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Assessment of Floristic Composition of Ornamental Plants and Their Production Conditions in Benin (West Africa): Highlights Ornamentals' Role to Bolster Ecological Conservation and Urban Greening

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Abstract. This study characterizes ornamental plant sites in Benin, acknowledging horticultural role in Urban Greenery. Surveying 136 sites revealed 175 species from 139 genera and 56 families. Dominant families like Asparagaceae, Euphorbiaceae, Apocynaceae and Araceae showcased rich botanical diversity. Key species, including *Gerbera garvinea* and *Delonix regia* were noted. Analyses highlighted prevalent nano-phanerophyte and micro-phanerophyte life forms, indicating a preference for perennial plants. Chorological analysis emphasized pantropical and Afro-malagasy species dominance. Numeric classification revealed three site groups based on richness, age and area. These groups showcased species' richness ranging from 112 to 141. Diversity measures emphasized substantial ornamental diversity. These sites significantly contribute to biodiversity, necessitating strategic valorization plans. This study provides groundwork for economic potential exploration and ethnobotanical insights in ornamental plant production, which is essential for conservation and urban development.

Keywords: floristic diversity, taxonomy, horticultural sites, phytogeographic analysis, urban greenery

Introduction

The preservation of vegetative cover and the aesthetic needs of large cities demand the consideration of sustainable practices in the production and management of utilitarian plants, allowing for the conservation of biological diversity and the maintenance of natural equilibrium. In recent years, Urban and Peri-Urban Agriculture (UPA) has emerged within major cities, encompassing ornamental plant production. Within this sector, urban and peri-urban ornamental plant production, akin to other forms of cultivation, represents a significant opportunity in terms of job creation, income generation for various stakeholders and environmental improvements that enhance the urban setting and quality of life (Radji *et al*., 2010). Ornamental production within cities constitutes a revenue generating activity that provides substantial income, particularly for young individuals and women (Duchemin *et al*., 2010). However, there is a lack of studies on the floristic diversity of ornamental plant production sites. Yet, the quality of vegetative material used in land scaping profoundly impacts performance. Therefore, an investigation into the floristic composition and production conditions within ornamental plant production sites in Benin is necessary.

Research findings indicated significant floristic diversity of ornamental plants in west African cities. They exhibit a multi-layered arrangement resembling agroforestry systems, spatially arranging different species. This stratification and dynamic architecture, more than the identity of a single species and have been proven to create sustainable and resilient ecosystems (Smith *et al*., 2006), utilizing root structures at various soil nutrient levels effectively (Dalimier, 2022; Bohossou *et al*., 2020; Eyzaguirre and Linares, 2004).

Plants play a crucial role in the environment and nature preservation in urban and Peri-urban areas. Ornamental

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plants have become increasingly vital for biodiversity conservation, particularly in regions characterized by high population density (Oumar *et al*., 2021). In such situations, ornamental branch of horticulture can serve as an option for conserving species that have replaced goods and services previously found in forests. Several studies have indicated the presence of critically endangered species among cultivated ornamental plants (Kowarik *et al*., 2020).

In Benin, ornamental plant production sites have been steadily growing, especially in recent years, where landscaping has become a government priority (Besteliu *et al*., 2021). However, most producers rarely inquire about the origins of species, potentially facilitating the introduction of harmful species into local biodiversity (Vroh and Kouamé, 2022). Moreover, the size of the operations and production conditions often do not support consistent plant selection, increased yields or pest control.

Research on these concerns has been diverse in the sub-region. This includes, among others, a diagnostic study of ornamental flora in Togo (Radji *et al*., 2011). Vroh and Kouamé (2022) also described the diversity and cultivation practices of ornamental plants in Peri-urban agricultural zones in Abidjan. Similarly, (Dieng *et al*., 2020; Diouf *et al*., 2019) characterized ornamental flora in the Dakar region of Senegal. However, very few of these studies have focused on horticultural production sites to analyze their biodiversity potential and characteristics. It is to fill this gap that this study was initiated, with the objective of characterizing the floristic composition and structure of ornamental plant production sites in Benin.

Material and Methods

Study area. The republic of Benin, with a total area of 114,763 km², lies entirely within the intertropical zone, between latitudes 6°30' and 12°30' north and longitudes 1° and 3°40' east (Adomou *et al*., 2010; Adomou, 2005). It is bordered to the north by the republics of Niger and Burkina Faso, to the south by the Atlantic ocean, to the west by the republic of Togo, and to the east by the republic of Nigeria (Fig. 1). Except for the northwest region in the Atacora mountain range, Benin features relatively gentle terrain. Stretching from the gulf of Benin coastline to the Niger river valley, the republic of Benin exhibits a varied range of climates characterized by relatively low annual precipitation ranging from 900

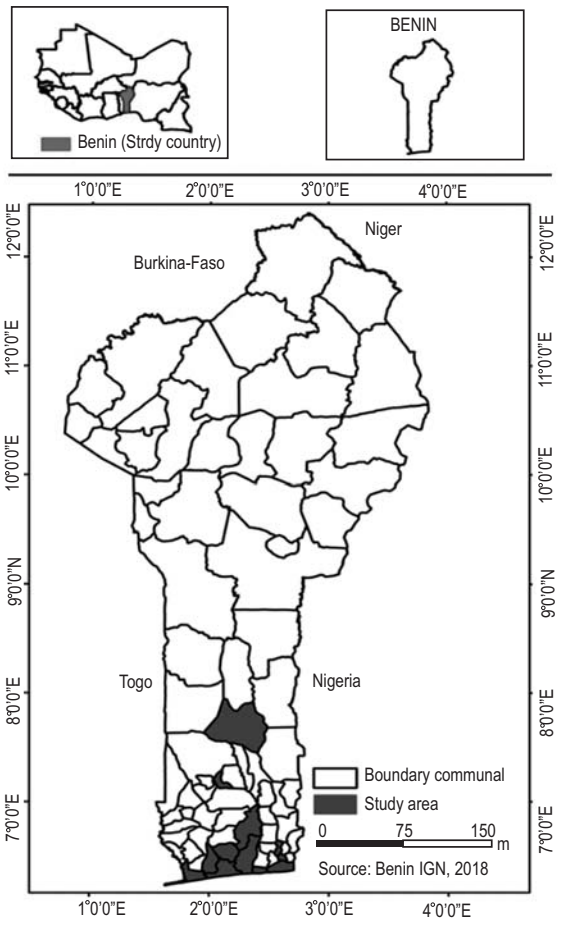

Fig. 1. Geographic location of the study area.

to 1300 mm per year. The combination of these seasons has given rise to three climatic zones spread from south to north the Guineo-Congolese zone, the Sudan-Guinean zone and the Sudanese zone (Sinsin et *al*., 2004). The country is characterized by mosaic landscapes of open forests, occasionally featuring dry dense forests, interspersed with wooded and shrub by savannas and intersected by forest galleries. Administratively, Benin comprises 77 municipalities distributed across three categories: municipalities with a special status, represented by heavily urbanized major cities, municipalities with an intermediate status and municipalities with an ordinary status.

Data collection. The "snowball" sampling approach was utilized to identify all horticultural sites within the study area. The snowball sampling method relies on the network structure of the target population. This sampling method involves identifying certain site owners

and asking them to designate others who own ornamental plant production sites. Individuals recruited by the initial subjects were then encouraged to identify additional persons, allowing the sample to grow as the process is repeated. This process continued until the saturation point is reached. Saturation point refers to the moment when all horticultural perimeters have been definitively identified and no new identifications are made.

Within each site, a systematic inventory of all ornamental plants was conducted and measurements of their surface area were taken using GPS. Species identification was done either directly in the field or at the National Herbarium of Benin by comparing collected plant specimens with reference samples. The botanical nomenclature of the Angiosperm Phylogeny Group (Angiosperm Phylogeny Group, 2003) and the plant list from Kew and Missouri botanical garden (http://www.theplantlist.org/) were used. For each identified species, a biological and phytogeographical type was assigned.

The biological types of the recorded ornamental plants adhere to Raunkiaer's classification (1934) and the phytogeographical types used are inspired by White's chorological subdivisions (white, 1983).

Biological types. The biological types include:

- Megaphanerophytes (MPh): trees over 30 meters tall
- Mesophanerophytes (mPh): trees ranging from 10 to 30 meters tall
- Microphanerophytes (mph): shrubs from 2 to 10 meters tall
- Nanophanerophytes (nph): sub-shrubs from 0.4 to 2 meters tall
- Woody climbing phanerophytes (Phgr)
- Chamaephytes (Ch): plants with dormant buds located at 0.50 meters above the ground
- Hemicryptophytes (He): plants that completely dry up during the dry season, with persistent buds located at ground level
- Geophytes (Ge): plants with a deciduous cauline apparatus and persistent buds located in the soil
- Therophytes (Th): plants with a short life cycle, annuals, spending the dry season as seeds
- Hydrophytes (Hyd): aquatic plants with persistent buds located in the water and whose life cycle occurs entirely in water, including helophytes (plants growing in mud), with some individuals submerged and others floating on the water's surface

Phytogeographical types. The phytogeographical types are based on White's classification (1983):

Cos = cosmopolitan species; Pan = pantropical; Pal = paleotropical; AA = Afro-American; AT = Afrotropical; AM = Afro-malagasy; PRA = Pluriregional african; GC = Guineo-congolian; G = Guinean; SZ = Sudanian-zambezian

Data analysis. The collected data were processed using Excel spreadsheets and the FactoMiner package in R version 4.3.2.software. The data analysis was conducted in three phases. Initially, the collected data were encoded in an Excel table into a floristic data matrix consisting of the number of production sites and the total number of ornamental plants encountered. Ornamental plants were then classified by family and overall specific diversity (number of families and species) was estimated. A rank frequency curve of species occurrence was generated to assess the significance of the most frequently observed ornamental plant species across all production sites. Subsequently, the spectra of biological and phytogeographical types were calculated.

Following this initial data processing phase, the typology of ornamental plant production sites in Benin was conducted using a clustering analysis of the production sites. Clustering aims to group ornamental plant production sites into larger, more easily described clusters. This was achieved using the FactoMiner package in R software.

Characterization of the major site production groups resulting from clustering was based on:

- Specific richness (S): This corresponds to the number of plant species per major group of ornamental plant production sites.
- Shannon-weiner diversity index (H): This index measures the specific diversity within a vegetation group. If H is less than 2.6 bits, it indicates that the group is dominated by a few highly demanded ornamental plant species, which constitute a significant portion of the plant cover in that group. If H ranges between 3 and 5 bits, it suggests that the ornamental plant community in that group is relatively diverse.
- Pielou's evenness (E): This measure indicates how equally represented species are within a vegetation group. E ranges from 0 to 1, with 1 representing maximum evenness when each species is represented by the same number of individuals. If E ranges

between 0.7 and 0.9, it indicates that all species are well represented within the group. When E is less than 0.6, it suggests a dominant species and less representation of others, indicating a less diversified group of production sites.

- Jaccard similarity coefficient (J): This index measures floristic affinities between different ornamental plant production sites when compared pairwise. It varies from 0 (no similarity) to 100 (complete similarity). If J is greater than 50%, it suggests a similarity between the two compared sites in terms of their floral composition.

Results and Discussion

Overall floristic diversity of ornamental plant production sites. A total of 175 ornamental plant species belonging to 139 genera and distributed across 56 botanical families were recorded across 136 sites. Fig. 2 illustrates the distribution of the most represented families based on the number of species. Analysis of this figure reveals that 14 families collectively account for 62.86% (110 species out of 175) of the recorded ornamental plant species. Families such as Asparagaceae, Euphorbiaceae, Apocynaceae and Araceae stand out as highly represented botanical families, each comprising at least 10 plants.

Distribution of ornamental plant frequencies. The relation between the rank and the relative frequency of the species recovered on the sites of production is presented on the Fig 3. Analysis of this figure reveals that the maximal rank is 175 whereas the maximal frequency is 82.5%. It was also observed that a strong concentration of the points arround the adjustment curve, what shows that the variable rank of species is in concordance with the relative frequencies. This report is confirmed by the raised value of the determination coefficient R^2 that is 0.98. It is evident from this analysis that the ornamental plants identified on the sites of production are nearly identical and of the same generation. What could indicate that the production is according to the demand.

The mains species observed across the inventory sites, in descending order include : *Gerbera garvinea* Sweet (81.62%), *Delonix regia* (Bojer ex Hook.) Raf. (77.21%), *Jatropha gossypiifolia* Carl Linnaeus (64.71%), *Gardenia jasminoides* J. Ellis (58.82%), *Stenocereus stellatus* (Pfeiff.) Riccob. (57.35%), *Cereus jamacaru* DC. (55.15%), *Helianthus annuus* L. (54.41%) and *Guaiacum officinale* L. (52.94%). Additionally, 65 ornamental plant species are observed across fewer than 5 production sites.

Geographical origins and life forms of ornamental plant species. Figure. 4 and 5 illustrate the distribution of phytogeographical and biological types of the recorded plant species. In terms of phytogeography (Fig. 4), pantropical species (38.29%) and Afro-Malagasy species (28.57%) are the most dominant. Cosmopolitan species (14.29%) are also present. The notable presence of pantropical species, characterized by broad geographical distribution, indicates that the flora within ornamental plant production sites primarily comprises exotic plant species. Considering the life forms of species (biological types), nano-phanerophytes (38.29%) and micro-phanerophytes (29.71%) are the most abundant (Fig. 5). Geophytes are the least abundant species on these sites. The prevalence of nanophanerophytes and micro-

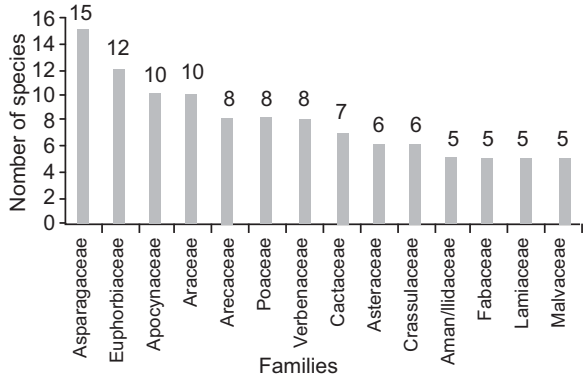

Fig. 2. Distribution of families based on the number of species.

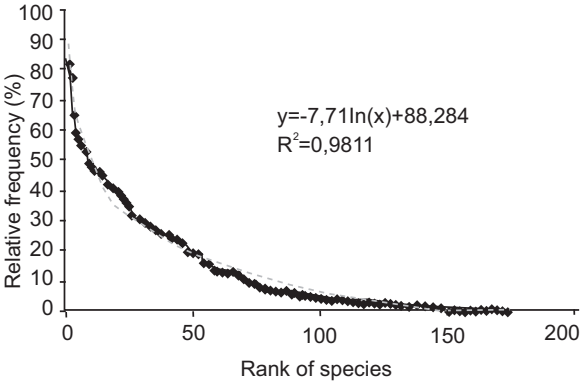

Fig. 3. Correlation between rank of species and relative in production sites.

phanerophytes, alongside chamaephytes and hemicryptophytes to a lesser extent, suggests that nursery operators favour perennial plants over annual ones.

Typology of ornamental plant production sites. The numerical classification performed on the surveyed ornamental plant sites, based on site-specific richness, area, and age, reveals heterogeneity within the inventoried ornamental plant production areas. However, three main groups emerge from this classification :

- Group G1 comprises sites inventoried in cities with special status (Cotonou, Porto-Novo, Parakou and Abomey-Calavi).
- Group G2 represents production perimeters of ornamental plants in municipalities with intermediate status (Ouidah, Sèmè-Podji, Bohicon and Dassa-Zoumè).
- Group G3 includes sites surveyed in municipalities with ordinary status (Grand-Popo, Zè, Tori-Bossito and Kpomassè).

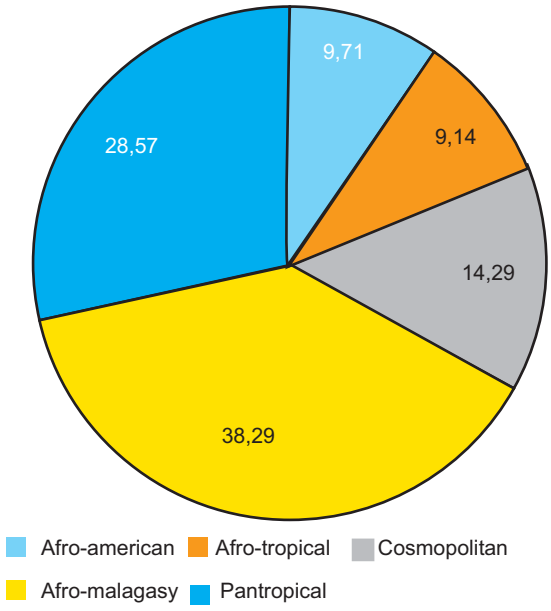

Fig. 4. Spectrum of phytogeographical types of ornamental plant species.

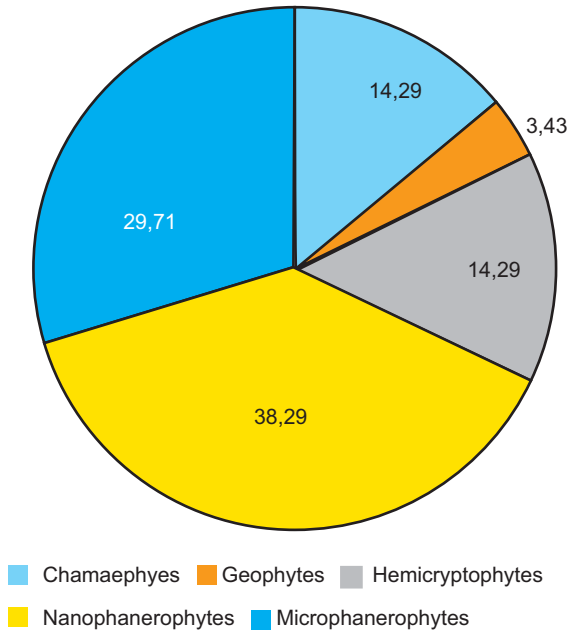

Fig. 5. Spectrum of biological types of ornamental plant species.

Structural characterization of ornamental plant production areas. ***Area and age of ornamental plant production sites.*** The occupied areas of the production sites vary widely, ranging from 50.19±14.38 m^2 to 120.89±36.34 m^2, with an average of 76.38±36.98 m^2. There's considerable variation in the sizes among the obtained groups. The average size of sites in groups G2 (120.89±36.34 m^2) and G3 (81.724±7.13 m^2) is the largest (Fig. 6). These groups consist of sites surveyed in municipalities with intermediate status like Ouidah and Sèmè-Podji and ordinary status municipalities that still have large exploitable areas for ornamental plant production. Sites in group G1 are smaller in terms of area (50.18±14.38 m^2). This smaller area for this group might be due to the limited space characteristic of larger cities like Cotonou, Porto-Novo, Abomey-Calavi and Parakou.

The age of the ornamental plant production sites varies among groups, with groups G1 and G2 containing the oldest sites, averaging 15 years or more. This average age indicates that cities with special (Cotonou, Porto-

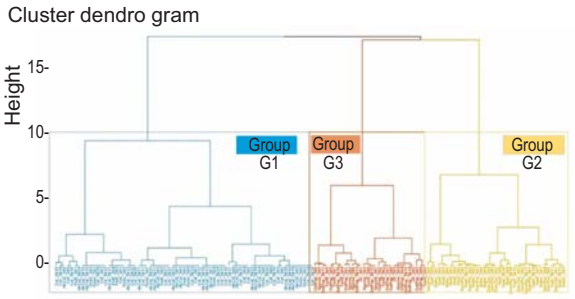

Fig. 6. Dendrogram of groups of ornamental plant production sites (site typology).

Novo, Parakou and Abomey-Calavi) and intermediate status (Ouidah, Sèmè-Podji, Bohicon and Dassa-Zoumè) have been involved in ornamental plant production for more than a decade. Conversely, sites in municipalities with ordinary status (Zè, Tori-Bossito and Kpomassè) are the youngest (maximum of 5 years), indicating the recent interest of these municipalities in ornamental plant production.

Species diversity within ornamental plant production sites. The specific diversity of species was described using the Shannon diversity index and Pielou's evenness coefficient. Results showed that the Shannon diversity index ranges from 4.62 bits to 4.95 bits for the different sites (Table 1). These high values obtained for this index indicate well-diversified communities of ornamental plants at the sites. Group G3 (sites in municipalities with ordinary status) obtained the highest value of the Shannon diversity index, while group G1 (sites in municipalities with special status) obtained the highest diversity value. Furthermore, Pielou's evenness coefficient ranges from 0.66 to 0.69. These regularity values (Pielou's evenness) are mostly greater than or equal to 0.6 for the three groups of ornamental horticulture sites. These values highlight groups where different species have nearly equal abundances within the environment.

Floristic affinity of ornamental plant production sites. Table 2 presents the values of the Jaccard similarity coefficient (J) resulting from the combination of the three groups of ornamental plant production sites. It's important to note a floristic affinity between groups. As the index values are all above 45%, there is an affinity between the sites. This affinity among these sites can be explained by the fact that the majority of ornamental plants used are exotic and producers share nurseries and seeds of the most demanded ornamental plants by clients.

Table 1. Specific richness (S), Shannon diversity index (H) and Pielou's evenness (E) of the groups

Sites	S	H	E
Sites in municipalities with special status (G1)	141	4,95	0,69
Sites in municipalities with intermediate status (G2)	139	4,71	0,66
Sites in municipalities with ordinary status (G3)	112	4,62	0,68

Table 2. Degree of similarity of ornamental plants between the groups of ornamental plant production sites

Site	Group G1	Group G2	Group G3
G1	0		
G2	88,5	0	
G3	56,7	48,7	0

Plant biodiversity in ornamental plant production sites in benin. The ornamental horticulture sites in Benin boast significant floral diversity, serving as a major repository for ornamental plants used in landscaping throughout the country. A total of 136 different sites have been identified within the study area, encompassing major cities in Benin. These sites harbor 175 ornamental plant species across 139 genera and distributed among 56 botanical families. This signifies that floral production sites offer a wide variety of ornamental plants for city beautification. However, these numbers are relatively lower compared to findings by Radji *et al*. (2010) who identified and cataloged 612 species for Togo, and Diouf (2019) who listed 516 species for sites in Senegal. It's essential to note that these studies were conducted across the entire respective countries. The broad range of ornamental plants available in these mentioned countries elucidates the interest that urban and peri-urban populations have in these plants and their contributions to their well being. These plants are cultivated for their aromatic qualities and are sought after for various events such as weddings, births, birthdays and religious ceremonies in major cities (Audate *et al*., 2018). They enhance the living environment and their components (leaves, roots, stems, flowers) accompany every emotional moment of city dwellers (Soro *et al*., 2019; Aké- Assi, 2002). However, Vrohand Kouame *et al*. (2022) found a relatively low specific richness of ornamental plants (88 species) in Ivory coast. This result nuances the conclusions drawn by previous authors but could be explained by the data collection methods used.

In terms of specific diversity, the values of the Shannon diversity index and Pielou's evenness are high. This signifies a vast variety and relative abundance of species within the production sites. The works of Vroh and Kouame (2022) also mentioned this conclusion, emphasizing the dominance of exotic species. Moreover, a strong similarity among the sites is evident regarding the species they contain. The species common to these sites vary between 45% and 88% of the specific richness

of the sites. This affinity among the sites can be explained by the high demand for certain species by populations due to their ecosystem services (Aké-Assi *et al*., 2020).

Structural characteristics of ornamental plant production sites in Benin. Pantropical species (38.29%) and Afro-Malagasy species (28.57%) dominate ornamental plant production sites in Benin. The prevalence of Afro-tropical and pantropical species observed in our findings is linked to the fact that the recorded plants are cultivated and sourced from various phytogeographical regions. Indeed, producers don't necessarily consider the ecological requirements of the plants but rather focus on their utility and aesthetic appeal. This justifies the choice of certain plants with a Western distribution. Additionally, there is a dominance of nano-phanerophytes on these sites because these plants are perennial and spare customers the need to replant their gardens every year. The results from Diouf study in (2019) indicate a higher proportion of phanerophytes. Similarly, research conducted by Vroh *et al*. (2022) in Ivory Coast yielded similar results. Regarding the size of production sites, the average area revolves around 76.38±36.98 m2, with an average age of 15 years. As a result, production areas are quite small, confirming the observations of Vroh and Kouame (2022). For efficient nursery production, the site area should ideally be three times that of the plants to be produced, providing optimal growth conditions for the plants (Sidibé *et al*., 2020). One of the reasons behind the small size of the sites is the lack of resources to maintain large plantations, making it difficult to employ multiple workers. Additionally, the availability of land near markets for these plants' distribution also contributes to the small sizes (Kimbatsa *et al*., 2018).

Conclusion

Based on the comprehensive exploration of ornamental plant production sites in Benin, this study contributes crucial insights into the floristic composition and structural dynamics, offering valuable implications for biodiversity conservation and urban development strategies. The investigation surveyed 136 sites across 12 townships in Benin, revealing a rich assemblage of 175 ornamental plant species distributed across 139 genera and 56 botanical families. Key ornamental plants emerged from these inventories, including *Gerbera garvinea*, *Delonix regia* and *Jatropha gossypiifolia* underscoring their prevalence and importance in these production sites. The analysis of life forms revealed a dominance of nano-phanerophytes and micro-phanerophytes, highlighting a preference for perennial species, while the chorological analysis emphasized the prevalence of pantropical and *Afro-Malagasy* species, indicating a wide geographical distribution among ornamental species. The classification of sites into three distinct groups based on species richness, age and area coverage elucidated heterogeneity within the perimeters. These groups ranged from sites in townships with special status to nurseries in communes with ordinary status, each showcasing varied species richness from 112 to 141 ornamental species. The measures of diversity within these groups, employing Shannon's index and Pielou's evenness, emphasized significant diversity and relative abundance of ornamental species in these diverse settings. These ornamental plant production sites act as reservoirs of biodiversity, urging the need for a strategic plan to harness and enhance their potential in Benin. Future, endeavors should focus on the economic viability and ethnobotanical knowledge associated with ornamental plant production, essential for sustainable urban development and effective biodiversity conservation strategies. This study provides a comprehensive overview of the ornamental plant production landscape in Benin, emphasizing the need for strategic planning and management of these sites. The findings may serve as a critical foundation for future studies, bridging the gap between biodiversity conservation, urban development and the economic potential of ornamental plant production in Benin's landscapes.

Conflict of Interest. The authors declare that they have no conflict of interest.

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