BARCODES ARE DEAD, LONG LIVE BARCODES! IMPROVING THE INVENTORY OF LIVING PLANT COLLECTIONS USING OPTICAL TECHNOLOGY

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ABSTRACT

The use of barcodes for record keeping in botanic gardens has been pioneered before, but attempts have not always been successful. It has even been claimed that, for use in living collections, barcodes are altogether obsolete. This is difficult to imagine given the success of barcodes in almost any professional logistic or auto-ID application. We have tried to find the 'sweet spots' of barcode use and have implemented the technology at the Hortus Botanicus Amsterdam. Integrated with the list-making functionality in the collection management software, barcodes have proved to be an invaluable tool in improving the quality and accuracy of the inventory.

INTRODUCTION

Two problems existed at the Hortus Botanicus Amsterdam (AMD) that led to the development of barcode-supported record keeping. Firstly, serious backlogs in the inventory of the Garden's plants had built up over the years. These backlogs had developed where major or frequent changes in the composition of the Living Collection occurred. Although there have always been well-established standards for the quality of taxonomic information, verifications and provenance, there was no apparent strategy on how to keep the inventory up to date. Time-consuming registration duties were frequently overruled by other priorities. Handwritten lists of plants, if compiled at all, lingered in the office for years. More efficient methods and clear procedures were needed to tackle the problem of a permanently incorrect inventory.

Secondly, and paradoxically, all plant labels in the public part of AMD were already designated with a barcode containing the eight-digit accession number of the plant. However, there was no barcode scanner in the organisation and there was no format for communication with the collection database. The barcodes gave the impression of a garden using state-of-the-art technology; however, this was purely cosmetic. This odd situation, perpetuated for decades, finally resulted in the actual application of the barcodes as pressure increased to take a decision about their future. It was decided that rather than just keeping up appearances, the barcodes were, at last, going to perform the task for which they were intended.

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The second problem was attended to first, and it seemed a straightforward one: to enable the collection software IrisBG (Rustan & Ostgaard, 2010–2016), running on a personal digital assistant (PDA) or desktop computer, to handle barcodes and pull up the accession record when a code was scanned. In order to create an adequate design for the software integration, we analysed situations in which barcode applications could be expected to be most effective. The two key qualities of barcode technology are accuracy and speed. A scan is much less likely to contain transcription errors than a number that is entered manually. For example, human transcription errors in a medical research database were measured to be between 0.01 per cent and 0.53 per cent (Khushi *et al.*, 2012). Speed is the other factor. A scan can instantly pull up an accession or add it to a list of accessions. It helps to reduce the time spent on updating changes in the Living Collection, especially when collection surveys and list making are involved.

METHODS

Three elements are required to implement the technology. Firstly, the plant labels have to feature a barcode containing the accession number. Secondly, a scanner that supports the type of barcode chosen must be acquired. Finally, the Collection software needs to interact with the scanner hardware. Poor integration of barcode technology with the database software is considered to be the main hurdle in implementing this technology (Aplin *et al*., 2007). Using additional software to collect and organise the scans would challenge the speed and adoptability of the solution.

AMD had previously printed Code128 linear barcodes. Although widely adopted by the retail industry, linear barcodes can be difficult to scan when physically damaged or dirty. More recent two-dimensional barcodes, such as QR codes or Data Matrix (DM) codes, implement Reed-Solomon error correction (Wikipedia, 2016), which increases their reliability even under difficult conditions. When the contrast is sufficient and the encoded information is limited, DM codes can be printed on a very small surface and retain good readability when using a professional scanner. They can be added inconspicuously and economically to the layout of nursery labels, interpretation labels or accession tags (Fig. 1). The largest DM code used in AMD on interpretation labels measures 6 × 14mm, while the smallest printed on the accession tag is 3 × 3mm. DM codes also support inverse printing, which makes it easier to incorporate the barcodes into the design of our white-on-brown interpretation labels (Fig. 1).

A 2D scanner is required for scanning DM codes. These scanners are more expensive than classic 1D scanners, but they can scan 1D as well as 2D barcodes and barcode orientation is of less importance with 2D scanners. After having tested a number of different scanners, we found that some professional 2D scanners could deliver an instant response from a scanning distance of approximately 30cm, whereas consumer-grade camera and laser scanners often struggled to scan or would take seconds to process the scan. These seemingly subtle differences can have a big impact on the overall user experience. Considerable system engineering was carried out to integrate the mobile

Fig. 1 (left to right) Nursery label, interpretation label and accession tag with Data Matrix codes containing the eight-digit accession number. Photos: Reinout Havinga.

collection management software with the scanner hardware. Once this had been done we had a mobile version of the software running on a PDA that could instantly pick up tiny DM codes and pull up the record linked to it. The mobile collection software was redesigned to support three workflows using barcodes, as follows:

1. A barcode is scanned and the record is displayed so that details can be checked and updated.
2. A barcode is scanned and only the plant status (e.g. dead, alive, etc.) can be updated directly. Additional details are not displayed.
3. A barcode is scanned and the record is added to a list, after which the next barcode can be scanned, enabling a list to be compiled quickly.

The third workflow can be used to build up a list of records in a matter of seconds. This list can be used to update all records at once or can be transferred to the desktop software for more advanced actions.

The desktop software was adapted to recognise scans from a wired device to find the corresponding accession or add the record to a list in its ‘list maker’ functionality.

RESULTS

Barcodes positively influenced the speed and ease of working in a number of record-keeping situations.

Most experience was gained in the nursery. The nursery is a very dynamic part of AMD where plant status changes are frequent from stored, sown, germinated or pricked-out to either established (potted or planted) or dead. It is a constant challenge to ensure that the recorded plant status corresponds with the situation on the ground. In 2015 we used barcodes to record the living plants in the nursery once or twice a week (Fig. 2). The resulting list was compared to the existing plant status and when applicable the status was updated, for example from 'sown' to 'germinated'. This yielded reliable status accounts for the nursery with an accuracy of around three to five days. The information was collected with very little effort and without major additional pressure on the organisation. The positive impact on the reliability of the database, however, was significant.

The second application was in mass plantings. To avoid soil exhaustion, many of the perennials in a garden area with 18 subsections were lifted in 2015 and moved to another subsection. The total inventory of the larger area did not need to change, but most of the inventories of the subsections were going to be completely different. To update the inventories after the reshuffle, a new list of plants in each subsection was composed using the mobile software on the PDA with integrated 2D barcode scanner. The resulting lists were used to analyse which plants were new to a subsection and which were still in their initial location. A number of the labels in the area had not yet been provided with a barcode. For these plants, information had to be typed in by hand, which caused a significant delay compared to the machine-readable labels. With the Living Collection available online for visitors to explore, being more up to date with the inventory now improves the online experience and enhances the profile of the Garden.

Fig. 2 Stocktaking plants in the nursery using a PDA with 2D scanner. Photo: Karin de Bont.

Finally, good results were achieved with barcodes in 'on-demand labelling' of seasonal display plants. In 2015, we had about 40 tulip varieties on display in spring, followed by 40 dahlia varieties in summer. To be on the safe side, a few more of these plants were propagated in the nursery and accommodated with practical nursery labels. When the display was opened, most, but not all, of the plants were brought to the public area. At this point, all selected plants were listed by scanning their nursery labels. The resulting list was then used to define which plants required new labels.

DISCUSSION

Prospective applications

Based on the supported scenarios and the activities in which barcodes have been useful, a number of other applications of the technology can be envisaged, such as up-to-date registration of seasonal plantings or making periodical inventories of the total collection (Rae, 2008). Rapid surveys of phenological events such as bud burst, flowering and fruiting (Blades *et al.*, 2008) that help predict how plants react to climatic change (Martin, 2014) could be carried out frequently. These kinds of registrations, which improve the quality and value of the collection data, often lie waiting due to the costs and effort involved. The time required to record this type of data is expected to drop dramatically when barcode technology is applied.

Radio-frequency identification (RFID) technology may be implemented in much the same way as barcodes, and this technology has already been tested in botanic gardens (Aplin *et al.*, 2007). However, producing RFID tags is more expensive than barcode technology and for building up experience using auto-ID solutions, the more mature barcode technology was deemed to be more appropriate. RFID tags can easily replace or be combined with barcodes in the future and many of the experiences from this project are directly transferable to an RFID tag implementation.

The merits of lists

In the case of the first workflow, pulling up and modifying the accession record after a barcode scan, the increased speed of barcode scanning over typing is not relevant. In the case of updating individual accession records, the time saved by scanning (<0.1 second) compared to typing (2–3 seconds) is negligible as most of the time is spent viewing and updating the data. However the third workflow – building up lists – is a process that is made easier and much faster by scanning, especially as the number of listed records increases. The workflow is simple: scan, go to next plant, scan, go to next plant and so on. Any other scenario that can follow this workflow should be able to benefit from barcode technology. Counting plants within accessions could be an interesting scenario to explore in the future.

A key feature in the software integration is the list-making functionality. This was pioneered in the 'Event Management' module of the Atlantis Botanic Garden software

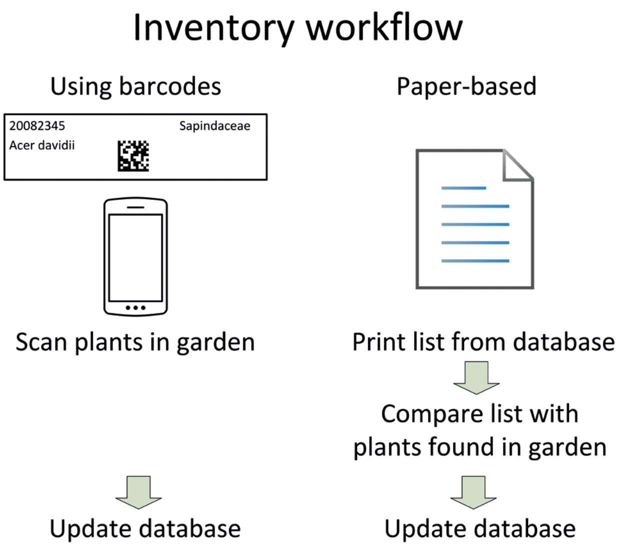

Fig. 3 Stocktaking workflows are often based on checklists reported from the database. Direct recording of the actual situation becomes an attractive alternative when barcodes are implemented. Diagram drawn by Havard Ostgaard.

(Persoon *et al.*, 2004) that inspired a similar functionality in version 3.1 of IrisBG (Rustan & Ostgaard, 2012). The implementation of barcodes appears to bear fruit in situations where the list-making ability is present in the collection software. At the Botanic Garden of the Natural History Museum in Oslo, Norway and at Utrecht Botanic Garden, the Netherlands, smartphones are now used to scan DM codes and compile lists of specimen numbers in simple text files. In Oslo, the list is pasted into a 'task' form in IrisBG (A. Kool, pers. comm.). In Utrecht, the list is imported into an 'event' form in Atlantis BG (E. Gouda, pers. comm.). Although slightly less integrated than the solution used in AMD, the examples from Oslo and Utrecht illustrate the importance of a list-building element in the software, which is necessary to make the implementation of barcodes worthwhile.

We found that having machine-readable labels can speed up the inventory of accessions so that it becomes a viable alternative for working with checklists based on the existing inventory in the database (as described by Latta, 2007). The traditional approach would be to prepare a list of plants that are expected to be present and compare this list to the current situation. Barcodes enable a more direct approach: a list is made of plants which are currently present in (a part of) the garden. This list is then used to update the database inventory (Fig. 3).

Other considerations

In situations where efficiency improves, a rebound effect can be expected: having more time on their hands, registrars may start recording more, perhaps unnecessary, data. On the other hand, backlogs in botanic garden collection inventories are common and more recordings may lead to a more reliable inventory list and thus improve the data quality of the collection.

Many botanic gardens tend to focus on the durability of their labels and accept expensive materials and complicated production methods. Some gardens have adopted a model of using labels that are fast to produce and cheap to replace, accepting compromises in durability. Most gardens will probably have a mixture of both models, depending on label type (Jebb, 2003) and institutional policy. Adequate labelling of the collection in the 'durability model' is achieved by reducing the need of replacement, whereas the 'replace model' aims to reduce the costs of replacement. Barcode technology will aid the latter model by supporting regular stocktaking of labels that need to be renewed. Contrary to what Aplin *et al.* (2007) found, we believe that successful implementation of barcodes is not so dependent on the durability of the plant labels.

The advantage of encoding the accession number is that the encoded information will be stable over time. Also, accession numbers are relatively short, which allows especially DM codes to be printed on a very small surface. Instead of mere accession numbers, it can be attractive to include information that defines the location or the specimen within an accession (as is done in Oslo and Utrecht Botanic Gardens). This will improve accuracy, but it will also add complexity. Another option with the IrisBG collection software is to print QR codes with a website URL that will guide a visitor to an online plant profile. The PDA software can use the same URL to identify the relevant accession record.

In many industries, barcode technology is used as a tool for auto-ID. In botanic gardens, labels are often not physically attached to a plant and can become separated for various reasons. The use of barcodes as a way to automatically identify a plant is therefore limited to situations where labels are nailed to a tree, tied to a branch or stuck on a seed packet. In structurally rich botanic gardens with trees, shrubberies, perennial and annual beds, nurseries and seed storage rooms, the barcodes will support efficiency only when handled by knowledgeable horticulturists.

CONCLUSION

Barcode technology can be a very useful tool in Living Collection management and record keeping in botanic gardens. We have demonstrated that barcodes can be successfully implemented when the following factors are considered.

Adoptability. Software and hardware have to be easy to use and the barcode infrastructure should be used on a regular basis. Therefore, the designed scenarios are best built on existing workflows with the possibility of entering the encoded information manually. The aim should be to make the technology a part of everyday record keeping, and integration with the collection management or database software is advisable.

Efficiency improvements. Barcode technology has most value in scenarios where working speed is important or data volume is high. Some record-keeping activities that were previously considered too labour-intensive are now possible with the help of barcode technology, especially when they involve the compilation of lists.

Dynamic environments. Barcode technology is suited to increasing efficiency in the logistic chain and has most effect in situations where regular changes occur and need to be registered. For quick results and a short feedback loop in the implementation process, it is recommended to start the use of barcodes in the most dynamic parts of the collection, such as the nursery or the annual beds.

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POSTCARDS FROM THE FIELD: THE ROLE OF PARTNERSHIP AND HORTICULTURE IN PLANT CONSERVATION IN SOUTH-EASTERN UNITED STATES OF AMERICA

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ABSTRACT

Increasingly, botanic gardens and arboreta are highlighted as effective partners to conserve plant species diversity and restore natural communities at a time when the need for these activities has become more urgent. Capacity for restoration and conservation at botanic gardens comes directly from staff expertise for horticulture and research. Botanic gardens make good partners for connecting botanical science with conservation practice. They are in a position to communicate information about rare plant species to owners and managers of public and private lands, and they can be instrumental in creating networks for effective conservation action. Several examples from south-eastern United States of America illustrate how this has been put into practice. These examples provide evidence that efforts to expand collaboration between federal agencies, states and non-governmental organisations can lead to effective alliances to conserve plant biodiversity, especially when plants receive a disproportionately low share of resources for conservation.

INTRODUCTION

Increasingly, botanic gardens and arboreta are highlighted as effective partners for conserving plant species diversity and restoring natural communities (Hardwick *et al*., 2011; Shaw *et al*., 2015). The need for these activities will only become more urgent in coming years as one in five plants face extinction and we realise the impacts of global climate change (RBG Kew, 2016; Thuiller, 2007). Capacity for restoration and conservation at botanic gardens comes directly from staff expertise in horticulture and research, including experience in seed storage techniques, propagation and insight for identifying appropriate microsites for augmentation and introduction into natural habitats. This is particularly helpful because re-introducing rare plants into the landscape requires understanding of a species' biology and ecology (Falk *et al.*, 1996). Furthermore, gardens have resources for maintaining georeferenced databases and researching taxonomic and population genetic diversity, as well as programmes for training and outreach. In effect, gardens are ready-made centres for conservation as places with botanical and horticultural expertise at a time when we need them more than ever.

The Global Strategy for Plant Conservation (GSPC) outlines targets for plant conservation to be reached by 2020 (CBD, 2012). Several of the recommended approaches to

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