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Research paper

Phylogeny of medicinal plants depicts cultural convergence among immigrant groups in New York City

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ABSTRACT

New York City (NYC) has a diverse range of immigrant populations that consequently brought to the city their traditional herbal knowledge. Medicinal plants have been used by different cultures worldwide, long before the development of pharmaceuticals. Studying the traditional uses of plants in a phylogenetic framework can help determine pharmacologically important plant families. A phylogeny of common medicinal plant species sold in NYC and traditionally used in Ayurvedic/Indian, Chinese, Latin/Caribbean, Middle Eastern/Islamic, and African cultures has been reconstructed, and the traditional medicinal function of each plant was mapped on the phylogeny. The results showed that the plant families Apiaceae, Burseraceae, Combretaceae, Fabaceae, Lamiaceae, Lauraceae, Malvaceae, Meliaceae, Rubiaceae, and Zingiberaceae have disproportionate importance to herbal medicine in NYC, and collectively, show applications for gastrointestinal, cardiovascular, respiratory, musculoskeletal, gynecological conditions, and as antibiotic/anti-parasitic agents. Our study has demonstrated that different immigrant groups converge on related plants for similar ailments. This cultural convergence, possibly through independent discoveries of these plants' medicinal uses, suggests that there may be underlying bioactivity that should be further explored. Our study also highlights the utility of phylogenetic analysis in uncovering new medicinal applications and novel therapeutic sources. Addition of more plant species to the phylogeny may uncover plant families that could be medicinally important for other applications or health conditions.

1. Introduction

Traditional medicine uses knowledge based on the beliefs and experiences native to different cultures for the promotion of health and in the prevention and treatment of diseases, and often includes herbal remedies (Wachtel-Galor and Benzie, 2011). There are many different practices of herbal medicine, and they vary with geographic location, culture and the flora available (Wachtel-Galor and Benzie, 2011). It is estimated that there are between 10,000 and 53,000 traditionally used plant species worldwide. Some of these have been integrated in pharmaceuticals, with at least 25% of modern medicines derived from plants (Saslis-Lagoudakis et al., 2012). Traditional herbal medicine continues to be a vital resource for modern day drug discovery (Fabricant and Farnsworth, 2001).

Herbal medicine has become an integral part of the health and wellness in the United States (Mahady et al., 2001; Bent, 2008). It has been found that 4 out of 10 American adults use some form of complementary alternative medicine (CAM) annually with 17.7% of treatments being herbal medicine (Barnes et al., 2008). In the ethnically diverse New York City (NYC), use of herbal medicine is prevalent. In one study, 57% of >2100 study participants admitted to herbal use at some point in their lives (Adusumilli et al., 2004). At least 25% of asthmatic New Yorkers have reported herbal remedy use (Roy et al., 2010). Ayuverdic herbal supplements have also gained popularity among 9/11 victims to alleviate their respiratory health problems (Dahl and Falk, 2008). Dominican immigrants have been reported to use traditional herbs even more so than the locals of their country (Vandebroek and Balick, 2012). Chinese immigrants suffering from cancer have also been found to rely heavily on traditional medicine (Leng and Gany, 2014). These studies indicate that urban ethnobotany is flourishing in NYC, as herbal medicines remain an important part of the culture of immigrant communities (Balick et al., 2000).

Herbal medicinal products (HMPs[1]), or botanical drugs (US FDA, 2010) contain one or more herbal substances from one or more

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[1] Herbal medicinal products (HMP's included in this study were either in the form of non-standardised tinctures, cut/powdered plant material in packets, or capsules containing ground material.

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plant species as active ingredients (European Commission, 2015). HMPs sold in NYC mainly derive from five different cultural groups: Ayurvedic/Indian, Chinese, Middle Eastern/Islamic, Latin/Caribbean and African. Ayurveda is an ancient medical system in India, dating back c. 5000 years, and offers a holistic approach to health (Lad, 1999) using many herbal products, including about 20,000 medicinal plants (Pandey et al., 2013). Traditional Chinese Medicine (TCM) is a 2500-year old healing practice developed in China including herbal medicine, acupuncture, massage and dietary modifications (NCCIH, 2013). It is estimated that China has over 11,000 medicinal species (Zhang and Yang, 2012). Middle Eastern herbal medicine refers to herbs used in countries of Western Asia such as Turkey, Oman, Israel, Iran, Iraq, Saudi Arabia and Egypt. About 200–250 plant species are still in use in Arab traditional medicine (Azaizeh et al., 2006). Latin America includes the Caribbean region and South America and has more than 100,000 vascular plant species, and over 400 indigenous groups that utilize various medicinal plants (Montenegro and Stephens, 2006). In Africa, traditional healers focus on treating the psychological basis of a disease, before treating the symptoms with prescribed herbs, which includes >5000 medicinal plant species (Mahomoodally, 2013).

The confluence of various immigrant communities and their traditional medicines in NYC – and the distinct ethnic enclaves in which these HMPs are easily found and purchased – makes this city an interesting venue in which to study cultural convergence on plant products used in herbal medicine. Here we addressed a series of tiered research questions to investigate patterns in the use of HMPs across immigrant groups in NYC: (1) What plant species within HMPs are most commonly used by five major immigrant groups (Ayurvedic/Indian, Chinese, Middle Eastern/Islamic, Latin American/Caribbean, African) in NYC?; (2) What phylogenetic relationships exist among plant species contained within imported HMPs despite their different geographic origins?; and (3) Are evolutionarily-related HMP species from different cultures used for the same therapeutic applications? These questions were answered by constructing a species-level phylogeny of the medicinal plants sold in NYC by major immigrant groups to determine if they converge on related plants used for treatment of similar ailments. This phylogenetic pattern may imply independent discoveries of these plants' medicinal uses and underlying bioactivity that may be further explored.

2. Materials and methods

We found HMPs in NYC to be sold in various forms, including tinctured extracts and dried, cut or powdered plant parts in packets for teas. The HMPs in this study each contained single plant species and represented medicinal plant species available from NYC herbal pharmacies specializing in HMPs from five prominent ethnic groups (Table 1): Ayurvedic (19 species), Chinese (17 species), Middle Eastern/Islamic (17 species), Latin/Caribbean (20 species), and African (22 species). Scientific names, if not given, were searched for based on the common name given on the HMP label (indicated in Table 1, except for African plants, for which only Latin names were provided on the HMP label). These were then verified to match accepted species names in "The Plant List" (2013), a working list of all known plant species maintained by the Royal Botanic Gardens and the Missouri Botanical Garden. Traditional medicinal uses were obtained from the label, when available, and verified using references in PubMed (see Table 1). Medicinal uses for each plant were categorized according to the following applications: gastrointestinal; cardiovascular; respiratory/immune support; female reproductive or gynecological; male reproductive; nervous; musculoskeletal; anti-parasitic/antibiotic; stimulant/energizing; urinary; endocrine (non-reproductive); ophthalmological; dental; weight loss; and cosmetic/aesthetic. Many plant species have multiple applications, and these were all retained in the analyses.

Research was also conducted for each plant to ensure that the species is indigenous to the geographic region of the immigrant ethnic group, and that the plant's medicinal uses were based on the originating ethnic group to exclude acquired, naturalized plants and/or their acquired medicinal uses. For example, barley, *Hordeum vulgare*, is cultivated in many regions, but originated in the Middle East. It is thus assigned to this indigenous group in our study. Plants with multiple geographic and/or cultural origins were only represented once. For example, *Balanites aegyptica* is native to both Africa and Middle East and both cultures have uses for it based upon literature search (Chothani and Vaghasiya, 2011). However, although we surveyed Middle Eastern stores we only found it sold in one African store in NYC, and assigned it as African. The same is true for ginger, *Zingiber officinale*, whose origin is uncertain, but have been used traditionally by Chinese and Indians for over 5000 years (Bode and Dong, 2011). Since we found ginger from one Chinese store, and there is evidence that it may have originated in tropical China (UCLA Louise M. Darling Biomedical Library, 2002), its cultural origin was designated Chinese in this study. These measures prevent generating spurious results of cultural convergence. Certain HMPs like guduchi and yerba buena referred to species that used to have restricted distributions, *Tinospora cordifolia*, and *Mentha x citrata*, respectively, but have now been synonymized with species (*T. sinensis*,*M. x piperita*) that have more widespread distributions. Since guduchi was found in an Ayurvedic store and yerba buena was from a Latin herbal store, we assigned them to these cultures. We may have missed instances of cultural convergence with this conservative approach, but this was favored over the potential for false positives.

Blastn (Zhang et al., 2000) using default parameters was used to obtain plastid rbcL sequences from the Genbank database (www.ncbi.nlm.nih.gov/genbank) for each plant species in Table 1. The sequences from the top blast hits (*e*-value = 0, query coverage > 50%) for each species were downloaded. rbcL sequences were not available in GenBank for the following species: *Aloe ferox, Ampelocissus africana, Asparagus racemosus, Balanites aegyptiaca, Boswelia sacra, Boswelia serrata, Cinnamomum cassia, Combretum adenogonium, Combretum micranthum, Commiphora mukul, Costus spicatus, Crateva magna, Detarium microcarpum, Eruca vesicaria, Flueggea virosa, Gossypium barbadense, Holarrhena floribunda, Handroanthus impetigonosus, Sarcocephalus latifolius, Nigella sativa, Parkia biglobosa, Saba senegalensis, Sterculia setigera, Stylosanthes erecta* and *Valeriana jatamansi.* In these instances, the rbcL sequence for any species within the corresponding genus was downloaded instead. Subsequently, the sequences from the respective plants were aligned using default parameters in MAFFT (Katoh and Standley, 2013). The maximum likelihood consensus phylogeny was generated using PhyML (Guindon and Gascuel, 2013) with 100 bootstrap replicates applying the appropriate substitution model. The indigenous geographic origin of the medicinal plants and their traditional medicinal functions from Table 1 were mapped on the PhyML phylogeny (transformed into a cladogram) using ITOL (Interactive Tree of Life, www.itol.embl.de). We analyzed the phylogeny for cultural convergence, defined here as three or more plant species within the same plant family being used for similar medicinal purposes (e.g. gastrointestinal) by at least two different cultures.

3. Results

Phylogenic analysis of 95 medicinal plants species revealed that plant families converge in uses for specific health conditions (Fig. 1). The resulting phylogeny corresponds to the expected