Testing bioclimatic hypotheses with botanic garden collections - curatorial considerations

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Abstract

Hardy plant accessions for botanic garden collections can be chosen with the help of bioclimatic vegetation maps. If plants grown in the collections are of known provenance one can study their survival in relation to source zone. This offers a framework for testing the validity of vegetation maps. We used such plant accessions to test the validity of the vegetation zoning for the northern hemisphere developed by Finnish scientists. We estimated the probability of survival of accessions in relation to their source zone in order to see if plants moved to the target location from a putatively corresponding vegetation zone have a higher probability of survival than plants moved from milder or harsher zones. The actual results are reported elsewhere; the focus of this paper is on the suitability of botanic garden collections for this kind of a study. Due to various horticultural and curational problems we were only able to utilize ⅓ of the available accessions. This resulted in parts of the realized analyses becoming unreliable. We found the deterioration of the collection data to be a waste of the original acquisition effort. We therefore conclude that for botanic gardens to ensure the scientific value of their collections, it is better to have fewer accessions with well-maintained data represented by many individuals than to grow large numbers of accessions with single individuals and poor data. If this principle is adhered to, we see good potential for botanic garden collections also in research on plants and climate change.

Key words

Bioclimatic zone system, boreal, curation, hardiness, phytogeography, provenance, vegetation zone, zonation

Introduction

A substantial part of the work of botanic gardens (henceforth BGs) deals with growing exotic plants. Especially in harsh climates, selecting the right provenances of plants to be grown is crucial for their success. The selection can be guided by vegetation maps, since climate is among the decisive factors governing the occurrence of plants and, therefore, the vegetation they form. Many practices for dividing the world's vegetation into smaller entities have been presented (Holdridge, 1947; Walter, 1976). One approach is to delimit climatically defined vegetation zones and regions whereby so-called bioclimatic vegetation maps can be drawn (e.g. Thornthwaite, 1948; Krajina, 1959; Küchler 1964; Hare & Richie, 1972; Walter, 1979; Box, 1981; Rivas-Martinez & Rivas-Saenz, 1996-2009). These can be applied to choose plant accessions from other parts of the world with the expectation that plants transferred between bioclimatically corresponding areas should succeed in the target location. This principle is routinely applied in forestry and horticulture but actual tests of the validity of bioclimatic vegetation maps seem to be scanty.

If plants grown in BG collections are of known provenance one can study their survival in relation to source zone. This offers a framework for testing bioclimatic theories. Therefore, BG collections can improve our understanding of plant survival in relation to climate and the range of climatic conditions that plants tolerate. This in turn can offer important information on plants in a changing climate.

We used BG plant accessions of known provenance to study the validity of a bioclimatic vegetation scheme. We tested if plants moved to the target location from a putatively corresponding vegetation zone have a higher probability of survival than plants moved from milder or harsher zones. The actual results of the study are thoroughly reported elsewhere (Hällfors *et al.*, submitted manuscript). The focus of this paper is on the quality and suitability of BG collections as a basis for this kind of a study, and on implications for the curational practices of the collections. We conclude with some recommendations for BG horticulture and collection curation.

Material and methods

We used Helsinki University Botanic Garden's (HUBG) collection in Kumpula to test the vegetation zoning developed by Finnish scientists during the mid and latter part of the 20th century (Kalela, 1961; Ahti *et al*., 1968; Hämet-Ahti *et al.,* 1974; Ahti, 1980; Tuhkanen, 1980, 1984; Hämet-Ahti, 1981). This so-called bioclimatic zone system (BZS; Goward & Ahti, 1992) divides the northern parts of the northern hemisphere into phytogeographically and climatically corresponding regions (Hämet-Ahti, 1981). According to the BZS, Helsinki is situated in the northernmost part of the hemiboreal zone (Fig. 1). The studied plant material consisted of accessions of known wild origin collected in the 1990's. Four expeditions were carried out and yielded accessions as follows: Japan 1993 (402 accessions), China -94 (336), Canada -95 (250), Japan -99 (55); the total number of accessions was 1,043.

HUBG's database T-puska (Lipponen & Schulman, 2005) was used as the primary source of data. The aim was to define, for each accession, the number of plants originally planted and the number still alive in the years 2007-2009, when the data were collated. From these numbers we calculated the proportion of surviving individuals in each accession. These accession-wise proportions were then pooled within each of the source zones, resulting in a single survival probability characterizing the zone. To test the BSZ hypothesis, the survival proportion of each of the zones was compared to that of the hemiboreal zone, the one where HUBG is situated. The comparison of proportions was done using logit models (Collett, 2002). The results of the comparison of the survival proportions are represented as Odds Ratios (OR), which can be used to describe proportions and to compare probabilities (Komonen & Rita, 2008).

Simultaneously with the collation of the data, the usefulness and quality of the information on each of the original accessions were evaluated. This resulted in the following step-wise reduction of accessions to be included in the final analyses:

1. For 92 accessions there were no follow-up data. These accessions had been collected and entered into the database but since then information about them has, for some reason, never been updated. Removing these left 951 accessions to be treated further.
2. The number of accessions that never germinated, died as seedlings or were removed from the collections before leaving the nursery was 198. Thus, 753 accessions remained.
3. For enabling statistical analyses we had to discard all accessions with fewer than five planted individuals. This meant removing a further 138 accessions from the data, leaving 615.
4. A total of 120 accessions had to be abandoned for one of the following reasons: the accession had not been collected in the wild but from e.g. another garden during the expedition; there was no mentioning of collection zone; parts of or whole accessions were planted in the other collection area of HUBG where local climate and gardening practices differ somewhat from those in Kumpula; the curational data were too deficient to be included in the study (there were either obvious errors in the original or later counts or the up-dating had been too infrequent leading to plants having disappeared in between counts without an obvious reason or, in some cases, we suspected that plants had reproduced in between counts). After these exclusions we were left with 495 accessions.
5. During the process of qualifying accessions presented above, we became aware that there still existed some problematic cases. The information concerning some accessions was

difficult to interpret. We decided to discard accessions of species in which the individuals are difficult to define and, therefore, to count accurately. We also decided to discard species that we suspected are naturally short-lived whereby deaths of individuals possibly were not caused by external factors. We were also more skeptical to questionable entries in the database and decided to discard an accession if the recorded data about it were somehow dubious. Because we wanted to divide species into life forms we also discarded some large woody species that could not be readily defined as either a tree or a shrub. In order to avoid extra noise due to these problems we decided to discard from the dataset a further 116 accessions.

In the end the study material consisted of 379 accessions, which is about 36% of the 1,043 accessions originally available.

Results

According to our hypothesis, the survival probability characterizing the hemiboreal zone should be the highest, and the zone-specific probabilities should decay progressively when moving to zones further away from the hemiboreal one. However, the results show a somewhat different picture (Fig. 2). The survival probabilities increase from the temperate zone towards hemiboreal, as expected, but the highest survival probability is exhibited by plants from the middle boreal zone. This could have been interpreted as a reason to refute the hypothesis. However, we continued by dividing the accessions into life forms (e.g. woody species and herbaceous) to single out possibly differing responses caused by differences in life history traits.

The woody accessions, when analysed separately, showed a more similar signal to what we expected (Fig 3). There are no unexpected deviations in the curve. Also, the survival probability within the different subzones of the boreal region are similar to each other, while there is a substantial drop in the probability of survival in the temperate and hemiarctic accessions. The results for the herbs, however, show no clear or logical signal and the overall picture is completely different from the expected (Fig. 4).

Discussion

The prerequisites for this study were good considering the large collection of accessions of known wild origin. Unfortunately, though, problems with the data left us with only c. ⅓ of the original number of accessions in the database for the actual analyses. This, we believe, affected the results of the study. For example, of the more than 170 original herbaceous accessions, we could analyse only 72. The numbers of herbaceous accessions originating from the more northern bioclimatic zones hence became very low (middle boreal zone: n=2; northern boreal zone: n=2; hemiarctic zone: n=4). Our conclusion, therefore, is that the results on the herbs are not at all reliable.

The difference in the clarity of the results between woody and herbaceous accessions may also be attributed to the fact that woody species are easier to count and handle. Many woody species do not spread vegetatively and their sexual reproduction does not go unnoticed. The data on woody accessions are therefore more reliable. Thus, by separating species with different life forms and curational needs we were able to outline sources of error and possible explanations for the results. While it is probably unavoidable that part of the potential data are lost with seeds failing to germinate, and with human mistakes involved in collection management, it is of the utmost importance to be meticulous with curation and up-dates to prevent unnecessary loss of accessions and deterioration of the quality of the collection. Notwithstanding the good preconditions in Kumpula BG considering the high number of wild-collected plants with exact information on provenance zone, the quality of the data had been allowed to deteriorate. This was an unfortunate waste of the effort put into the gathering of the plant collection, since much more understanding could have been gained on the plants' relationships to climate, had this not occurred. The obvious explanation for the imperfect collection curation is variation in management resources over the years. The collection simply was too large for the available staff to perfectly curate constantly. For the BG community, we therefore recommend to only keep as many accessions as one is able to properly manage. Furthermore, within accessions it would be important to have several individuals instead of building 'stamp collections' with plenty of taxa represented by single accessions consisting of only one or two individuals. This is important not only for the value of the collections in conservation, but also for studies demanding a large volume of raw data.

In summary, we recommend to value quality before quantity to ensure the scientific value of BG collections. If these recommendations are adhered to, we see good potential for BG collections also in research on plants and climate change.

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Figures

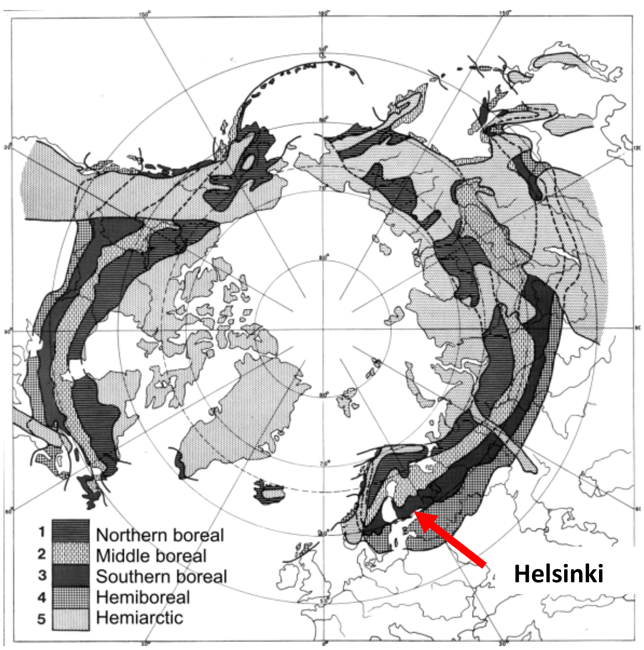

Fig. 1 The circumboreal zone and its transcontinental subzones according Hämet-Ahti (1981). Reproduced with kind permission from the Finnish Geographical Society. The position of Helsinki added.

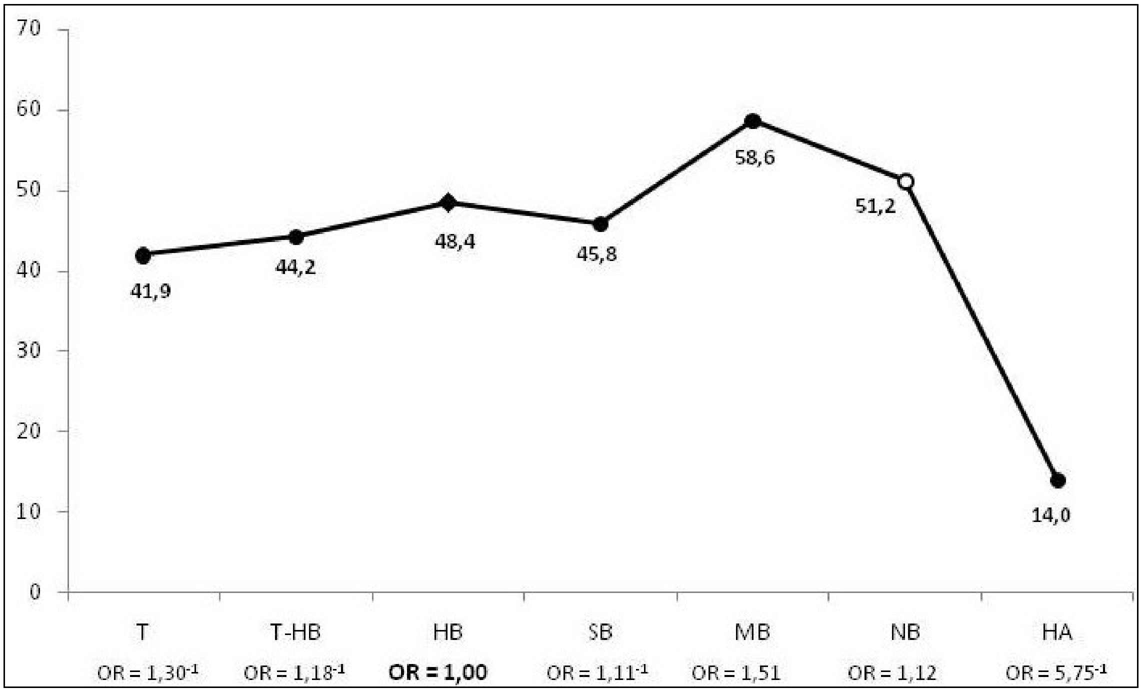

Fig. 2 Comparison of survival proportions (expressed as odds ratios; OR) in the dataset (total N=379) of accessions collected from different source zones to that of accessions collected from the hemiboreal zone. ORs below one (amount of decrease) and above one (increase) marked as suggested by Rita & Komonen (2008) to allow for comparison. n(T)= 119; n(T-HB)= 33; n(HB)= 95; n(SB)= 66; n(MB)= 45; n(NB)= 13; n(HA)= 8. Closed circle= significantly different from reference class, open circle= not significantly different from reference class (Wald's test, p<0.05 and p>0.05 respectively); rhomb= reference class.

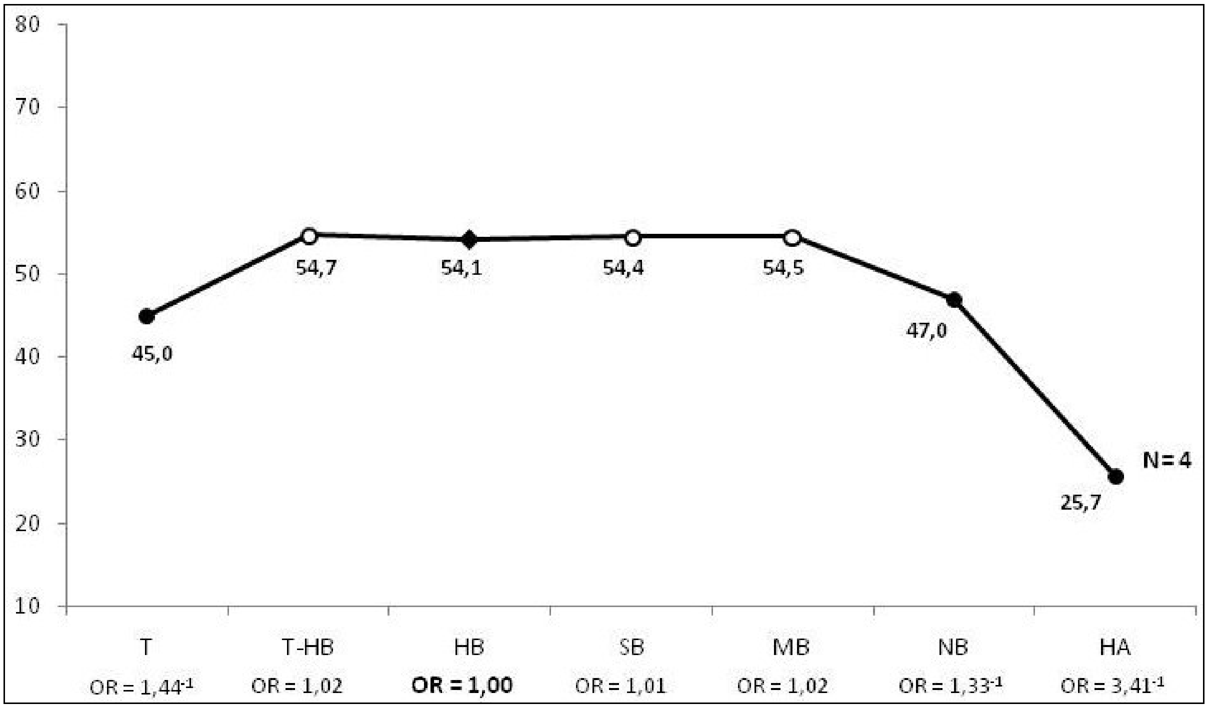

Fig. 3 Comparison of survival proportions (expressed as odds ratios; OR) in the dataset of **woody** accessions (total N=307) collected from different source zones to that of accessions collected from the hemiboreal zone. ORs below one (amount of decrease) and above one (increase) marked as suggested by Rita & Komonen (2008) to allow for comparison. n(T)= 90; n(T-HB)= 26; n(HB)= 81; n(SB)= 52; n(MB)= 43; n(NB)= 11; n(HA)= 4. Closed circle= significantly different from reference class, open circle= not significantly different from reference class (Wald's test, p<0.05 and p>0.05 respectively); rhomb= reference class. Cases where n<5 marked.

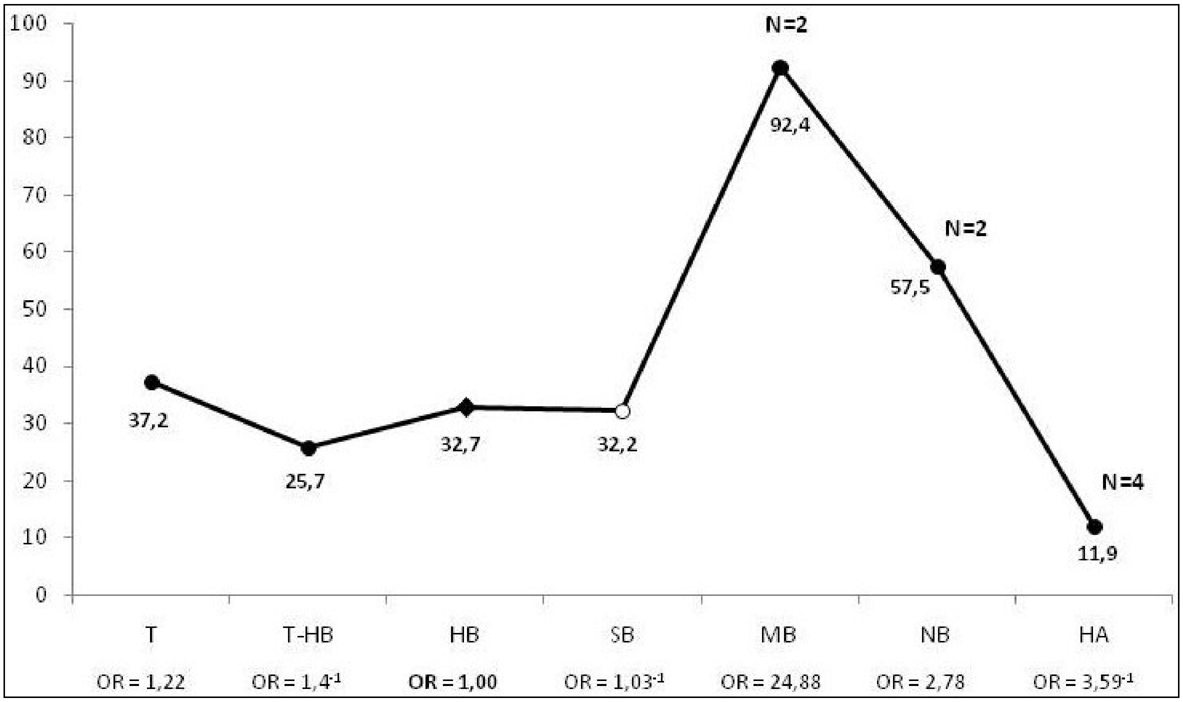

Fig. 4 Comparison of survival proportions (expressed as odds ratios; OR) in the dataset of **herbaceous** accessions (total N=72 collected from different source zones to that of accessions collected from the hemiboreal zone. ORs below one (amount of decrease) and above one (increase) marked as suggested by Rita & Komonen (2008) to allow for comparison. n(T)= 29; n(T-HB)= 7; n(HB)= 14; n(SB)= 14; n(MB)= 2; n(NB)= 2; n(HA)= 4. Closed circle= significantly different from reference class, open circle= not significantly different from reference class (Wald's test, $p<0.05$ and $p>0.05$ respectively); rhomb= reference class. Cases where $n<5$ marked.