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The development and future of the Jamaican Virtual Herbarium

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ABSTRACT: The Jamaican Virtual Herbarium (JVH) is an online database utility, serving text and imagery data for over 2,300 plant specimens. These are physically housed in the island's two internationally recognized herbaria: the Institute of Jamaica's (IOJ) Natural History Division Herbarium and the University of the West Indies' (UWI) Mona Campus Herbarium. The UWI herbarium houses some 35,000 vascular plant specimens, while the larger IOJ herbarium curates over 85,000. The project was a collaborative effort between both herbaria with logistical assistance provided by the Fairchild Tropical Botanic Gardens and funding from the Environmental Foundation of Jamaica. The JVH was developed based on the WAMP software application stack that involved the integration of the Windows (XP) operating system, Apache web server, MySQL database server and PHP Hypertext Pre-processor. The incorporation of the latter three open-source, community developed and supported utilities was integral to the functioning of the JVH. Specimen images were scanned at 300 dpi and were saved in both PDF and JPEG2000 formats. The database architecture currently facilitates web-based interfaces that handle in-house data entry and maintenance as well as client-based queries from the internet. The JVH currently handles approximately 1,075 internet visits per month; 339 of these being new monthly visits (May–July, 2014). This paper outlines the development of the JVH as well as summarises the achievements and future prospects of the web-based tool that has the proven capability of assisting in plant identification and curation, ethnobotanical research and ecological surveys. The JVH may be accessed at www.jamaicavirtualherbarium.com. One major challenge encountered thus far, includes obtaining the funding and human resources necessary for effectively growing the JVH beyond its original scope. Nonetheless, steps have been made to achieve this growth through partnerships with entities and researchers conducting ecological studies for which historical/baseline data would be valuable.

Keywords: Biodiversity, database, digitization, informatics, herbarium, virtual

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1. INTRODUCTION

The Jamaican Virtual Herbarium (JVH) is an electronic catalogue system capable of digitally preserving herbarium specimens and associated data. It facilitates the efficient retrieval of this data and imagery by incorporating both into an online, queryable, database utility for the country's two internationally recognised herbaria. These are the University of the West Indies Herbarium at Mona, Jamaica (UWI) and the Institute of Jamaica's (IOJ) Natural History Division Herbarium.

The JVH was custom designed to be portable, scalable, intuitive-to-use and easy to maintain. Its main purpose was to add value to the existing physical herbaria's collections by increasing access to the information reposited within them. It accomplishes this by handling both local and international queries via the World Wide Web. A key feature of the JVH is that it provides access to specimen imagery;

significantly improving the preservation of specimens for posterity by way of reducing the need for physical handling.

The JVH platform was built using the WAMP/LAMP application software stack, which is an integration of the Windows (and later Linux) operating system; Apache web server software; MySQL database server; and the PHP scripting software. The integration of these software tools is key to the functioning of dynamic web-page utilities such as the JVH.

This paper will provide an overview of the development of the JVH as well as summarise how specimen-records are entered and accessed. It will also provide information on the project's current status and achievements including usage statistics and realised applications and advantages. It will finally outline the challenges and future goals for the JVH project.

2. PROJECT OVERVIEW

Rationale and Conceptualisation: The Jamaican Virtual Herbarium was developed based on the realisation of four major concerns regarding the importance of specimen preservation, as well as the ease of access to natural history data in Jamaica. These concerns were:

1. A herbarium is extremely useful for taxonomic research but very difficult to use for conservation and education projects. Accessing the reposited specimen information can be a very tedious process based on how the specimens are organised. For example, projects requiring species lists for given research sites, ecosystem types or altitudes would either require a physical search for each specimen (an exhaustive process considering the over 120,000 specimens contained in both herbaria) or the rearrangement of the collections according to locality (which is

inefficient for the core taxonomic purpose of a herbarium).

2. The wide range of applications for herbarium data tends to be unrealised by the majority of its potential users. Owing to the aforementioned difficulty associated with a physical search, herbarium use (particularly in Jamaica) was mainly restricted to taxonomic purposes. As a result, the broader potentialities such as the generation of species distribution and ecological lists, were effectively ignored.

3. The available electronic cataloguing solutions (at the time of the JVH's conception) tended to be non-specific to an institution's unique needs. They required stand-alone software installations and external assistance was necessary in the event of a system failure. In cases where the software was no longer supported (i.e. if products were discontinued) it was envisaged that the rectification of acute issues would become difficult over time. As such, a tailored system was required.

4. Herbarium specimens have a very long but finite storage-life. Although the rate of decay for pressed and dried plant specimens is very slow (capable of lasting over hundreds of years) specimen longevity depends highly on the level of curation afforded the samples as well as how often the specimens are handled.

It was, therefore, determined that a web-based, electronic database solution (capable of cataloguing and serving textual data as well as specimen imagery) would be best at addressing these issues. The main objectives of the project were set out in 2005. Firstly, a selection of important Jamaican species in the IOJ and UWI herbaria were to be identified and their specimens digitized (including the

capture of specimen-label information); secondly, a customised MySQL database would be created for the storage of specimen data; and finally, a web-based system would be developed to facilitate both the entry of specimen data as well as the processing of user queries in order to retrieve specimen imagery over the world wide web.

Development: At conception, the JVH project was designed to be a collaborative effort between the IOJ, UWI and the Fairchild Tropical Botanic Gardens (FTBG) Herbarium (Miami, Fl., USA). Funding was provided by the Environmental Foundation of Jamaica (EFJ). The acquisition of scanning equipment, personal computers and servers began in 2005, while database creation, programming and specimen digitisation began in 2006/07. The project was completed in 2009 culminating with the launch of the JVH website (www.jamaicavirtualherbarium.com) on September 15th that year.

Owing to the large number of specimens retained in both herbaria, a decision was made to focus on eight of the most common tropical plant families with the greatest world-wide distribution (Judd 2005; Primack & Corlett 2005; Turner 2001) and within those families focus was placed on those specimens collected by William Harris (collected from 1887–1919) (UWI) and George Proctor (1954–2010) (IOJ). The eight plant families prioritised were: Annonaceae, Bignoniaceae, Fabaceae (Caesalpiniodeae, Mimosoideae, and Faboideae), Euphorbiaceae, Lauraceae, Moraceae, Myrtaceae and Rubiaceae.

Data Entry: The data entry process was designed so that personnel with limited technical experience could contribute to the inputting of information into the JVH. The process-flow for UWI specimen is outlined in **Error! Reference source not found.**. The physical specimens were retrieved from the collection and each were tagged with a sequentially incremented, archival quality barcode. This barcode number would eventually serve the triple purpose of being the

unique identifier for the specimen's database record as well as become the name of the specimen's image file and label text. Images were scanned at 300 dpi and saved in both JPEG2000 and PDF file formats. After scanning, the specimens were each re-filed. It should be noted here that the IOJ collections were not barcoded. Instead, their images and data were linked to the respective specimen's accession number.

The scanned images were then processed to enhance image quality, where image properties (such as contrast, sharpness and brightness) were adjusted in batch. Any text inscribed on the specimen-sheets was recorded by an Object Character Recognition (OCR) programme. Using the JVH's "back-end" (personnel-facing) web interface, the specimen's image was used to confirm the specimen's identity, nomenclature and to correct the associated OCR text. There were no stand-alone installations of the JVH and the personnel-facing website was accessible over the UWI intranet. After verification, the complete record was made available to the World Wide Web for online access via the JVH's "front-end" (client-facing) portal at (www.jamaicavirtualherbarium.com).

Client Data Retrieval: The end-user utility exists at www.jamaicavirtualherbarium.com. It consists of a series of pages that steps the user through a three-step specimen search process. The user is initially presented with a query form where each field that is completed adds to search parameters and hence, refines the results (Figure 2). At the final step, the user may view the available herbarium specimen-images that match their search criteria. Users are not limited to queries and results based primarily on plant names and specimen-images. In fact, the ability to retrieve data regarding the geographic distribution of species and species lists for particular habitats and localities are the main strengths of the JVH system (Rose et al. 2011).
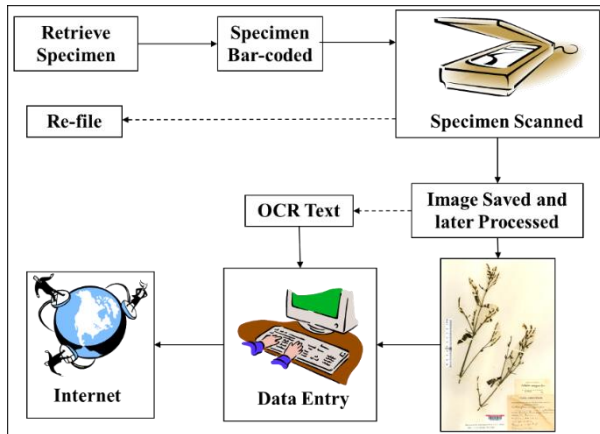
Figure 1: Data entry process flow for the capture of specimen imagery and label text for University of the West Indies (UWI) specimens.

3. COMMON APPLICATIONS/ADVANTAGES OF THE JVH

The key attributes of the JVH are its speed, flexibility and ease of use. There are 15 possible combinations of search criteria available to the end-user for querying specimen-records and filtering results. As such, not all queries need be taxonomically based and search criteria may be built on the names of collectors (and/or their assistants), the collection date, label text, common names and locality information (among others) (**Error! Reference source not found.**Figure 2). Since its launch, the JVH has proven to be an effective utility in the areas of plant identification, curation, ethno-botanical research, and ecological surveys. Its portability is also a key feature, as the JVH may be accessed anywhere there is a fixed or mobile internet connection.

Plant Identification and Curation: Based on scenarios done in 2010, it took personnel at the UWI herbarium, 2 minutes and 41 seconds (on average) to locate and retrieve a known specimen from the physical collection. Comparatively, it took persons approximately 20.9 seconds to follow through the three steps

of the JVH query procedure to view the image of a known specimen.

Figure 2: The JVH query form (step 1) (Rose 2009)

The identification of unknown samples poses a greater challenge and may take anywhere from 10 minutes to an hour when searching the physical collections. This time depended largely on the level of familiarity one may have with the plant's taxonomy, as well as the time one was able to devote to the request. Even if the family was known, searching the records of several genera to find a match is tedious and potentially destructive to the specimens. Here too, the speed of the JVH would greatly improve efficiency; and the fact that the specimens themselves are digitised, would reduce the level of deterioration on the physical collection. Therefore, the JVH may

play a significant role in enhancing the curation of specimens.

A majority the specimens, served from the JVH, were collected in the early- to mid-20th century (Figure 3). However, an appreciable number (431) were collected in the 1890's. These images are infinitely accessible and repeated access poses no harm to the physical collection.
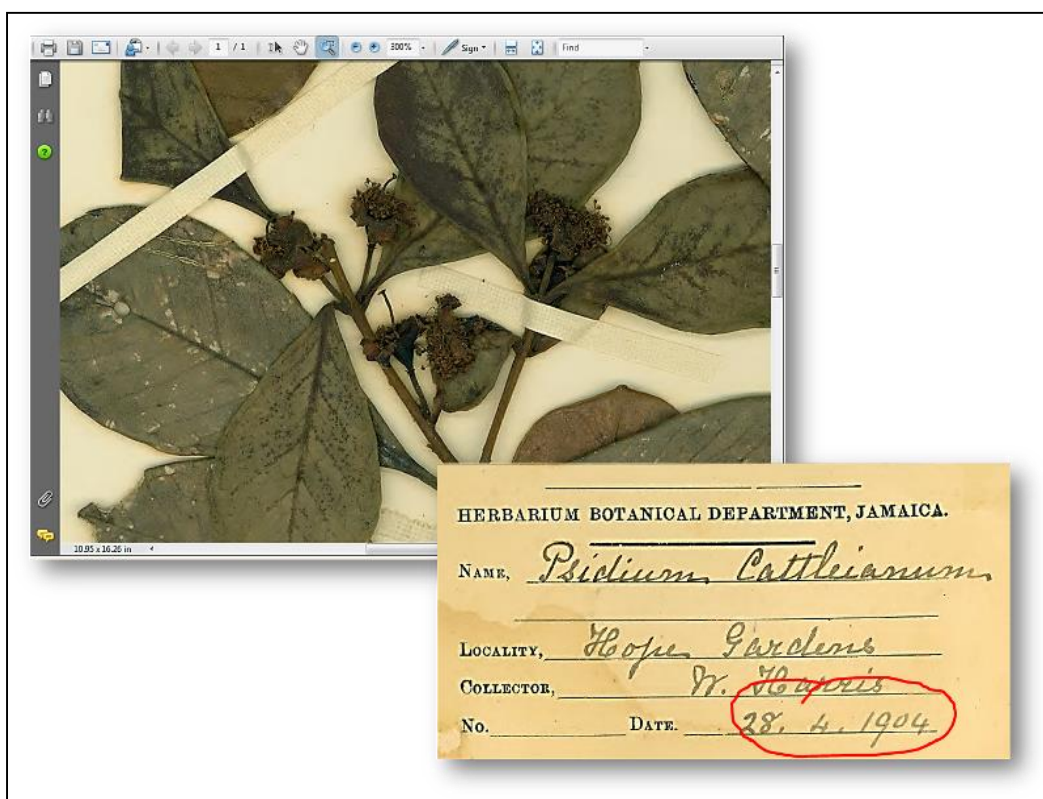

Figure 3: Enlarged image of a *Psidium cattleianum* Sabine (Strawberry Guava) specimen and associated label, collected on April 28, 1904 (Rose 2009).

Ethnobotanical Research: The label-text for all JVH specimens have been entered into a MySQL database and are, therefore, queryable. Figure 4 is a cropped image of the specimen label for the legume, *Abrus precatorius* L.; one of three results found when a query for the term "skin" was submitted (see section on seeds in (Figure 4). In addition to the label describing the other uses of the plant, it goes on to describe how to prepare it for each use. A physical search,

based on similar criteria, would require the tying up of resources, namely personnel and time, and would be quite difficult to accomplish due to the specificity of the search and the large number of specimens to examine.

Ecological Surveys: Havens et al. (2014) noted that effective plant conservation required key sets of baseline data, which include, species composition, species distribution and rarity. One of the most powerful group of JVH search fields relates to

locality information. Generating a species list based on parish, town, location, altitude and/or ecological habitat would require the researcher to either go through the entire collection and/or consult additional literature. It currently takes the JVH's MySQL database server, on average, 0.0059 seconds to return a species list based on any combination of these criteria. This translates to an average total search time of 20.9 seconds (from the entry of search criteria to the 3rd and final result screen).

ABRUS PRECATORIUS, Linn.

Wild Liquorice, Crab's Eyes.

Native of India. Naturalised in West Indies.

A twining plant, belonging to the Pea Family (*Leguminosæ*), with rose-coloured flowers and scarlet seed with black eye.

Root has been used as a substitute for liquorice.

Leaves.—Fresh leaves, steeped in warm castor oil, relieves local pain.

Seeds.—" Used internally in affections of the nervous system and externally in skin diseases, ulcers, affections of the hair." (Dutt) One to 3 grains boiled with milk is a tonic; unboiled, purgative and emetic. Decorticated and finely ground, cause purulent ophthalmia, due to a substance *abrin* which is poisonous to the blood, but not in the stomach.

Used by goldsmiths in India as weights; the Arab name *qirat* is said to be the origin of the weight *carat*.

Used ornamentally for necklaces, etc. The specific word *precatorius* points to their use for rosaries.
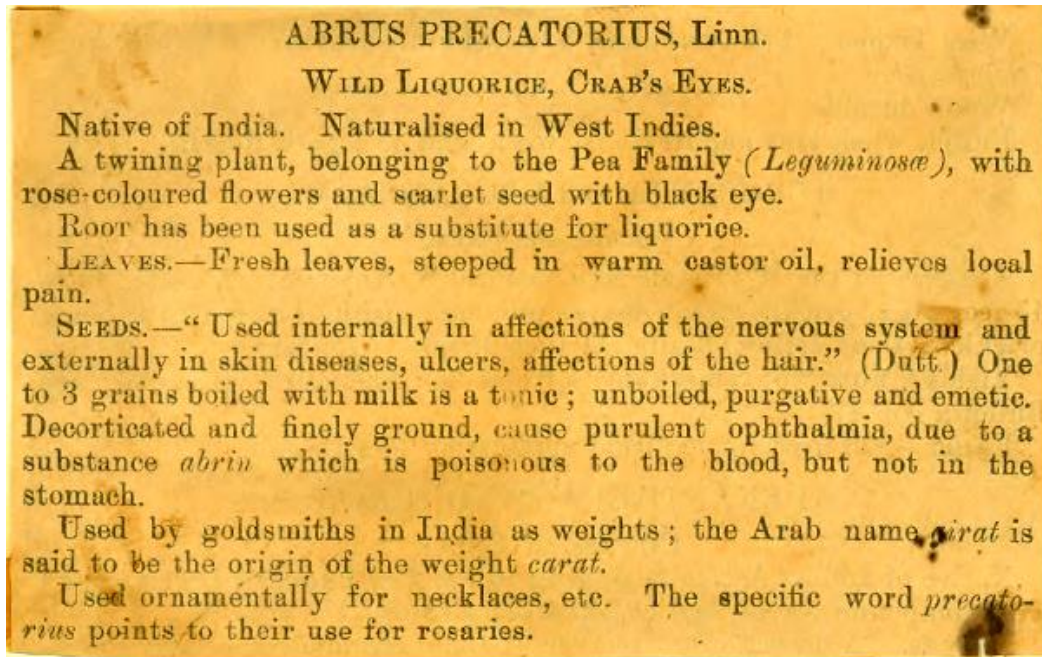
Figure 4: Specimen label for an *Abrus precatorius* L. (Wild Liquorice) specimen (collected by William Harris in 1904), detailing the medicinal uses and preparations of the plant. The label-text for all specimens is stored in the JVH database and may be searched (Rose 2009).

4. CURRENT STATUS AND ACHIEVEMENTS

When completed in 2009, the JVH consisted of a robust, user-tested, functioning database utility containing some 140,000 records on personnel, localities, nomenclature and specimens. This data was stored across 23 tables. The personnel-facing component (which dealt with user-access; the editing of taxonomic nomenclature and hierarchical systems; as well as record updating and retrieval) was managed by 15 web pages built with over 5,000 lines of PHP, HTML and JavaScript code. In 2010, data on over 1,900 specimens were available to the public.

By 2014, the JVH managed 2,346 specimen records. It received visits from 7,088 visitors annually, 25.2% of which were classified as new users. Comparatively, the two local herbaria (combined) received 173 visitors annually, between 2005 and 2013. Monthly visits also showed significant increases per annum; from a low of 83 visits/month in 2010 to 1,260 visits/month in 2014 (Figure 5). Since monitoring began in 2010 the JVH has handled 61,542 page queries with the majority (70.1%) occurring in 2013 and 2014 alone (22,290 in 2013 and 20,875 up to November, 2014).
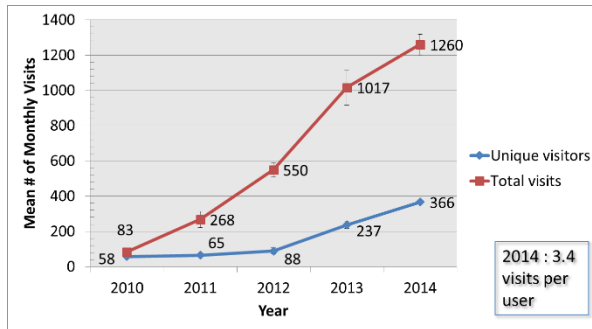
Figure 5: Mean monthly user visits to the JVH website per annum since 2010. Bars represent 1 SE unit.

5. CHALLENGES AND FUTURE PROSPECTS FOR THE JVH

Challenges: The most important and real challenge faced by the JVH project is growing the virtual catalogue beyond its initial scope (i.e. to include the remaining 117,000 specimens). The question of ever being able to have 100% of all collections online is one commonly faced by most virtual herbaria (in particular, large herbaria with over one million specimens and growing) (Vollmar et al. 2010; Rose et al. 2011). The full potential of the JVH will never be realised unless the majority of specimens of either herbaria are available for query.

However, the entering of textual and imagery data is quite labour intensive; and herein lies another challenge – human resources. At the Institute of Jamaica, staff are assigned to data entry, however, not exclusively and additional staff would be ideal. At the UWI no staff are assigned and data entry depends largely on undergraduate projects, volunteerism and indirect funding from environmental projects. Direct grant funding is currently being sought.

Another challenge is the somewhat continuous shift in software technology. When this project began in 2005, the image format JGEG2000 was a promising platform, able to compress a 50 MB TIFF image file down to 650KB with only an insignificant loss in image quality. Unfortunately, this format did not quite get a foothold among web developers and as such, most browsers do not support this format. Hence, the images were also stored in the PDF file format, which offers somewhat similar file compressibility and image quality. Web coding standards have also changed since the JVH's launch. So too have the database and scripting utilities. However, keeping abreast with these upgrades have been a minor challenge.

Future Prospects: The future of the JVH depends on growing the online collection. To achieve this, plans have been set in motion to further collaborations with existing and new partners. In this way, through direct and indirect funding from ecological studies, it is believed that the desired growth may occur. Other facilities to be added to the JVH include incorporating the database with GIS mapping technologies; and adding a facility to track inter-herbarium loans.

6. CONCLUSION

The Jamaican Virtual Herbarium is still in its infancy. However, great strides have been made in terms of enhancing access to information typically confined to the cabinets containing the physical collections. By continuing its expansion, the JVH has the potential to contribute tremendously to how conservation and taxonomic research will be conducted in Jamaica. If this is done, the end result will be a comprehensive database of all collected plant specimens in Jamaica that will be universally accessible via the internet from anywhere in the world. This, coupled with the ability to retrieve specimen images at a relatively high resolution and conduct location-specific queries in a fraction of the time it would take to conduct physical searches, are two of the most important features of the JVH.

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