The use of bar-codes beyond the supermarket: possibilities and challenges for living collections

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Information stored about plants is what puts the word 'botanic' into our institute's name. Curators and garden staff are obliged to record and maintain considerably more information about their accessions than they once did. At the same time, the demands on staff time have never been greater. Traditional practices in data collection (writing lists) are extremely time consuming and prone to transcription errors. In addition, many institutes hold a great wealth of plant diversity. The National Botanic Garden of Belgium (NBGB), is no exception, its holds c.25,000 accessions (stock items), each with potentially an enormous amount of associated data.

Supermarkets also contain a vast and diverse array of stock items that constantly change in number. They rise to this challenge by managing their stock by using databases for which bar-code technology is an important tool. In the same way, the NBGB has recently initiated this practice, making it possible to collect data in a fraction of the time it once took. The practical use of bar-coding have only currently been fully integrated in a single collection (wild Phaseoleae). The challenge is now to integrate this methodology into the rest of the collections and to fully utilise its potential.

A brief history

The term 'bar-code' refers to a series of linear bars and spaces of predetermined width that relates to a particular identification code. The idea of capturing product information automatically *via* bar-codes was first conceived in 1949. It was not until 1974 that the first retail product featuring a bar-code, a pack of chewing gum, was sold in America (Seideman 1993). Since then, bar-coding has been widely adopted in a range of industries and sciences. Its use in cataloguing biological specimens is regarded as particularly valuable because it provides a simple and reliable mechanism for retrieving complex and accurate data. In 1984, herbarium vouchers in botanic gardens received their first codes (*pers. comm*. R. Russell, Smithsonian Institution, USA). Until recently however, bar-coding was almost exclusively reserved for non-living material. This is surprising, considering its considerable advantages to a curator of a living collection whose records are stored in a database.

In 2000, the NBGB decided to implement this technology for the management of living collections. The capabilities of the in-house databases LIVCOL and PHASEO were enhanced in order to accept this technology, by converting the existing numeric accession numbers into bar-code format. During the same period an Epilog Laser Engraver machine (Epilog Laser, Denver, Colorado, USA) was purchased. This versatile machine enabled us to engrave rigid acrylic plant labels with information. Programs have been developed in order to produce laser engraved labels automatically from LIVCOL. They are written using languages such as PERL and Encapsulated PostScript (see Empain 2000). A programmable bar-code reader (Unitech) is used for reading the original stored information on the labels and for entering additional data.

Quick, accurate and straightforward data collection

There are a number of advantages of using bar-codes to curate living collections. The speed of data collection is dramatically increased, compared with checking lists. The task is simple and can be done at almost any angle, making even awkwardly positioned labels accessible.

Furthermore, the risk of errors from scanning is miniscule compared with transcription errors from manually reading or copying long data sequences. Transcription errors by hand typically happen if data is recorded over long periods, or when the operator is dyslexic. On average, one in ten people demonstrate some form of

dyslexia (Hornsby 1984) for whom errors are literally unavoidable. Tests on the accuracy of bar-code scanning have put the maximum error rate at one in 394,000, with the minimum error rate at just under one in a million (Fitz & Russ 2005).

Bar-coding is a relatively straightforward job for garden and curation staff and the time saved by using it can be diverted into more rewarding aspects of collection management. The hand-held reader need not employ complex or expensive technology. Since the popularisation of mobile phones in the late 1990s, people have grown accustomed to operating a hand-held device with a keypad, and as a result, technophobia is now less likely.

A unique code

In order to utilise the technology of bar-coding it is vital that each discrete plant or group of plants (seeds and spores) has a unique identification sequence. Ideally this should be the accession code (normally a number) since it is often the only unique item of information for a particular accession and saves re-coding the entire holdings. In order to be compatible with the most common bar-code 'languages' (EAN-13 and U.P.C.) accession numbers need to have less than 13 digits with no alphabetical sequences. However, if the accession sequence comprises alphabetical or alphanumeric sequences then other languages exist capable of translating this data. There are also other languages capable of translating numeric sequences over 13 digits.

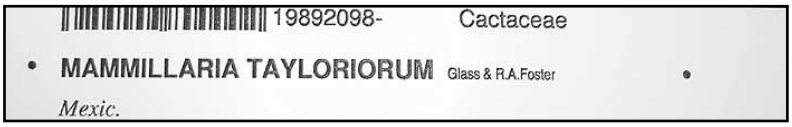

Figure 1 Typical engraved label with separated bar-code and accession used at NBGB

The majority of bar-codes contain a corresponding numeric code at the immediate base of the linear sequence. The label design at the NBGB separates them (Fig. 1). This helps safeguard information in the event that the label becomes broken. Therefore there is always a good possibility that either the accession number or linear sequence remains intact. This can be important in the field. If the bar-code reader is unable to scan the coded sequence the accession number can be typed using the keypad, automatically updating the stored list.

An efficient bar-coding system must ensure data integrity and enable the retrieval of information about an accession and its different components. To achieve this, items such as herbarium vouchers, photographs, slides etc. must also have a unique 'item identifier'. At the NBGB, item identifiers are constructed by joining sections of information. A slide for example will always start with the same two digit number, followed by its specific collection and serial numbers and finally by control digits. This produces a 12 digit number that is then converted into bar-code format. Links between these different items are then recorded in the database.

Significantly aiding curation

The potential of bar-coding in the living collections department is vast, yet to the best of our knowledge this is the first paper to be written on the subject. At NBGB we have highlighted several key areas where this technology is, or will be, a vital component in collection management, although this is by no means a definitive list.

Collecting phenological data

The conservation collection of wild Phaseoleae is fully bar-coded and in use on a regular basis. At weekly intervals, phenological data is collected and inventories produced (Fig. 2). This is done by a programmable, hand-held reader (Figure 3) by prompting the operator with questions. For example, the NBGB has a simple system to record flowering data in the wild Phaseoleae collection. First a program is selected by pressing a 'program key', this prompts the operator to enter a date, followed by the cultivation season, week number and the number of plants and their flowering status. The latter is recorded on the key pad, by typing key '0' for no flowers, '1' buds, '2' open flowers, '3' flowers and pods or '4' pods only. When complete, the data is directly uploaded to the PHASEO database.

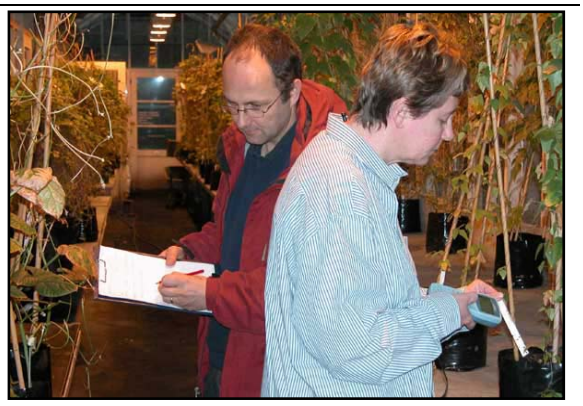

Figure 2. Quentin Groom & Ann Van de Vyver collecting data using the 'list' and 'bar-code' methods.

Prior to adopting this new technology, data collection and database updates typically took four hours *per* week. This comprised of three hours of data collection and one hour to update the database. With bar-coding both jobs are complete in a single hour, with the largest time saving being made when uploading the PHASEO database, which now takes 60 seconds.

Making inventories

The labels of our *Agave* collection were recently updated to those bearing a bar-code. In an exercise, we decided to compare making inventories by bar-code with ticking off plants from a printed list. At the NBGB, the 'list method' involves making a query from the database, printing the list and ticking off the plants when encountered. The list is then used to enter changes manually into the LIVCOL database. Bar-coding simply requires the operator to scan labels and upload the data to a database. The collection comprised of 218 plants from 143 accessions. Their positioning on the bench was random. Using the bar-code reader, data was recorded in 13 minutes, compared with 61 minutes by the list method.

Figure 3. A programmable, hand-held bar-code reader

Bar-coding presents a significant time saving, compared to checking lists. However, the full benefit is only realised if automatic updates are possible. This occurs in the recently developed PHASEO database because bar-code technology was incorporated in its design phase. The living plant collections database LIVCOL, however, was developed much earlier, in 1991, addressing the needs of curators at that time and before bar-coding was implemented at the Institute. As a result, fully automatic updates without any data loss and without mistakes are currently not possible. This problem is currently being discussed and will be addressed in the near future.

In advance of this, curation staff are currently working towards replacing all old plant labels with those carrying a bar-code. In the indoor collections alone, this amounts to an estimated 27,600 labels. Until recently, plant labels were simply replaced when broken, when a name changed, or when new displays were created. Now we want to systematically update all labels and reap the rewards of rapid and accurate data collection. This is an important and vital next step in order to maintain our databases with a high degree of accuracy and to provide accurate information contributing to one of the aims of Target 8 of the GSPC (60% of threatened taxa in *ex situ* collections).

Producing lists

Most gardens will want to make lists of plants for various purposes. The education department at the NBGB are currently investigating using the bar-code reader to help plan themed botanical walks in the Garden. For example, for a given season or theme the operator can pace the intended route of the walk scanning the

plants of interest as they go. The list of plants can then be downloaded in the order scanned providing the botanical blueprint for the walking guide.

Identification

The NBGB are currently investigating the possibility of using bar-codes to aid identification in the field. This could be facilitated by scanning a plant's bar-code *via* a wireless handheld computer and immediately viewing text, keys or photographs. This would be particularly useful in our collection of annual plants where seedling identification sometimes presents challenges.

What other institutes do

Despite the obvious advantages of bar-coding at the NBGB we decided to conduct an e-mail survey to: a) establish which institutes routinely use bar-codes in the curation of their living collections b) identify challenges to bar-code implementation c) discover what alternative methods exist.

The email was sent to c.600 addresses, greatly facilitated by the American Public Gardens' Association. The response rate was low at 9%, but nevertheless provides a good reflection of common problems and an insight on what happens at other institutes.

Institutes routinely using bar-codes in the curation of their living collections

All recipients of the questionnaire were asked, even if they did not use bar-coding, if they knew of institutes that routinely use bar-coding in their living collection management and to provide their names. Surprisingly, our survey revealed relatively few gardens using this technology. Despite this, the subject did generate interest amongst the replies with 33% demonstrating an enthusiasm to be kept informed of the results. This implies that curators are interested in this technology even though they have not yet adopted it in their collection management.

The institutes who currently utilise bar-coding in the management of their living collections are: the Marie Selby Botanical Gardens, Sarasota, USA (MSBG), Arboretum Kalmthout, Heuvel, Belgium (AK), National Botanic Garden of Belgium (NBGB) and Royal Botanic Garden Edinburgh, UK (RBGE). In addition, the Fairchild Tropical Botanic Garden (FTBG), Missouri Botanical Garden (MBG), Cambridge University Botanic Garden, and the Royal Horticultural Society at Wisley are able to print bar-coded labels from their databases, although they do not utilise them for data capture (*pers. comm*. M. Griffiths; R. Sucher; P. Atkinson; G. Skilton, respectively). Whereas the United States Botanic Garden in Washington DC is currently in the process of developing a bar-code management system (*pers. comm*. Kyle Wallick). The University of Connecticut (UConn) has used this technology previously, but is now utilising other tools for collection management.

What are the challenges of implementing bar-code technology?

Consistently, the over-riding drawback stated by those institutes utilising bar-codes was its integration into an existing database. This involves writing and manipulating database software. MSBG overcome the problem by purchasing the commercial inventory software 'WASP' (Wasp Barcode Technologies, Texas, U.S.A.) and uploading the data into a Microsoft Access database (*pers. comm*. B. Holst). RBGE also found software issues difficult to resolve, *pers. comm*.. R. Cubey). UConn began bar-coding with hand-held PDAs (Symbol SPT1500) in the late 1990s. Although it worked well, downloading data, synchronising the database and other software problems resulted in other technology being utilised (see section 'c'). A possible solution to software incompatibility is the use of the commercially available database BG-BASE™. It allows the transfer of a wide-range of information (e.g. phenology, plant health, measurements) from the bar-code reader to the database as long as the output from the reader complies with the BG-BASE transfer format specification (pers. comm. K. Walter, BG-BASE). This procedure is just starting to be used by AK who do not anticipate any problems (*pers. comm.* A. Rammeloo).

The long-term durability of plant labels is an important issue. The NBGB has been using rigid acrylic plant labels for over seven years with no apparent deterioration. However, it is not known whether this will be the situation after 20 or more years. The American Public Gardens Association recommends anodised

aluminium since this material is believed to be more robust, especially for long-lived perennial species (*pers. comm*. Pam Allenstein).

In tropical humid environments, algae can build-up on labels and obscure bar-codes, making them illegible to the reader. This has occurred at MSBG, but was solved by placing clear laminate over the code, greatly inhibiting the algal growth (*pers. comm*. B. Holst). The NBGB has yet to experience these problems, but has occasionally encountered soil splashing onto the labels, so that they require a wipe prior to scanning. NBGB also discovered that engraved bar-codes on reflective acrylic do not provide sufficient contrast to record data.

What alternative technologies are used?

Interestingly, the vast majority of botanic gardens use no automated system to collect accession data. On a limited basis, GIS and GPS are used to map plants at the University of North Carolina, University of Michigan Botanical Gardens and The National Arboreta, Bedgebury Pinetum in the UK.

Initially, having been a pioneer in the utilisation of bar-codes for living plant management, UConn now utilises **wireless internet** technology *via* a Windows mobile handheld device. By this method searches and checklists can be produced *in situ* allowing the operator to update the database directly from the device (*pers. comm*. C. Morse). Real-time integration of information to the database was also a priority for the RBGE. Experiments there using a bar-code reader began ten years ago in 1997. However, it was only recently that a bar-code reader using **Bluetooth technology** and wireless links was purchased. This enables live updating of the database (*pers comm*. J. Latta).

The MBG currently use a **touch screen tablet computer** to facilitate data collection. It works *via* a high resolution orthophotograph (in ESRI's ArcGIS). An orthophotograph is an aerial photograph that has been geometrically corrected so that the scale of the photograph is uniform and equivalent to a map. The operator then simply taps on the screen where the plant is located and types in the accession number (*pers. comm.* R. Sucher).

Boyce Tankersley of the Chicago Botanic Garden is trialling **Radio Frequency Identification** (RFID) in their living collections. This technology is currently used for tracking large-scale warehouse items such as pallets or placed under the skin of household pets for registering and security purposes. In the future, this application could mean that a curator could insert an RFID chip into the bark of a tree or on a label and simply point an RFID-reader towards a group of plants and immediately receive their records. The RFID components of this technology are also believed to be very durable and long lasting. Currently, there are a number of problems to resolve around the sensitivity of scanning and duplicate codes assigned to different taxa. Solving these problems could open the way to super-fast data collection.

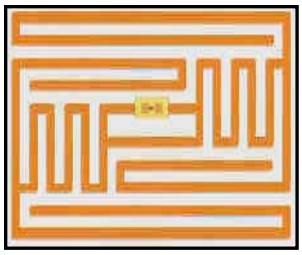

Figure 4. RFID, is it the future?

Concluding remarks

The advantages of collecting data using bar-code technology are evident in the case studies undertaken at the NBGB. This practice clearly enables staff to dramatically reduce the time taken to collect data and significantly minimises errors. Technology advances quickly and there are currently a range of ways that curators can meet the growing demands of living collection management. While specifically concentrating this article on the use of bar-codes, we acknowledge that GIS, GPS and wireless technology and possibly RFID can all contribute to data capture. The decision about which to select depends on the specific requirements of the individual garden.

Despite the technology being available, the majority of gardens fail to adopt such advances, maintaining laborious practices to collect data while risking transcription errors. The main reasons appear to be threefold: insufficient funding; perceived problems integrating new technology with existing database(s); lack of awareness that alternatives exist. It is suggested that a cost benefit analysis will justify the first reason, communication between institutes aid the second and this paper help dispel the final reason. Finally consider this: a curator with a carefully managed botanical database which only partly corresponds to reality in the

garden simply has a plant list, not a botanic collection. If Target 8 of the GSPC is to be successfully reached then curators need accurate up-to-date knowledge about their holdings. We believe bar-coding to be an essential tool for the management of living collections, don't restrict it to the supermarket!

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References

Empain, A., (2000). *Laser engraver, documentation about the program and the macro definitions*. www.br.fgov.be/SCIENCE/INFORMATICS/apps/engraver/index.html

Fitz, J. & Russ, D.H. (2005). *Code 16k and Code 49 data integrity test*. Centre for Automatic Identification, Ohio University, USA.

Hornsby, B. (1984). *Overcoming dyslexia: Aapositive health guide.* Harper Collins, UK

Seideman, T. (1993). Bar codes sweep the world. In: *American Heritage of Invention and Technology*. 4, pp. 9 – 11.