs, nor a classification based on plant traits and their utilisation in different climatic conditions. The current study aims to characterise the potential of Chilean native plant species in VGSs, which is crucial information for future studies and the commercial utilisation of Chilean native plants in VGSs, also pointing to a new alternative for ex situ conservation of Chilean native flora. At the same time, the present work has the objective to investigate the Chilean public's perceptions and attitude towards LWs, GFs, native flora and the potential use of native plants in VGSs.

2. Materials and Methods

2.1. Bibliographical Research

To identify relevant publications related to this study, a search was conducted using the Web of Science database [51]. Moreover, for a more specific search on Chilean native plants, the digital library of the University of Chile [52] was used. For both cases, the time span of 1970 to 2022 was applied. For general search the following terms were used:

- "Chilean native species"
- "Chilean endemic species"
- "Chilean native species" AND "ornamental value"
- "Chilean endemic species" and "ornamental value"

Moreover, for specific taxonomic and morphological descriptions, search was performed using the scientific name of each species [53–57].

2.2. Analysis of the Information

The information collected was filtered applying several discrimination criteria and then organised using classification criteria. To facilitate the processing of data, species were divided according to their geographical localization in Chile, in four zones: North (from Arica y Parinacota Region to Coquimbo Region), centre (from Valparaíso Region to Maule Region), south (from Ñuble Region to Magallanes y la Antártica Chilena Region) and the Andes Mountains (above 1000 m of altitude).

2.2.1. Discrimination Criteria

Several criteria were applied in order to narrow the list of species and select only those with a potential for VGSs.

The first criterion applied was the "ornamental value" of Chilean endemic and non-endemic species. This criterion was based on the bibliographical search described above and confirmed with the books "*Flora nativa con valor ornamental*" [53–56].

After this, the following criteria were applied:

- Growth habit: Tree, shrub, herbaceous, climbing/creeping, fern.
- Life cycle: Annual, biannual, perennial (only perennials were selected for the present study).
- Plant height: Minimum and maximum in metres. For each category, GF and LW, different maximum and minimum height were established for the selection (Table 1), The plant height ranges were adapted to the plant list minimum and maximum height for each zone, based on the plant traits information according to the aforementioned bibliographical research.

Table 1. Plant height criteria considered for potential use in green façade and living wall.

Zone	Green Façade		Living Wall	
	Minimum Height (m)	Maximum Height (m)	Minimum Height (m)	Maximum Height (m)
North	0.4	4.0	0.3	1.2
Centre	2.0	10.0	0.3	0.5
South	4.0	20.0	0.1	0.3
Andes Mountains	0.4	2.0	0.3	0.3

2.2.2. Classification Criteria

The application of classification criteria allowed the characterization and clustering of the selected species according to their morphophenological traits and habitat. These are the criteria:

- Ornamental value: Leaf shape; flower colour, size and scent.
- Habitat/Annual precipitation: Scores 1 to 7, according to Table 2.
- Habitat/Temperature: Scores 1 to 6, according to Table 3.

Table 2. Classification of habitats of endemic and non-endemic species considering the annual precipitation.

Score	Annual Precipitation (mm)
1	<10
2	10 to 50
3	50 to 200
4	200 to 1000
5	1000 to 2500
6	2500 to 4500
7	>4500

2.3. Questionnaire Design and Survey Distribution

To evaluate the public's appreciation of Chilean native plants and their potential use in LWs and GFs, an online questionnaire in Spanish was applied using Google® Forms (Mountain View, CA, USA). The questionnaire is available as a Supplementary Material (Table S1). Briefly, the online form was comprised of 19 questions regarding basic personal and demographic information (questions 1–8), knowledge and opinion on LWs and GFs (questions 9–12) and on Chilean native plants (questions 13–15), as well as questions on the criteria for the selection of ornamental and/or Chilean native plants in LWs and GFs (questions 16–19).

Table 3. Classification of habitats of endemic and non-endemic species considering the minimum temperature registered in the coldest month (July) and the maximum temperature registered in the hottest month (January).

Score	Minimum T° (°C) Registered in July	Maximum T° (°C) Registered in January
1	<0	<5
2	0 to 5	5 to 11
3	5 to 9	11 to 17
4	9 to 13	17 to 25
5	13 to 17	25 to 32
6	>17	>32

The online questionnaire was disseminated through emails, WhatsApp groups and social media sites (Facebook, LinkedIn, Instagram and Twitter) to the participants and participants were requested to forward the survey. The questionnaire was open from 3 November 2022 until 3 December 2022.

Data were analysed using JMP® 16.0 (SAS Institute Inc, Cary, NC, USA) and Microsoft® Excel (Redmond, WA, USA). Demographic data and attitudinal data were evaluated using descriptive statistics. Attitude-based data regarding LWs, GFs and native plants (replies at questions 9–19) were pooled into summary graphs and analysed using logistic fit and contingency analyses in comparison with demographic data.

3. Results

3.1. Endemic and Non-Endemic Species with Ornamental Value

From the 4655 Chilean native species described [48], 1594 species were selected according to their ornamental value (Supplementary Materials Table S2). From this list, 62.9% (1002 species) were non-endemic and 37.1% (592 species) were endemic. The Andes Mountains concentrated the highest number of species with ornamental value (37.7%) compared to the rest of the geographical zones. The most common growth habits were shrubs and herbaceous with 34.5% and 51.1% of the total species, respectively (Table 4).

Table 4. Summary of the endemic and non-endemic Chilean species selected according to the criterion "ornamental value", describing their geographical distribution and growth habit.

Zone.	N° of Species	T	S	H	Cr	F
North	334	20	136	154	14	10
Centre	338	36	109	155	29	9
South	321	51	80	137	25	28
Andes Mountains	601	6	225	368	2	0
Total	1594	113	550	814	70	47

T = Tree; S = Shrub; H = Herbaceous; Cr = Creeping/Crawling; F = Fern.

The highest levels of endemism were observed in the centre and north zones with 68.3% and 58.6%, respectively, much higher than the average observed in the whole country (37.1%) (Figure 1).

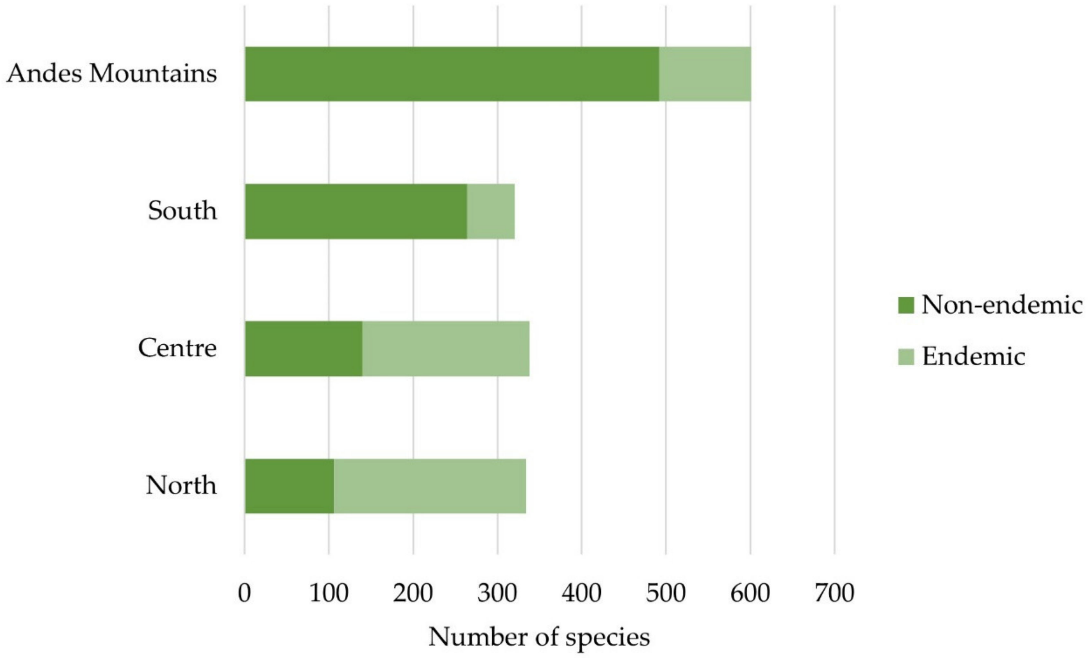

Figure 1. Number of Chilean endemic and non-endemic species with ornamental value distributed in each geographical zone.

The most common family was Asteraceae with 294 species, most of them concentrated in the Andes Mountains (173). The other relevant families are *Fabaceae* and *Solanaceae* contributing with 69 and 46 species, respectively. While *Fabaceae* is also concentrated in the Andes Mountains (54 species), *Solanaceae* is exclusively present in the north and centre zones (Figure 2).

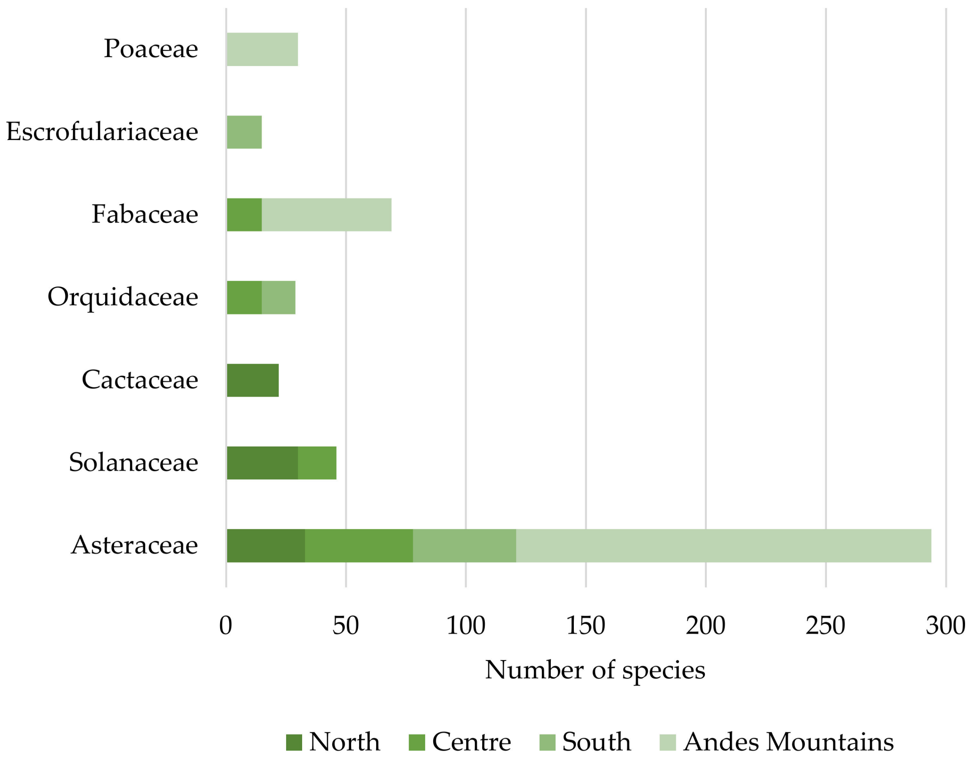

Figure 2. Dominant taxonomic families in terms of number of Chilean native species with ornamental value, distributed in each geographical zone.

3.2. Endemic and Non-Endemic Species Selected for Vertical Greening Systems

A total of 109 species were selected with potential use in VGSs, according to the classification criteria described in the Materials and Methods section. Most of them were selected for LWs (70 species) and a high level of endemism among these species was observed (44%) (Table 5).

Table 5. Number of endemic and non-endemic species from different zones of Chile considered with potential use for green façade and living wall.

Zone	Non-Endemic		Endemic		Total
	Green Façade	Living Wall	Green Façade	Living Wall	
North	0	3	9	13	25
Centre	5	9	10	8	32
South	10	17	1	3	31
Andes Mountains	3	14	1	3	21
Total	18	43	21	27	109

3.2.1. Green Façades

For potential use in GFs, a total of 39 Chilean species, including 18 non-endemic and 21 endemic, were selected. These species were mainly concentrated in the centre (15 species) and the most common families were Apocynaceae with 4 species (*Diplolepsis* spp.) and Tropaeolaceae with 6 species (*Tropaeolum* spp.). Moreover, most of the species show a creeping or crawling growth habit (84.6%) (Table 6). In terms of the habitat of these species, the maximum temperature ranged between 17 and 32 °C (4 and 5), while the minimum temperature and precipitation was very dependent on each geographical zone.

3.2.2. Living Walls

A total of 70 Chilean native species, 27 of which are endemic, were selected for their potential use in LWs. These species were equally distributed across the country, ranging between 16 species in the north and 20 species in the south. Most of the selected species were herbaceous (49), but also a group of ferns endemic and non-endemic to the south, mainly from the Hymenophyllaceae family, was important (10 species). The Amaryllidaceae family was present in all the geographical zones with 4 genus and 9 different species. Furthermore, in general the group of species selected was very diverse taxonomically, including a total of 38 families (Table 7).

3.3. Survey-Based Analysis of the Public's Appreciation of Chilean Native Plants and Their Potential Use in Living Walls and Green Façades

3.3.1. Demographic Characterisation

A total of 482 responses were collected through the online questionnaire. A summary of the demographic data is presented in Table 8. The participants were primarily females (n = 265, 61.9%), aged between 41 and 65 years old (n = 191, 44.6%). Most of the participants hold a university degree (n = 186, 43.5%) or a postgraduate title (n = 122, 28.5%) and grew up in urban areas of the Metropolitan Region of Santiago (n = 129, 30.1%) or in other regions (n = 234, 54.7%). The same tendency was observed regarding the current place of participants' residence (urban areas of the Metropolitan Region of Santiago: n = 130, 30.4%; urban areas in other Regions: n = 252, 58.9%). Most of the participants live in self-acquired properties (n = 284, 66.4%) with a garden or a balcony. Lastly, the participants described themselves mostly as quite or very interested in gardening (n = 271, 63.7%).

3.3.2. Knowledge and Opinion on Living Walls, Green Façades and Chilean Native Plants

The questionnaire included the definitions of LWs, GFs and native plants and the participants were asked to reply whether they knew the terms prior to reading the definitions (questions 9, 10 and 13). The participants replied positively to all those three questions, namely regarding their prior knowledge of the term "Living walls" (n = 325, 75.9%), the term "Green façades" (n = 233, 54.4%) and the term "native plants" (n = 398, 93.0%). Most participants agreed or strongly agreed that it would be a nice idea to use LWs and/or GFs inside their house/apartment (75.5%) and in their garden/balcony (90.0%). Moreover, most of the participants agreed or strongly agreed with the use of Chilean native plants inside their house/apartment (75.0%) and in their garden/balcony (84.4%) (Figure 3).

Table 6. Selected Chilean endemic and non-endemic species with potential for green façades, including information about their growth habit, height, origin and habitat (maximum and minimum temperature and precipitation).

Zone	Family	Scientific Name	Growth	Height (m)	Origin	Maximum T° Score	Minimum T° Score	Precipitation Score
North	Apocynaceae	*Diplolepis geminiflora* (Decne.) Liede & Rapini	Cr	2	E	4, 5	2, 3, 4	1, 2, 3, 4
		Diplolepis boerhaviifolia (Hook. & Arn.) Liede & Rapini	Cr	2	E	4, 5	2, 3, 4	1, 2, 3, 4
		Diplolepis viridis (Phil.) Hechem & C.Ezcurra	Cr	2	E	4, 5	2, 3, 4	1, 2, 3, 4
	Asteraceae	*Mutisia cana* Poepp. & Endl.	Cr	1.5	E	4, 5	2, 3, 4	2, 3, 4
		Mutisia spectabilis Phil.	Cr	4	E	4, 5	3	3
	Tropaeolaceae	*Tropaeolum beuthii* Klotzsch	Cr	0.5	E	4	4	1
		Tropaeolum tricolor Sweet	Cr	2	E	4, 5	2, 3, 5	1, 2, 3, 4, 5
	Asclepiadaceae	*Tweedia stipitata* G.H.Rua & Liede	Cr	ni	E	4	3	3
	Alliaceae	*Nolana rupicola* Gaudich.	H	0.4	E	4	3 y 4	1, 2, 3
Centre	Vitaceae	*Cissus striata* Ruiz & Pav.	Cr	5	N-E	4, 5	2, 3	3, 5
	Dioscoreaceae	*Dioscorea bryoniifolia* Poepp.	Cr	3	E	4, 5	2, 3	3, 5
	Apocynaceae	*Diplolepis geminiflora* (Decne.) Liede & Rapini	Cr	2	E	4, 5	2, 3, 4	2, 4
		Diplolepis menziesii Schult.	Cr	3	E	4, 5	2, 3, 4	3, 4
	Bignoniaceae	*Eccremocarpus scaber* Ruiz & Pav.	Cr	5	N-E	4, 5	2, 3	3, 5
	Griseliniaceae	*Griselinia scandens* (Ruiz & Pav.) Taub.	S	2	E	4, 5	1, 2, 3	3, 5
	Hydrangeaceae	*Hydrangea serratifolia* (Hook. & Arn.) F.Phil.	Cr	10	N-E	4, 5	1, 2, 3	3, 5
	Lardizabalaceae	*Lardizabala biternata* Ruiz & Pav.	Cr	6	E	4, 5	2, 3	3, 5
	Asteraceae	*Mutisia decurrens* Cav.	Cr	4	N-E	4, 5	1, 2, 3	4, 5
	Passifloraceae	*Passiflora pinnatistipula* Cav.	Cr	6	N-E	5	3	3
	Asteraceae	*Proustia pyrifolia* DC.	S	5	E	4, 5	2, 3	3, 5
	Tropaeolaceae	*Tropaeolum azureum* Bertero ex Colla	Cr	1.5	E	4, 5	2, 3, 4	1, 4
		Tropaeolum brachyceras Hook. & Arn.	Cr	2	E	4, 5	2, 3	3, 4
		Tropaeolum ciliatum Ruiz & Pav.	Cr	4	E	3, 4, 5	2, 3	3, 5
		Tropaeolum tricolor Sweet	Cr	3	E	4, 5	2, 3, 4	1, 2, 3, 4, 5
South	Flacourtiaceae	*Berberidopsis corallina* Hook.f.	Cr	15	E	4, 5	2, 3	4, 5
	Bignoniaceae	*Campsidium valdivianum* (Phil.) W.Bull	Cr	15	N-E	4, 5	1, 2, 3	4, 5
	Vitaceae	*Cissus striata* Ruiz & Pav.	S	5	N-E	4, 5	2, 3	3, 5
	Phytolaccaceae	*Ercilla syncarpellata* Nowicke	S	5	N-E	4, 5	2, 3	4, 5
	Hydrangeaceae	*Hydrangea serratifolia* (Hook. & Arn.) F.Phil.	Cr	10	N-E	4, 5	2, 3	3, 5
	Lardizabalaceae	*Lardizabala biternata* Ruiz & Pav.	Cr	6	N-E	4, 5	2, 3	3, 5
	Gesneriaceae	*Mitraria coccinea* Cav.	Cr	8	N-E	4, 5	1, 2, 3	4, 5
	Polygonaceae	*Muehlenbeckia tamnifolia (Kunth) Meisn.*	S, Cr	20	N-E	4, 5	2, 3	3, 5
	Asteraceae	*Mutisia decurrens* Cav.	Cr	4	N-E	4, 5	1, 2, 3	4, 5
	Philesiaceae	*Philesia magellanica* J.F.Gmel.	S, Cr	5	N-E	4	1, 2, 3	4, 5
	Tropaeolaceae	*Tropaeolum speciosum* Poepp. & Endl.	Cr	5	N-E	4	2, 3	5
Andes Mountains	Calceolariaceae	*Calceolaria inamoena* Kraenzl.	S	0.4	E	5	5	1
	Tropaeolaceae	*Tropaeolum incisum* (Speg.) Sparre	Cr	0.5	N-E	4, 5	2, 3	4, 5
		Tropaeolum leptophyllum G.Don	Cr	2	N-E	4, 5	2, 3	4, 5
		Tropaeolum tricolor Sweet	Cr	2	N-E	4, 5	2, 3, 4	1, 2, 3, 4, 5

Cr = Creeping/Crawling; S = Shrub; E = Endemic; N-E = non-endemic.

Table 7. Selected Chilean endemic and non-endemic species with potential for Living walls, including information about their growth habit, height, origin and habitat (maximum and minimum temperature and precipitation).

Zone	Family	Scientific Name	Growth Habit	Height (m)	Origin	Maximum T° Score	Minimum T° Score	Precipitation Score
North	Amaranthaceae	*Alternanthera halimifolia* (Lam.) Standl. ex Pittier	S	0.3	N-E	4, 5	4, 5	1, 2
	Malvaceae	*Cristaria aspera* Gay	H	0.9	E	4	3, 4	1, 2, 3
		Cristaria integerrima Phil.	H	1.2	E	4	4	1
		Cristaria viridiluteola Gay	H	1.2	E	4	4	2
	Amaryllidaceae	*Leucocoryne coquimbensis* F.Phil. ex Phil.	H	0.3	E	4, 5	3	3, 4
		Leucocoryne purpurea Gay	H	0.5	E	3	4	3
		Placea amoena Phil.	H	0.4	E	3	4	3
		Rhodophiala laeta Phil.	H	0.4	E	4	4	1, 2
		Rhodophiala phycelloides (Herb.) Hunz.	H	0.3	E	4	3, 4	2, 3
	Oxalidaceae	*Oxalis megalorrhiza* Jacq.	S	0.3	E	4, 5	2, 3, 4, 5	1, 2, 3, 4
		Oxalis ornithopus Phil.	H	0.3	E	4	4	1, 2
		Oxalis ovalleana Phil.	H	0.3	E	4	3, 4	1, 2, 3
		Oxalis tortuosa Lindl.	H	0.3	E	2, 3	4, 5	3, 4
	Tecophilaeaceae	*Zephyra elegans* D.Don	H	0.3	E	3, 4, 5	4, 5	1, 2, 3
	Bromeliaceae	*Tillandsia capillaris* Ruiz & Pav.	B	0.3	N-E	4, 5	3, 4, 5	1, 2, 3
		Tillandsia marconae W.Till & Vitek	B	0.3	N-E	5	5	1
Centre	Alstroemeriaceae	*Alstroemeria ligtu* L.	H	1.5	E	5	2	4, 5
		Alstroemeria pseudospathulata Ehr.Bayer	H	0.3	N-E	4, 5	2, 3	4, 5
		Alstroemeria umbellata Meyen	H	0.3	N-E	5	2	4
	Plumbaginaceae	*Armeria maritima* (Mill.) Willd.	H	0.3	N-E	3, 4, 5	1, 2, 3	3, 4, 5
	Calceolariaceae	*Calceolaria corymbosa* Ruiz & Pav.	H	0.3	E	4, 5	2, 3	3, 4, 5
	Alliaceae	*Nothoscordum gramineum* Beauverd	H	0.3	N-E	4, 5	2, 3	3, 4, 5
	Asteraceae	*Perezia carthamoides* Hook. & Arn.	H	0.2	N-E	4, 5	2, 3	3, 4, 5
	Amaryllidaceae	*Placea arzae* Phil.	H	0.3	E	5	2	4
		Placea ornata Miers	H	0.3	E	5	3	3
	Iridaceae	*Sisyrinchium azureum* Phil.	H	0.3	N-E	4, 5	1, 2, 3	3, 4, 5
		Solenomelus segethii (Phil.) Kuntze	H	0.3	N-E	4, 5	2	3, 4
	Acanthaceae	*Stenandrium dulce* (Cav.) Nees	H	0.3	N-E	4, 5	2, 3	3, 4, 5
	Asteraceae	*Trichocline aurea* Reiche	H	0.3	E	4, 5	2, 3	3, 4, 5
	Asparagaceae	*Trichopetalum plumosum* (Ruiz & Pav.) J.F.Macbr.	H	0.3	E	4, 5	2, 3	3, 4, 5
	Tropaeolaceae	*Tropaeolum sessilifolium* Poepp. & Endl.	H	0.3	E	4, 5	2, 3	3, 4
	Valerianaceae	*Valeriana papilla* Bert. ex DC.	H	0.3	E	4, 5	2, 3	3, 4
	Blechnaceae	*Blechnum hastatum* Kaulf.	F	0.7	N-E	4, 5	2, 3	3, 4, 5
South	Aspleniaceae	*Asplenium dareoides* Desv.	F	0.3	N-E	3, 4, 5	1, 2, 3, 4	3, 4, 5
	Gleicheniaceae	*Gleichenia squamulosa* (Desv.) T.Moore	F	0.3	E	4, 5	1, 2, 3, 4	4, 5
	Hymenophyllaceae	*Hymenophyllum caudiculatum* Mart.	F	0.3	N-E	3, 4, 5	1, 2, 3, 4	4, 5
		Hymenophyllum dentatum Cav.	F	0.3	N-E	4	1, 2, 3	4, 5
		Hymenophyllum dicranotrichum (C.Presl) Sadeb.	F	0.3	E	4	1, 2, 3	4, 5
		Hymenophyllum ferrugineum Colla	F	0.3	N-E	3, 4, 5	1, 2, 3, 4	4, 5
		Hymenophyllum fuciforme Sw.	F	0.3	N-E	4	1, 2, 3, 4	4, 5
		Hymenophyllum krauseanum Phil.	F	0.3	N-E	4	1, 2, 3	4, 5
		Hymenophyllum pectinatum Nees & Blume	F	0.3	N-E	4, 5	1, 2, 3, 4	4, 5
	Dryopteridaceae	*Polystichum plicatum* Hicken ex Hosseus	F	0.3	N-E	3, 4, 5	1, 2, 3	3 a 5
	Rosaceae	*Acaena magellanica* (Lam.) Vahl	H	0.3	N-E	3, 4, 5	1, 2, 3, 4	1, 2, 3, 4, 5
	Calceolariaceae	*Calceolaria biflora* Lam.	H	0.3	N-E	3, 4, 5	1, 2, 3	3, 4, 5
	Brassicaceae	*Draba gilliesii* Hook. & Arn.	H	0.3	N-E	4	2, 3	5
	Asteraceae	*Erigeron cinereus* A.Gray	H	0.15	N-E	4, 5	2, 3	4, 5
		Haplopappus diplopappus J.Rémy	S	0.25	N-E	4, 5	2, 3	4, 5
	Urticaceae	*Pilea elliptica* Hook.f.	H	0.3	N-E	4	2, 3	5
	Polygalaceae	*Polygala gnidioides* Willd.	H	0.3	E	3, 4, 5	1, 2, 3	4, 5
	Amaryllidaceae	*Rhodophiala bakeri* (Phil.) Traub	H	0.25	N-E	4, 5	2, 3	4, 5
	Asteraceae	*Senecio trifurcatus* C.Jeffrey	H	0.2	N-E	3, 4	1, 2	4, 5
	Iridaceae	*Sisyrinchium pearcei* Phil.	H	0.3	N-E	4	2	5
Andes Mountains	Rhamnaceae	*Discaria nana* (Clos) Benth. & Hook.f. ex Weberb.	S	0.3	E	4, 5	2, 3	3, 4, 5
	Krameriaceae	*Krameria lappacea* (Dombey) Burdet & B.B.Simpson	S	0.8	N-E	4, 5	4, 5	1
	Asteraceae	*Mutisia oligodon* Poepp. & Endl.	S	0.3	N-E	4	2, 3	5
	Escalloniaceae	*Tribeles australis* Phil.	S	0.3	N-E	3, 4	1, 2	4, 5
	Rosaceae	*Acaena alpina* Poepp. ex Walp.	S	0.3	N-E	4, 5	2, 3	3, 4, 5
	Phrymaceae	*Erythranthe cuprea* (Dombrain) G.L.Nesom	H	0.3	N-E	4, 5	2, 3	4, 5
	Euphorbiaceae	*Euphorbia collina* Brandegee	H	0.3	N-E	4, 5	2, 3	3, 4
	Scrophulariaceae	*Famatina cisandina* Ravenna	H	0.3	E	5	2	4
	Amaryllidaceae	*Latace andina* (Poepp.) Sassone	H	0.3	N-E	4, 5	2, 3, 4	3, 4
	Iridaceae	*Mastigostyla cyrtophylla* I.M.Johnst.	H	0.3	N-E	5	5	1
	Asteraceae	*Perezia pedicularidifolia* Less.	H	0.3	N-E	4, 5	1, 2, 3	4, 5
	Apiaceae	*Sanicula graveolens* Poepp. ex DC.	H	0.3	N-E	4, 5	2, 3	3, 4, 5
	Saxifragaceae	*Senecio zoellneri* Martic. & Quezada	H	0.3	N-E	5	5	1
	Malesherbiaceae	*Malesherbia lanceolata* Ricardi	H	0.4	E	4	3	3
	Caryophyllaceae	*Spergularia pissisi* (Phil.) I.M.Johnst.	H	0.3	N-E	4	3, 4	2, 3
	Cyperaceae	*Carex gayana* Desv.	H	0.3	N-E	3, 4, 5	1, 2, 3, 4	2, 3, 4, 5
	Poaceae	*Festuca chrysophylla* Phil.	H	0.3	N-E	4, 5	4, 5	1

S = Shrub; H = Herbaceous; F = Fern; E = Endemic; N-E = non-endemic.

Table 8. Demographics of the survey.

	No. (%)		No. (%)		No. (%)		No. (%)
Gender		**Age (y.o.)**		**Max. Educational Level Completed**		**Grew Up In**	
Female	265 (61.9)	18–25	74 (17.3)	No studies / Basic	0	Urban areas—MR *	129 (30.1)
Male	157 (36.7)	26–40	146 (34.1)	Middle	72 (16.8)	Urban areas—Other Regions	234 (54.7)
I do not wish to disclose	6 (1.4)	41–65	191 (44.6)	Technical degree	48 (11.2)	Non-urban/Rural areas—MR *	12 (2.8)
		66–80	17 (4.0)	University degree	186 (43.5)	Non-urban/Rural areas—Other Regions	53 (12.4)
		>80	0	Postgraduate	122 (28.5)		
	No. (%)		**No. (%)**		**No. (%)**		**No. (%)**
Presently living in		**Presently living in**		**Living in**		**Interested in gardening**	
Urban areas—MR *	130 (30.4)	Self-acquired property	284 (66.4)	House with small garden (<15m^2)	121 (28.3)	Not interested	20 (4.7)
Urban areas—Other Regions	252 (58.9)	Rent	144 (33.6)	House with big garden (>15m^2)	126 (29.4)	Slightly interested	121 (28.3)
Non-urban/Rural areas—MR *	13 (3.0)			House w/o garden	33 (7.7)	Indifferent	14 (3.3)
Non-urban/Rural areas—Other Regions	33 (7.7)			Apartment with balcony	123 (28.7)	Quite interested	117 (27.3)
				Apartment w/o balcony	25 (5.9)	Very interested	156 (36.4)

MR *: Metropolitan Region.

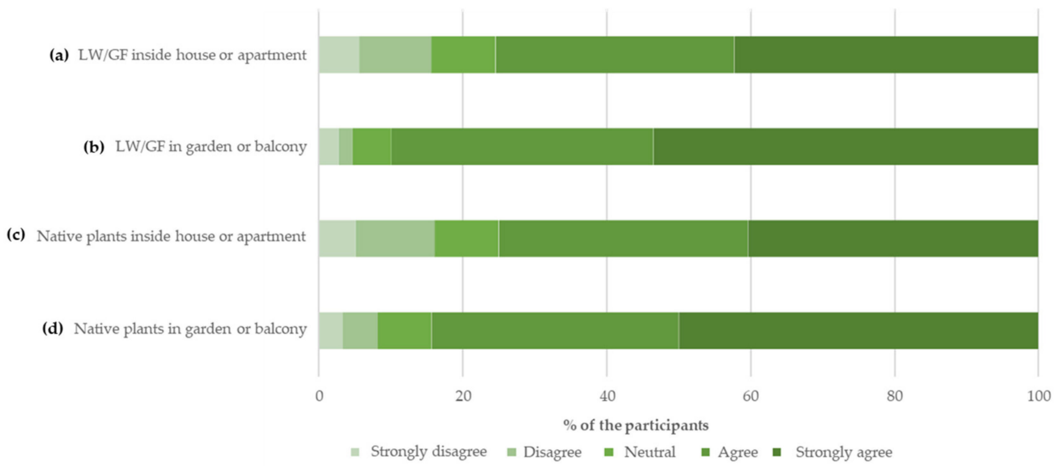

Figure 3. Participants' attitude regarding the phrase "It would be a good idea to have: (**a**) Living walls (LWs) and/or green façades (GFs) inside my house or apartment; (**b**) LWs and/or GFs in my garden or balcony; (**c**) native plants inside my house or apartment; (**d**) native plants in my garden or balcony".

Furthermore, the participants were asked to evaluate the importance of several criteria for the selection of ornamental plants for a LW and/or a GF inside their house/apartment or in their garden/balcony (Figure 4). The evaluation of the proposed criteria presented the same tendency between indoor and outdoor VGSs, while the participants agreed or strongly agreed on the importance of all seven criteria included in the survey, namely easy maintenance (82.0% indoors, 81.1% outdoors), cost (72.0% indoors, 71.3% outdoors), flower colour (71.7% indoors, 70.6% outdoors), foliage traits (70.6% indoors, 71.5% outdoors), aroma (69.6% indoors, 63.8% outdoors) and native origin (47.7% indoors, 53.3% outdoors).

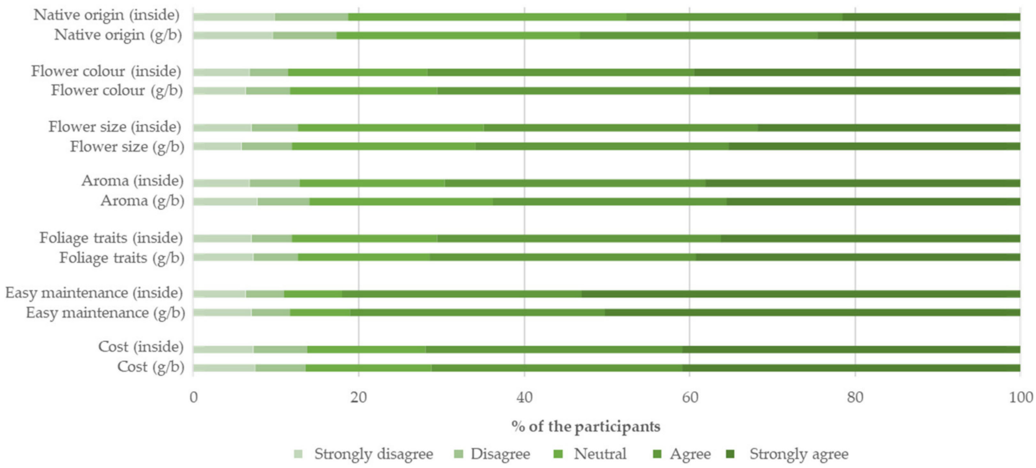

Figure 4. Participants' evaluation of the criteria for the selection of ornamental plants to be used in Living walls and/or green façades inside their house or apartment and in their garden or balcony (g/b).

Finally, the participants were asked to evaluate several criteria based on which they would or would not prefer to use Chilean native plants in a LW and/or a GF (Figure 5). The majority agreed or strongly agreed that they would prefer to use Chilean native plants because this permits species conservation (79.4%) and because native plants adapt better to the local environmental conditions (78.3%). Moreover, most of the participants agreed or strongly agreed with the selection of Chilean native plants because they were considered more original (61.9%) and more attractive (53.7%). On the contrary, the participants, in general, rejected the proposed reasons to refuse the use of Chilean native plants in VGSs. Specifically, the participants disagreed or strongly disagreed with the arguments that the use of Chilean native plants in LWs and/or GFs is not preferable because they are unknown (63.6%) and of higher cost (47.9%) and that they require higher maintenance (45.6%). Still, 46.3% of the participants declared that they would not prefer the use of Chilean native plants because they are less available in the market.

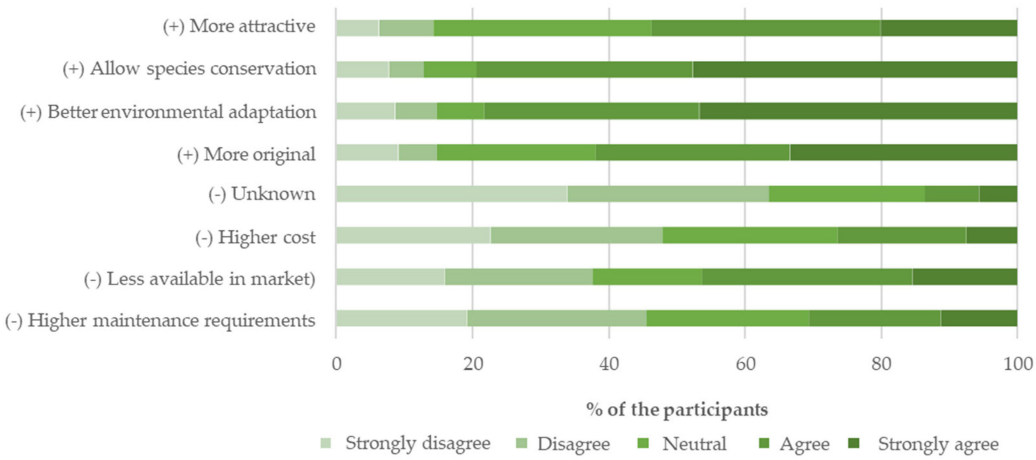

Figure 5. Participants' evaluation of the proposed criteria for the selection (+ in Figure) or refusal (- in Figure) of Chilean native plants to be used in living walls and/or green façades.

3.3.3. Comparison of Attitude-Based Data with Demographics Using Contingency Analysis

All demographic data were analysed using contingency analysis against attitude-based data regarding LWs, GFs and native plants. In continuation, the only results that were found to be statistically significant ($\alpha = 0.05$) using both the Pearson and Likelihood Ratio tests are discussed.

Attitude-Based Data on Living Walls and Green Façades

Educational level was found to have a statistically significant relationship with whether the participants were familiar with the definitions of LWs and GFs (Table 9), being those with completed postgraduate studies the ones with higher percentage of prior knowledge of both definitions. Moreover, in the case of the definition of LWs, a statistically significant relationship can be attributed to the age of the participants (higher percentage of prior knowledge of the definition in those aged between 41 and 65 years), while a significantly higher level of prior knowledge of the GF definition was observed as the participants' age raised (Table 9). Individuals who grew up in non-urban or rural areas of all regions of Chile presented a significantly higher level of prior knowledge of the GF definition (Table 9). Furthermore, those living in houses with big gardens (>15 m^2), as well as those interested and very interested in gardening were the ones with statistically significant higher percentages of prior knowledge of both the LW and the GF definitions (Table 9).

Table 9. Statistical significance (Pearson Chi test value) based on contingency analysis of attitude-based data on living walls (LWs) and green façades (GFs) against demographic data.

Data.	Before Reading the Definition, Did You Know What a LW Was?	Before Reading the Definition, Did You Know What a GF Was?	Opinion Regarding the Phrase, "It Would Be a Good Idea to Have a LW/GF in My House or Apartment".	Opinion Regarding the Phrase, "It Would Be a Good Idea to Have a LW/GF in My Garden or Balcony"
Sex	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Age	0.0146 *	<0.0001 *	*n.s.*	*n.s.*
Max. Educational Level Completed	<0.0001 *	0.0248 *	*n.s.*	*n.s.*
Area where one grew up	*n.s.*	0.0181 *	0.026 *	*n.s.*
Area where one lives	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Type of property where one lives (Self-acquired or in rent)	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Type of property where one lives (Presence/size of garden/balcony)	0.0104 *	0.0145 *	*n.s.*	*n.s.*
Interest in gardening	0.0006 *	0.0001 *	<0.0001 *	<0.0001 *

n.s.: not statistically significant, *: statistically significant ($\alpha = 0.05$).

Regarding the level of acceptance of the phrase, "It would be a good idea to have a Living wall or a Green façade in my house or apartment", a significant difference was observed among participants who grew up in different areas (Table 9). For example, among those who grew up in urban areas in the Metropolitan Region of Santiago, 65.12% agree or strongly agree with having a LW or a GF inside their house or apartment (Figure 6). Still, the same level of acceptance was observed for the 79.92% of those who grew up in urban areas of other Regions in Chile. No statistically significant differences were observed regarding the use of those VGSs in gardens or balconies among the residents of different areas.

Finally, the participants who described themselves as interested and very interested in gardening were the ones with the highest acceptance levels regarding the use of LWs or GFs, both indoors and outdoors.

Attitude-Based Data on Chilean Native Plants

No statistically significant relationship was observed among demographic data and participants' prior knowledge of the definition of native plants (Table 10). Regarding the use of native plants in indoor VGSs, the participants who grew up in urban areas of the Metropolitan Region of Santiago presented significantly lower levels of agreement with the phrase, "It would be a good idea to have native plants in my house or apartment". Moreover, the participants' interest in gardening significantly affected their opinion on the use of native plants both indoors and outdoors; those interested and very interested in gardening were the ones with significantly higher percentages of acceptance of the use of native plants.

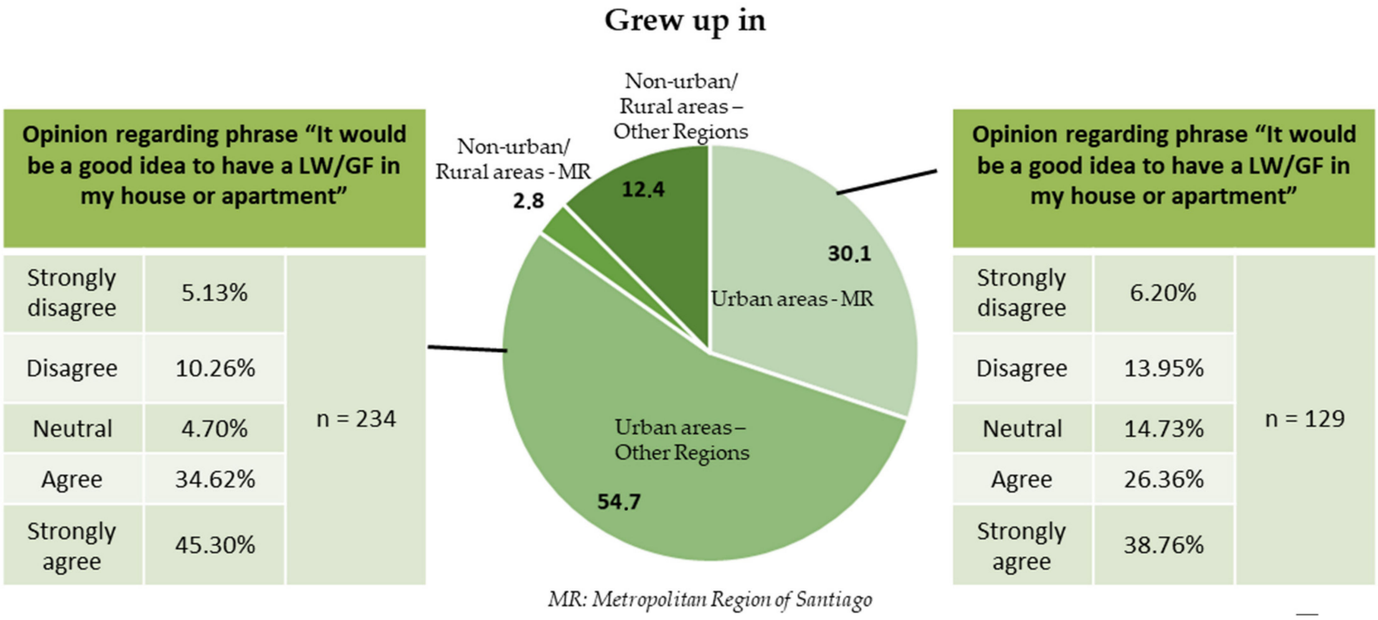

Figure 6. Participants' acceptance of the phrase, "It would be a good idea to have a Living wall (LW) or a Green façade (GF) in my house or apartment" against the area where they grew up.

Table 10. Statistical significance (Pearson Chi test value) based on contingency analysis of attitude-based data on native plants against demographic data.

Data	Before Reading the Definition, Did You Know What a Native Plant Was?	Opinion Regarding the Phrase "It Would Be a Good Idea to Have Native Plants in My House or Apartment".	Opinion Regarding the Phrase, "It Would Be a Good Idea to Have Native Plants in My Garden or Balcony"
Sex	*n.s.*	*n.s.*	*n.s.*
Age	*n.s.*	*n.s.*	*n.s.*
Max. Educational Level Completed	*n.s.*	*n.s.*	*n.s.*
Area where one grew up	*n.s.*	0.02 *	*n.s.*
Area where one lives	*n.s.*	*n.s.*	*n.s.*
Type of property where one lives (Self-acquired or in rent)	*n.s.*	*n.s.*	*n.s.*
Type of property where one lives (Presence/size of garden/balcony)	*n.s.*	*n.s.*	*n.s.*
Interest in gardening	*n.s.*	<0.0001 *	<0.0001 *

n.s.: not statistically significant, *: statistically significant (α = 0.05).

Attitude-Based Data on Attributes of Ornamental Plants

The relationships among demographic data and perception on attributes of ornamental plants for indoor and outdoor use in LWs and/or GFs are presented in Table 11. With respect to indoor use, no significant effects of demographics were observed on the importance of the plants' native origin. The age of the participants significantly affected the importance they attach to the flower colour for indoor use, with the trait being progressively less important among older participants. Furthermore, participants 66–80 years old gave significantly less importance to the indoor plants' foliage traits, easy maintenance, and cost in comparison to the other age groups. Another significant relationship was observed between the area where the participants grew up and the importance they attach to flower colour of plants used indoors; those who grew up in non-urban or rural areas of all regions tend to perceive flower colour as less important than those who grew up in urban areas. On the contrary, flower colour of indoor plants is considered significantly more important by those who live in houses without gardens. Finally, those interested and very interested in gardening attached significantly less importance to the flower size and significantly higher importance to the foliage traits of the plants to be used in indoor VGSs.

Table 11. Statistical significance (Pearson Chi *test* value) based on contingency analysis of attitude-based data on attributes of ornamental plants for indoor (In) and outdoor (Out) use in living walls and/or green façades against demographic data.

Data.	Native Origin		Flower Colour		Flower Size		Aroma		Foliage Traits		Easy Maintenance		Cost	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Sex	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Age	*n.s.*	0.0083 *	0.0001 *	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	0.0028 *	*n.s.*	0.005 *	*n.s.*	0.03 *	*n.s.*
Max. Educational Level Completed	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Area where one grew up	*n.s.*	*n.s.*	0.039 *	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Area where one lives	*n.s.*	0.0131 *	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	0.0212 *	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Type of property where one lives (Self-acquired or in rent)	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Type of property where one lives (Presence/size of garden/balcony)	*n.s.*	*n.s.*	0.0319 *	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Interest in gardening	*n.s.*	*n.s.*	*n.s.*	0.0448 *	0.0372 *	*n.s.*	*n.s.*	0.0174 *	<0.001 *	<0.001 *	*n.s.*	*n.s.*	*n.s.*	*n.s.*

n.s.: not statistically significant, *: statistically significant ($\alpha = 0.05$).

Regarding the attributes of ornamental plants for use in outdoor VGSs, participants aged between 41 and 65 years attached significantly higher importance to the plants' native origin than participants of the other age groups (Table 11). Regarding the importance of native origin for plants for outdoor use, a significant difference was observed among participants that live in different areas (Table 11). For example, among the residents of non-urban or rural areas in the Metropolitan Region of Santiago, 46.16% agreed or strongly agreed with the importance of native origin when choosing an ornamental plant for a LW or a GF in their garden or balcony (Figure 7). Still, the same level of acceptance was observed for the 69.7% of the residents of non-urban or rural areas of other Regions in Chile. Moreover, participants living in different areas attached significantly different importance on foliage traits for plants used in outdoor vertical gardening systems (Table 11), being the residents of non-urban or rural areas of the Metropolitan Region of Santiago those who consider them less important.

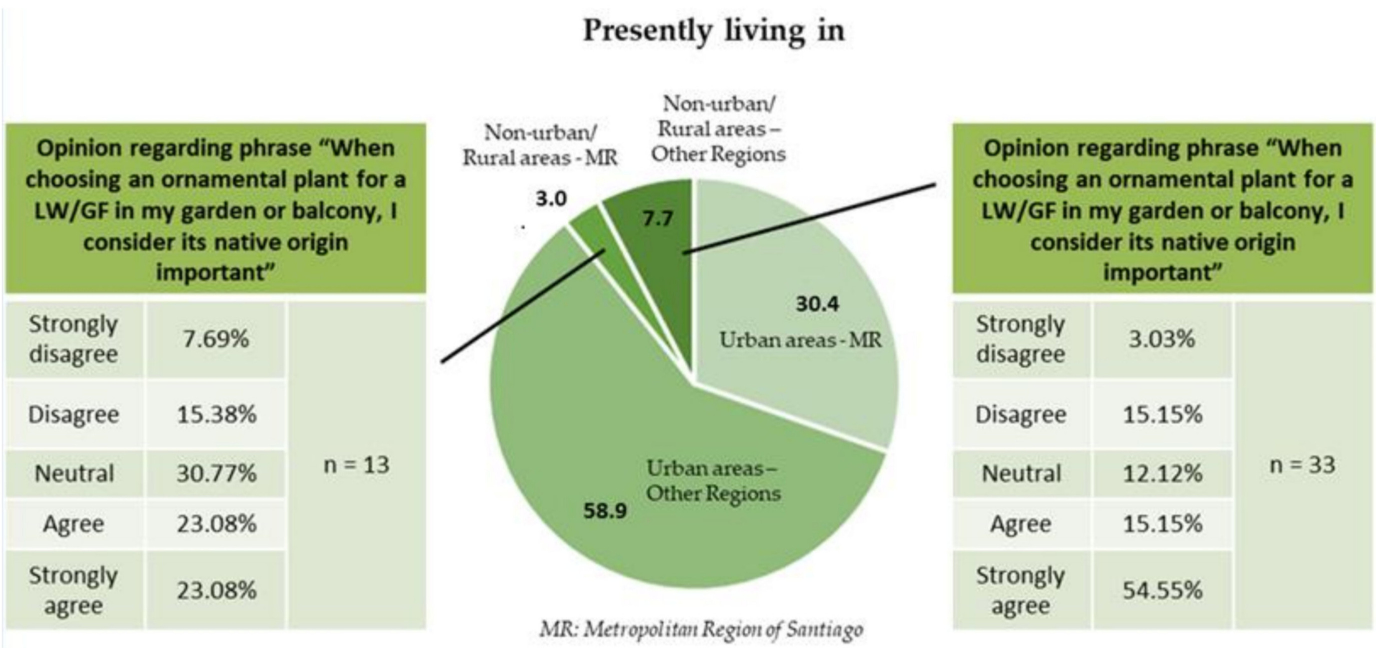

Figure 7. Participants' acceptance of the phrase "When choosing an ornamental plant for a living wall (LW) or a green façade (GF) in my garden or balcony, I consider its native origin important" against the area where they presently live.

The participants' interest in gardening was found to significantly affect the importance they attach to some of the traits (Table 11). Those neutral or not interested in gardening considered flower colour and aroma of outdoor plants more important than the rest of the participants. However, those with a neutral opinion about gardening attached a significantly lower importance to foliage traits than the rest of the participants.

The relationships among demographic data and the participants' opinion regarding attributes of native plants used in LWs and/or GFs are presented in Table 12. The participants' age was found to be significantly related to their preference for native plants in VGSs; participants aged 66–80 years old showed a lower level of agreement with the arguments that native plants would be preferred because their use promotes species conservation and because they are more original. The same age group presented a significantly higher level of disagreement with the arguments that the use of native plants would be hindered because they are unknown and less available in the market. Moreover, as the participants' age increased, there was a progressively increasing level of disagreement with the arguments that the use of native plants would be discouraged because they are of higher cost and higher maintenance.

Table 12. Statistical significance (Pearson Chi test value) based on contingency analysis of attitude-based data on attributes of native plants for use in living walls (LWs) and/or green façades (GFs) against demographic data.

	I Would Prefer Native Plants in My LW/GF Because				I Would Not Prefer Native Plants in My LW/GF Because			
Data	**They Are More Attractive**	**It Permits Species Conservation**	**They Adapt Better in Environmental Conditions**	**They Are More Original**	**They Are Unknown**	**They Have Higher Cost**	**They Are Less Available in Market**	**They Require Higher Maintenance**
Sex	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Age	*n.s.*	0.0163 *	*n.s.*	0.0046 *	0.0245 *	0.01 *	0.0002 *	<0.0001 *
Max. Educational Level Completed	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	0.0160 *	*n.s.*	*n.s.*
Area where one grew up	*n.s.*	*n.s.*	*n.s.*	*n.s.*	0.0156 *	*n.s.*	*n.s.*	*n.s.*
Area where one lives	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Type of property where one lives (Self-acquired or in rent)	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	0.0184 *	*n.s.*	0.0124 *
Type of property where one lives (Presence/size of garden/balcony)	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Interest in gardening	*n.s.*	<0.0001 *	0.0001 *	0.0388 *	*n.s.*	0.0020 *	0.0024 *	0.0104 *

n.s.: not statistically significant, *: statistically significant ($\alpha = 0.05$).

The maximum level of education completed was found to be significantly associated with the acceptance of the argument that native plants' use would be hindered due to their higher cost (participants with completed postgraduate studies presented higher level of disagreement).

Furthermore, it was observed that the area where the participants grew up produced a significant variability in the level of agreement with the argument that the use of native plants in LWs and/or GFs would be restricted because they are unknown. For example, 24.5% of those who grew up in non-urban or rural areas of regions other than the Metropolitan Region of Santiago agreed or strongly agreed with the argument. However, none of those who grew in non-urban or rural areas of the Metropolitan Region of Santiago accepted the argument.

Regarding whether the participants live in self-acquired properties or in rent, this characteristic was found to be significantly related with the level of acceptance of the arguments that native plants' use in vertical gardening systems would be hindered by their higher cost and their higher maintenance needs, with those living in rent presenting higher levels of agreement with both arguments (Table 12).

Finally, the participants' interest in gardening significantly affected their opinion on the strengths and weaknesses regarding the use of native plants in LWs and/or GFs (Table 12). For example, those uninterested in gardening presented significantly lower agreement with the phrases that stated that they would prefer to use native ornamental plants in their LW and/or GF because it permitted the conservation of species or because they adapted better to the environmental conditions. Likewise, those uninterested in gardening were significantly more in accordance with the arguments that native plants' use would be discouraged due to their higher cost, their limited availability in the market and their higher maintenance needs. Moreover, those who described themselves as neutral towards gardening presented the higher (78.57%) level of non-agreement with the argument that native plants' use in VGS would be promoted because they were more original.

4. Discussion

Chile presents a rich diversity of native plants, due to its exceptional physical geography, including over 4500 taxa [48,58] many of which are local endemics [59]. In this study, the Andes Mountains concentrated the highest number of species with ornamental value (37.7%), probably due to its extension as it constitutes the largest geographical zone of the country including all the mountain territory across Chile. This territory is highly diverse in terms of latitude, altitude, soil quality and solar radiation, among others [60]. The Andes Mountains constitute the most characteristic feature of the South American topographic relief, which extends along the Pacific Coast, covering a surface of 2,870,596 km^2 and has great climatic and geomorphological variability that leads into a high natural ecosystem richness [61]. However, it should be underlined that they constitute fragile ecosystems, particularly vulnerable to climate change and susceptible to accelerated erosion. They suffer constant invasion from anthropogenic factors, such as migratory agriculture, unsustainable tourism, illegal logging, pollution, unsustainable extractive industry, invasion of exotic species, unsustainable use of hydric resources and loss of biodiversity underlying the necessity for immediate alternative solutions and ex situ conservation approach [61]. According to IUCN [62], two of the selected species for potential use in LWs (*Carex gayana* Desv. and *Tillandsia capillaris* Ruiz and Pav.) are included in the "Red List" of threatened species under the "Least Concern" conservation category. No other species suggested in the present investigation to be used in VGSs are included in the Red List.

The highest levels of endemism were exhibited in the centre and north zones with 68.3% and 58.6%, respectively. Particularly the central part of Chile has been identified as a hotspot of biodiversity and 34 hotspot areas are recognized globally [63,64]. According to Arroyo et al. [64], the Chilean hotspot extends from the Pacific coast to the Andes Mountains, including a narrow coastal strip, plus the Juan Fernández Islands, and a small area of adjacent forests in Argentina. It includes the central part of Chile and the north zone, characterized by winter rains, and part of southern Chile (Region of Araucanía to part of Region of Aysén del General Carlos Ibáñez del Campo) characterized by summer and winter rains [64]. Letelier et al. [63] declared that climatic change, and mainly global warming, increases the risk of eliminating various native plant species in hotspot areas, but simultaneously offers an opportunity for a longer-term genetic improvement using naturally adapted material [63] that might effortlessly adapt in urban environments and particularly in VGSs. Precisely, Fernández et al. [65] point out that resources for ex situ conservation are limited, based principally on expensive conservation strategies such as restoration, and propose a spatial multicriteria decision analysis framework to "identify, evaluate and prioritize" regional-scale locations for plant species restoration initiatives that can explicitly take into consideration future climatic change [65]. Therefore, the use of Chilean native species in VGSs may also be considered of paramount importance in terms of biodiversity conservation, as the increasing need for commercialization would, on the one hand, can potentiate the implementation of the already established propagation protocols and, on the other, drive the tendency to further investigate and develop innovative propagation methods especially designed for the Chilean native species. Consequently, as the availability of propagation material increases, an effective, positive feedback cycle is expected to be established, potentiating the short- and mid-term use of more native species in VGSs. It has been reported that 23 local endemic neglected and underutilized plant species from Crete, Greece can be incorporated into sustainable exploitation schemes mid-term due to the availability of certified propagation material [66]. Moreover, Krigas et al. [66] underlined the role of ex situ conservation as a strategy that could possibly help overcome the legal obstacles related with access and benefit sharing (ABS) policies. This point is of particular importance for Chile, where 9% of the population represents the nine indigenous Chilean peoples and the no ratification of the Nagoya Protocol raises several regulatory and scientific challenges that hinder a sustainable use of the Chilean flora that will safeguard ABS rights [67].

Focusing on the families and their potential introduction in VGSs, Asteraceae constituted the most common family with 294 species. This is an expected result since the Asteraceae family is the most diverse vascular plant family in the world with 24,000–30,000 species [68]. In Chile, this family has also been identified as the richest in the native flora, at the genus and species level, with a total of 121 genera and 863 species [69]. The genera of the family are distributed along the entire latitudinal gradient of Chile, with almost one third presenting small to medium-small latitudinal ranges, while two thirds present medium-large to large latitudinal ranges. Half of the continental genera (53%) occupy coastal and Andean environments, while 46% have their main distribution in the central Mediterranean. The Asteraceae family has attracted the attention of various academic studies providing the opportunity to access advanced knowledge and published results that facilitate the potential utilization and successful integration into VGSs [69–75].

Previous studies have reported several uses for Chilean native species, including a total of 995 native useful plants identified in Chile [76]. For example, León-Lobos et al. [77] identified 330 native species documented as food plants, which represent 7.8% of the total flora of Chile [77]. Considering the ornamental value, 300 species have been reported as ornamental species used in gardens, parks and greenery, cultivated in Chilean nurseries, and those used in breeding programs [76]. This study started with a total of 1594 species with ornamental value, and a total of 109 species were selected with potential use for in VGSs, according to the classification criteria described in the Materials and Methods section. Most of them were selected for LW (70 species) as the plant height criterion was more flexible for these species due to the LW system characteristics (See Table 1). LW technology does not require plants with increased covering capacity as in the case of GFs due to the elevated number of plants per square meter [8,11,14,78]. Conversely, plants suitable for green façades should have a greater overall height, as few plants planted in the ground or in pots should cover vertically a wall or façade surface [14].

Demographic data of the participants (Table 8) are in accordance with the general trends regarding the country's geographical distribution among regions and between urban and non-urban areas. However, it was observed that participation was lower in elders and higher in groups with higher educational level. Although these trends need to be further investigated, they are consistent with previous findings regarding the factors that affect response rates in online surveys [79].

Our findings demonstrate that Chileans have a highly favourable attitude (agree or strongly agree) towards incorporating native species both in their house or apartment (75%) and in their garden and/or balcony (84.3%). This tendency can promote the conservation and the sustainable use of the Chilean native flora in gardening systems, an area of particular concern in Chile. The urgent need to capitalise on the public's positive perception towards native flora can be highlighted by the fact that in Santiago, the country's capital and one of Latin America's megacities, 95% of the plant species found in urban park lawns were non-native, in contrast to the European example where urban parks play a key role to biodiversity conservation [80].

Regarding LWs and GFs, the participants approve (agree or strongly agree) having LWs and GFs mainly outdoors, but also indoors (Figure 3). Although in both cases the public's acceptance is high, it is suggested by the present work's findings that indoor VGSs might require additional measures to gain ground in Chile. The presence of indoor plants has been reported to have positive effects both on physical and on psychological health [81–86]. Therefore, it is suggested that the motives driving the lower acceptance of indoor vertical gardening systems in comparison to outdoor ones are further investigated. Although referring to non-Chilean public, the relative difficulty to accept indoor LWs systems has been previously reported [87], with the main concerns being related in that case with maintenance, potential problems with dampness and insects and installation cost.

The perceptions observed in the present work that need to be further addressed and investigated to exploit the full potential of Chilean native flora in LWs and GFs include the criteria for the selection of ornamental plants to be used in VGSs (Figure 4). The participants evaluated the two proposed 'practical' traits, i.e., easy maintenance and cost, as the most important, followed by morphological criteria such as flower colour, foliage traits and aroma. Low maintenance and large and colourful flowers have been previously identified by residents of the Chilean capital as preferable traits for plant species used in residential sidewalk gardens [88], while similar attributes as "aesthetics" in general and flower colour and aroma have been characterised as the most important among gardeners in the north-western USA [89] and Chilean and British non-trained ornamental flowers purchasers [90,91]. Although the criterion of "native origin" was considered important by the participants, it should be highlighted that it presented the lowest percentage of acceptance among the proposed traits. However, in the present study, this attribute was perceived as positive (expressed as "agree" or "strongly agree") when selecting plants for VGSs by 47.7–53.3% of the participants, while only 21% of Santiago's residents have previously been reported to prefer this trait in plants grown in residential sideway gardens [88]. Although a direct comparison between the two studies is not feasible due to the differences in their focus and the participants demographics, highlighting additional assets of native plants that were found to be considered as important in the present or other works may further promote the public's acceptance regarding the use of Chilean native flora for ornamental purposes. For instance, traits that can be associated with native plants and have been reported to raise the public's acceptance towards plants incorporating in greening systems include ecological aspects such as attractiveness to pollinators [88,89], plant variety in general and the emotional connection towards this trait and traits associated to specific uses of the plants, e.g., ornamental in general, alimentary, medicinal, etc. [92].

Associated perhaps with the aforementioned ecological traits in the present study, the participants approved (expressed as "agree" or "strongly agree") with the highest percentages the selection of Chilean plants in VGSs because this would promote species conservation (79.44% approval) and because these species would adapt better to the environmental conditions (78.27%) (Figure 5). This finding is in accordance with that of the previously mentioned study on residential sidewalk gardens in Santiago [88]. As in the present work, in that study too, while participants attached relatively low importance to native origin as a selection trait, 86% of them affirmed that they are interested in growing native plants in the future due to the importance they attribute to native plant conservation. Similarly, a previous study revealed that 88% of local Chilean viticulture stakeholders who participated in educational programs regarding biodiversity affirmed that the protection of native flora within their farms contributed to species conservation [93]. Thus, it is suggested that the Chilean public is both aware and embraces the sustainability-related traits that can be associated with native plants and their incorporation in various productive and/or greening systems, among which LW and GFs.

Among the findings of the present work, it must be highlighted that 46.26% of the participants agreed or strongly agreed that the lower market availability of native plants would discourage their selection. Although investigated from the suppliers' point of view, market inconsistencies have been identified as a factor hindering the growth of native plant resources in the south-western USA [94]. Therefore, it is important that Chilean native plant material suppliers, in collaboration with central and local policy makers and supported by researchers, improve this trait and/or the information regarding market availability to permit the optimum and most sustainable exploitation of the Chilean native flora to its full potential.

With respect to the demographics effect on the participants' opinions, no significant relationships were observed among all or almost all perception-related data, on one hand and the demographics regarding sex, maximum educational level completed and type of property where the participant lives, on the other. However, several associations among attitude-based and the rest of the demographic data were observed.

As it was expected, the rise of the participants' interest in gardening was associated with a more positive opinion of almost all perceptions regarding both LWs and GFs, as well as Chilean native flora and its use in VGSs (Tables 9–12). While all participants in the present survey were adults, it is worth mentioning that being engaged in gardening activities and tree planting resulted in students strengthening a positive perception towards plants [95]. It must be further investigated whether, in the case of adults, gardening activities can generate habits that promote VGSs and the use of native flora in them. This would be of particular importance not only regarding the sustainable use of native flora, but also due to the multiple benefits that gardening with native plants can bring to the individuals. For instance, a study involving native plants' home gardeners in Canada revealed that they consider that this activity was associated with positive outcomes in environmental, psychological, physiological and social level [96].

Furthermore, the participants age was correlated with their prior knowledge of the definition of LW and GFs (Table 9), which can be attributed to the more widespread use of VGSs during the last decade [8,10,14,74,75,78,97–101]. Native origin was more important to participants aged 41–65 years when selecting plants for outdoor systems (Table 11), a tendency that can be taken into consideration by the local stakeholders interested in promoting the use of Chilean native flora. Interestingly, older participants (66–80 years old) showed the lowest level of agreement with the argument that native plants' use would be promoted due to them contributing in species conservation or due to them being more original (Table 12). Moreover, older participants presented the lowest level of agreement with the argument that native plants' use would be discouraged due to them being unknown, less available in the market, of higher cost or of higher maintenance. Therefore, it seems that older participants present a more stable acceptance pattern regarding the use of Chilean native flora in vertical gardening systems. Although their perception needs to be further investigated, the present work's findings indicate that older participants have a positive opinion on the use of native plants in LWs and GFs that is not based at a significant level on current trends.

Finally, the participants' perception was found to be significantly associated with the area where they grew up and/or the area where they currently live. Interestingly, individuals who grew up in urban areas of the Metropolitan Region of Santiago presented a lower level of acceptance regarding the use of LWs and GFs inside their homes than individuals who grew up in urban areas of the other Regions of Chile (Table 9 and Figure 6). This trend may suggest that the latter are more familiar with the presence of plants in their direct environment, a result that is in accordance with the study by Fančovičová & Prokop [95].

Similarly, those who grew up in non-urban and rural areas attached lower importance to flower colour of indoor plants than those who grew up in urban areas (Table 11), a perception that can be associated with the lack of colour in urban landscapes that in general highlights the individuals' need to intervene at the grey urban landscape. The high importance that city residents attach to the existence of plants and their preference for colour diversity has been well documented by many researchers [102–105].

Interestingly, native origin is more important as an outdoor plant criterion for the residents of non-urban or rural areas of regions other than the metropolitan (Figure 7), a trend that needs to be further investigated and can possibly be associated with the fact that the Chilean native flora is characterised by high morphological variability among regions, thus creating a unique landscape which the participants are looking to replicate. However, in the case of the Metropolitan Region of Santiago, urbanisation has disrupted the landscape to a degree that the residents no longer have a specific landscape to use as a reference. In this context, the fact that none of those who grew up in non-urban or rural areas of the Metropolitan Region of Santiago agreed/strongly agreed with the argument that the use of native plants would be restricted due to them being unknown needs to be further investigated in order to clarify whether this perception is actually associated with the misconception that the native flora is limited to the plants that those individuals are familiar with. Although a direct correlation with the present study's findings cannot be attempted, it should be noted that in a previous study regarding ecosystem services preferences within local stakeholders in Central Chile it was observed that while participants from urban environments favoured regulating services (e.g., erosion and pest control, air and water regulation, climate change, etc.), participants from rural areas prioritised services that emphasised the symbolic value of native plants [106]. In this context and in accordance with our findings, it should be validated through further research the indicated tendency according to which native Chilean flora has also a strong cultural fingerprint especially for those living in less urbanised environments.

5. Conclusions

A total of 109 potentially usable species from the north (25 species), centre (32 species), south (31 species) and the Andes Mountains (21 species) were selected for VGSs, showing a high level of endemism (43.1%). According to the filters applied, 39 species were selected for GFs while 70 species were selected for LWs. The current study characterised the potential of Chilean native plant species in VGSs, however further empirical studies are still required to confirm the use of these Chilean native species in LW systems and GFs to enrich scientific knowledge by promoting green areas and encouraging the ex-situ conservation and interest in native species improving biodiversity in urban areas.

Meanwhile, the Chilean public's perception was found to be rather positive regarding the use of LWs and/or GFs inside or outside their homes, as well as regarding the selection of Chilean native plants for that. Interesting particularities were observed in respect of the interactions among demographic data, e.g., age, urban or rural origin and/or current residence, etc., and the participants' attitude towards VGSs and native flora. In this context, it is suggested that the consideration of the present study's results by local stakeholders, as well as further investigation of the Chileans' opinions may contribute to the unravelling of the full potential of the country's native flora as integral part of VGSs.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15064944/s1, Table S1: Questionnaire used in the online survey.; Table S2: List of endemic and non-endemic Chilean species selected according to their ornamental value.

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