American Journal of Plant Sciences, 2021, 12, 1436-1444
https://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Botanic Garden Collections—An Under-Utilised Resource

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How to cite this paper: Hudson, A., Smith, P., Gori, B. and Sharrock, S. (2021) Botanic Garden Collections—An Under-Utilised Resource. *American Journal of Plant Sciences*, **12**, 1436-1444.
https://doi.org/10.4236/ajps.2021.129101

Received: August 6, 2021
Accepted: September 20, 2021
Published: September 23, 2021

Abstract

Botanic gardens and arboreta around the world are repositories of diverse collections of useful plants in their gardens and seed banks. However, the crop and forestry communities often overlook these collections, and so they are an underutilised resource. For example, in analysis of the *ex situ* conservation status of 6,941 socio-economically important plant taxa using data from forestry and crop collections, but omitted collections in botanic gardens and arboreta. In this paper, we compared the socio-economically important taxa identified by Khoury *et al.* from GRIN-Global World Economic Plants (WEP) with data on living and seed collections held in botanic garden and arboreta, as recorded in BGCI's global PlantSearch and ThreatSearch datasets. This analysis produced an assessment of the proportion of these taxa that are found in botanic gardens and arboreta, the number of gardens or arboreta they are found in and what potential they have to contribute to research, conservation and sustainable use. We also compared the species conservation comprehensiveness assessments carried out by Khoury *et al.* with the threatened status of those species, according to the IUCN Red List and other threat assessment methodologies in order to ascertain whether threatened, useful species are well-conserved in botanic gardens. At least 6017 of the 6941 socio-economically important WEP taxa (86.7%) were currently found in the living and seed collections of botanic gardens and arboreta with 1456 taxa (21%) held in >40 collections. Khoury *et al.* suggested that 6748 of the WEP taxa are of either medium or high conservation priority. However, our analysis suggested that just 1153 taxa have been assessed as threatened at a national or international level. We concluded that the botanic garden/arboretum community can contribute significantly to plant conservation and sustainable development, including data and material from many collections of socio-economically important taxa that are not present in the crop and forestry communities. We examined the reasons why botanic garden/arboreta collections are currently under-utilised and make recommendations for increasing their visibility and use.

Keywords

Botanic Gardens, Arboreta, Socio-Economic Plants, Sustainable Use, Conservation

1. Introduction

Ex situ living collections of socio-economically important plant species are an important resource for sustainable development research and use [1]. Globally, botanic gardens propagate and grow a third of all known higher plant species [2]. This means they have the potential to provide the scientific community with plant material and a wealth of knowledge about how to grow plants successfully, the starting points for their study and sustainable use. Although botanic garden and arboretum collections are acknowledged as important *ex situ* conservation repositories in FAO's Second Global Plan of Action for Plant Genetic Resources in Food and Agriculture [3] and their State of the World's Forest Genetic Resources report [4], botanic garden collections remain largely unknown and under-utilised by the crop and forestry communities.

For example, Khoury *et al.* [5] recently published a paper entitled "Comprehensiveness of conservation of useful wild plants: An operational indicator for biodiversity and sustainable development targets". This paper concludes that 70% of these taxa are conserved *ex situ*, and only 33.5% are adequately conserved *ex situ* in 11 or more collections. However, their analysis did not include data on *ex situ* living collections and seed bank collections in botanic gardens. This despite the fact that many botanic gardens and arboreta were established with a strong focus on economic botany, and historically were largely responsible for the establishment and the global distribution of valuable plant-based commodities such as rubber, tea, coffee and cinchona [6]. Furthermore, plant conservation efforts led by botanic gardens over recent decades have included a strong focus on socio-economically important plant species, including crop wild relatives, wild food plants and timbers [7] [8] [9].

Botanic Gardens Conservation International (BGCI), a network of botanic gardens and arboreta in >100 countries, maintains a database of the plants that are grown and conserved in more than 1100 botanic gardens and arboreta around the world [10]. In this paper, we compare this dataset with the dataset of 6941 socio-economically important plants taken from the analysis carried out by Khoury *et al.* [5] to assess whether botanic garden and arboreta collections contain a significant proportion of socio-economically important plant species, and whether they have a role in contributing to future research and use of such species. We also examine the reasons why botanic garden/arboreta collections are under-utilised, and make recommendations for increasing their visibility and use.

2. Methods

2.1. Representation of Socio-Economically Important Plants in Botanic Gardens

The dataset from PlantSearch on living and seed bank collections of 1157 botanic gardens worldwide was compared with Khoury *et al.*'s GRIN-Global World Economic Plants (WEP) list of 6941 socio-economically important taxa. The two datasets were matched and combined in Microsoft Access using the recorded scientific names as the unique identifiers for each. This produced a combined dataset that showed for each species the conservation priority information from Khoury *et al.* alongside the number of botanic gardens and arboreta they are found in.

2.2. Genetic Representativeness of *ex situ* Collections in Botanic Gardens

PlantSearch does not provide accession-level data. It is a database of the names of plants in the living collections and seed banks of the world's botanic gardens. It is therefore not possible to assess the uniqueness or diversity of accessions for any given species, and therefore their genetic representation in *ex situ* collections. However, PlantSearch does record how many collections a taxon is held in (and where those collections are held). These data are a useful surrogate for the diversity of accessions for a species and for genetic representation. Therefore, for each species, the number of collections they are held in was used to assess the genetic representation of all collections with 11 or more having comparatively good representation.

2.3. Representativeness of Conservation Priority and Threatened Species in Botanic Gardens

In the paper by Khoury *et al.* [5], conservation priority categories of "high", "medium", "low" and "sufficiently conserved" were established from a calculation of a "Final Conservation score" for each taxon based on three other scores "Sampling Representativeness Score", "Geographical Representativeness Score" and "Ecological Representativeness Score". This "Final Conservation score" for each species was a score between 0 and 100 so that "high priority" species were those with values < 25; "medium priority" with values ≥ 25 and <50; "low priority" with values ≥ 50 and <75; and "sufficiently conserved" with values ≥ 75 (See [5] for full methodology).

The numbers of *ex situ* collections for the 6748 taxa assigned a medium or high conservation priority and, within those, the 3017 taxa assigned a high conservation priority by Khoury *et al.* [5] was then assessed. This showed how many of the species from these categories are found in at least one botanic garden or arboreta collection and how many are found in 11 or more collections.

In order to determine if species identified by Khoury *et al.* [5] as of high or medium conservation priority have also been listed as "threatened" through IUCN or other national red listing processes, the data were then compared with BGCI's ThreatSearch database (https://tools.bgci.org/threat_search.php) [11]. ThreatSearch is the most comprehensive database of plant threat assessments.

Data on species' threat status was combined with the full PlantSearch/Khoury *et al.* [5] dataset of 6941 species in Microsoft Access and analysis carried out on in R code language using R Studio. This produced the numbers of the plant taxa Khoury *et al.* categorised as medium or high priority that fall into the three IUCN Red List threatened categories or other threatened categories. This was then used to calculate the proportions of threatened socio-economically important plants conserved in botanic gardens.

The ThreatSearch database includes records of "Global", "National" or "Unknown" scope of assessments and can include multiple assessments carried out at any of these scopes. For species with multi-country distributions, multiple national assessments may have been carried out for different countries. For each of the scope categories, the most recent assessment was always the one used in the analysis. If a taxon then had "Global", "National" and "Unknown" records, or any combination of two of those, the "Global" assessment was prioritised and used in the analysis first, then, if no Global assessment existed, the "National" assessment.

3. Results

3.1. Representation of Socio-Economically Important Plants in Botanic Gardens

The comparison between Khoury *et al.*'s WEP dataset and PlantSearch showed that 6017 (86.7%) of the species identified as of socio-economic importance by Khoury *et al.* are currently conserved within the living and seed collections of the botanic gardens and arboreta in BGCI's network.

Using data from the crop and forestry communities as recorded in Genesys, Khoury *et al* reported that 30% of socio-economically important plant species (2084 species) are not currently conserved in any *ex situ* collections. However, when taking into account species in that list that are found in at least one botanic garden collection, our study reduces this number to 732 taxa.

BGCI's GardenSearch database currently lists 2952 botanic gardens globally [12]. Since BGCI's PlantSearch database currently contains accession records from 1157 botanic gardens, arboreta and similar institutions, despite it being the most comprehensive database of its kind, this means that 61% of gardens have not made their collections data available through PlantSearch. The figures in **Table 1** are therefore likely to be an underestimate of the coverage of socio-economically important plants in botanic garden *ex situ* collections.

In addition, PlantSearch and the WEP dataset on which the Khoury *et al.* study is based use different phylogenies and taxonomies. It is therefore likely that, due to synonymy, this analysis, which is based on direct name matches, is an underestimate of the taxa the two databases share in common, and therefore of the representativeness of botanic garden collections.

3.2. Genetic Representativeness of *ex situ* Collections in Botanic Gardens

As shown in Table 1, 716 socio-economic taxa are currently held in a single botanic gardens/arboretum collection and therefore likely to have very low genetic representation in *ex situ* conservation. At the other end of the scale, 1456 taxa are held in >40 *ex situ* collections indicating probable high genetic representation. Table 2 shows the number of species in each of the conservation priority categories that Khoury *et al.* [5] assigned that are found in different ranges of numbers of botanic garden and arboreta collections.

3.3. Representativeness of Conservation Priority and Threatened Species in Botanic Gardens

Of the 6941 useful wild taxa included in the Khoury *et al.* WEP dataset, 6748

Table 1. The numbers of the species in Khoury *et al.* [5] list that are currently found in different categories of numbers of botanic gardens.

No. of botanic garden collections	No. of socio-economically important taxa from [5]
0	924
1	716
2 - 10	2198
11 - 20	847
21 - 40	800
>40	1456
Total	**6941**

Table 2. Number of species with the different classifications defined by Khoury *et al.* [5] (High priority, medium priority, low priority and sufficiently conserved), and the number of species from those categories that are, or are not, conserved in Botanic gardens according to PlantSearch data.

Khoury *et al.* priority category	Number of taxa	Number of taxa conserved in between 1 and 10 BGs	Number of taxa conserved in 11 or more BGs	Number of taxa in no Botanic Gardens
High priority	3017	1428	1045	544
Medium priority	3731	1365	1998	368
Low priority	185	117	57	11
Sufficiently Conserved	8	4	3	1
Total	**6941**	**2779**	**3238**	**924**

were assigned a medium or high conservation priority by Khoury *et al.* This analysis shows that only 924 of these taxa are currently not present in any BG collection, and 3238 taxa are comparatively well conserved in 11 or more *ex-situ* collections.

Of the 3017 taxa to which Khoury *et al.* assign a high conservation priority, their analysis suggested that 1407 are not in *ex situ* collections. However, this analysis shows that just 544 of these taxa are currently not present in any BG collection. In addition, 911 of the 1407 taxa Khoury *et al.* suggest are not in any *ex situ* collection can be found in at least 1 botanic garden and 161 can be found in 11 or more collections each.

Finally, a more objective measure of conservation priority is provided by BGCI's ThreatSearch database, which is the most comprehensive database of threat assessments for plant species available. Of the taxa assessed by Khoury *et al.* as of medium or high conservation priority, 5253 have threat assessments included in ThreatSearch but only 1153 of these are classified as "Threatened". The breakdown of threat status categories is in **Table 3** below. Of the threatened species that are also medium or high conservation priority according to the Khoury *et al.* analysis, currently 86% are found in at least 1 *ex situ* botanic garden collection and 41% are found in 11 or more *ex situ* botanic garden collections.

4. Conclusions

Khoury *et al.*'s [5] analysis of the representation of WEP socio-economically important plants held in the *ex situ* collections of crop and forestry genebanks and shared on Genesys indicated that only 70% of these taxa are conserved *ex situ*, and only 33.5% are adequately conserved *ex situ* in 11 or more collections. In botanic gardens, these figures are 86.7% and 44.7%, respectively.

Khoury *et al.* [5] acknowledge that restricting analysis to "easily accessible online databases such as Genesys and GBIF, is certainly insufficient with regard to the totality of samples safeguarded in genebanks, botanic gardens and other living plant conservation repositories around the world, and may contribute to an overestimation of gaps in *ex situ* conservation for some useful wild plant species."

Table 3. Numbers of species assessed by Khoury *et al.* [5] as of medium or high conservation priority that are in ThreatSearch and have threatened status (other threatened includes Lower Risk: Conservation Dependent, Amenzado (threatened) and Rare). The scope of assessments is either unknown, Global or Not Global.

Number of species assessed on ThreatSearch	Number classified as "Threatened" on ThreatSearch	Number classified as Critically Endangered*	Number classified as Endangered**	Number classified as Vulnerable***	Number classified as other threatened^
5,253	1,153	153	390	552	58

*Includes categorises as CR, CR (PE), Critically Endangered, Critically Endangered (CR); **Includes categorised as EN, EN*, Endangered, Endangered (EN); ***Includes categorised as V, VU, VU*, Vulnerable, Vulnerable (VU), VU; ^Includes numerous alternative categories to the IUCN Red List official categories.

Our analysis confirms this supposition. However, they go on to say, "Some information on these holdings likely exists in additional, scattered online databases or in off-line datasets, while other conservation repositories may not yet have digitized their data." PlantSearch is a public facing meta-database, which is well known in the botanic garden and arboretum community that contributes data to it. In addition, BGCI, the global membership body that maintains PlantSearch, GardenSearch and several other global plant databases is well known to the crop and forestry communities. It is therefore likely that the reasons for not taking the collections of botanic gardens into account are more complex than the lack of available data.

One obvious problem is that, with a few exceptions, the botanic garden community does not share its collections level data with Genesys and the crop and forestry sectors. This is in part because the botanic garden sector has no equivalent data portal that enables the sharing of accessions level information. Instead, botanic gardens maintain their own accessions databases (in a variety of formats) and currently only share the names of those accessions on PlantSearch. Accession-specific information, such as collection number, date of collection, origin and so on, is not recorded in PlantSearch. This is about to change in that BGCI is developing an accessions-level module on PlantSearch which will enable responsible and informed exchange of plant material between institutions and which will be compatible with Genesys. This will greatly facilitate import of accessions level data from PlantSearch into Genesys.

A second problem is cultural rather than technical. Botanic garden collections are often grown or conserved for different reasons from those of the crop or forestry communities. These reasons include public display, conservation and scientific research. In addition, botanic garden collections are far more taxonomically diverse than the crop or forestry sectors are. Mounce *et al.* [2] estimate that, as a minimum, botanic gardens grow over 105,000 flowering plant species, increasingly collected from the wild. To this can be added several hundred thousand (largely ornamental) cultivars but, in general, botanic gardens do not cultivate or conserve large amounts of infra-specific genetic diversity. In contrast, crop and forestry gene banks conserve relatively few species but concentrate their efforts on conserving a huge diversity of landraces and cultivars of those species of greatest utility for food security, timber production and other human uses. This means that collection priorities, data and methodologies are not always comparable. The good news, however, is that the efforts of these different sectors are likely to be complementary, with huge potential to support each other.

PlantSearch data on botanic garden/arboretum accessions has already been used to contribute to Crop Conservation Strategies for coffee [13] and apples [14], and Hawai'i's National Tropical Botanical Garden hosts the Breadfruit Institute, whose collections feature strongly in the Crop Trust's Breadfruit Conservation Strategy [15]. As this paper clearly shows, the botanic garden/arboretum community has a lot more to contribute, including data and material from many significant collections of socio-economically important taxa that are not present in the crop and forestry communities. Botanic garden/arboreta could support overcoming identified issues to using socio-economically important plants by being a source of seedlings, trainers of technical skills needed to grow and sustainably use plants, and raising awareness of the importance of plants in the landscape [16].

As the new Global Biodiversity Framework emerges under the Convention on Biological Diversity, and as the dependency and links between biodiversity and delivery of the Sustainable Development Goals become more explicit, it is essential that the various communities concerned with the conservation and sustainable use of plant genetic resources work more closely together.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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