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# Spiritual and Ceremonial Plants in North America: An Assessment of Moerman's Ethnobotanical Database Comparing Residual, Binomial, Bayesian and Imprecise Dirichlet Model (IDM) Analysis

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ABSTRACT

*Ethnopharmacological relevance:* Ethnobotanical research and the study of plants used for rituals, ceremonies and to connect with the spirit world have led to the discovery of many novel psychoactive compounds such as nicotine, caffeine, and cocaine. In North America, spiritual and ceremonial uses of plants are well documented and can be accessed online via the University of Michigan's Native American Ethnobotany Database.

*Aim of the study:* The objective of the study was to compare Residual, Bayesian, Binomial and Imprecise Dirichlet Model (IDM) analyses of ritual, ceremonial and spiritual plants in Moerman's ethnobotanical database and to identify genera that may be good candidates for the discovery of novel psychoactive compounds.

*Materials and methods:* The database was queried with the following format "Family Name **AND** Ceremonial **OR** Spiritual" for 263 North American botanical families. Spiritual and ceremonial flora consisted of 86 families with 517 species belonging to 292 genera. Spiritual taxa were then grouped further into ceremonial medicines and items categories. Residual, Bayesian, Binomial and IDM analysis were performed to identify over and under-utilized families.

*Results:* The 4 statistical approaches were in good agreement when identifying under-utilized families but large families ( $>393$ species) were underemphasized by Binomial, Bayesian and IDM approaches for over-utilization. Residual, Binomial, and IDM analysis identified similar families as over-utilized in the medium (92–392 species) and small ( $<92$ species) classes. The families Apiaceae, Asteraceae, Ericacea, Pinaceae and Salicaceae were identified as significantly over-utilized as ceremonial medicines in medium and large sized families. Analysis of genera within the Apiaceae and Asteraceae suggest that the genus *Ligusticum* and *Artemisia* are good candidates for facilitating the discovery of novel psychoactive compounds.

*Conclusions:* The 4 statistical approaches were not consistent in the selection of over-utilization of flora. Residual analysis revealed overall trends that were supported by Binomial analysis when separated into small, medium and large families. The Bayesian, Binomial and IDM approaches identified different genera as potentially important. Species belonging to the genus *Artemisia* and *Ligusticum* were most consistently identified and may be valuable in future studies of the ethnopharmacology.



## 1. Introduction

The ritual and spiritual use of plants in ceremonies, the use of plants to contact the spirit or enhance religious experiences, and the use of plants to protect against evil spirits or ghosts is common among peoples in many parts of the world and many cultures. Species identified as spiritual plants convey a sense of well-being, are hallucinogens, or psychotics and can be used to treat a wide spectrum of neurological disorders (McKenna, 1995; O'Connor and Roth, 2005; Ross, 2012). Classic ethnobotany describes a strong connection between plants used to treat neurological diseases and those associated with metaphysical practices (Balick and Cox, 1999). In 1924, Louis Lewin described 28 mind-altering plants and suggested that plants identified as having a role in spirituality are a rich source of modern medicines to treat psychological and/

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or neurological ailments (Lewin, 1998). Since then, many well-known examples have been studied in detail such as *Cannabis sativa* L (Cannabaceae) *Erythroxylum coca* Lam. (Erythroxylaceae), and *Papaver somniferum* L. (Papaveraceae), while other species with subtler effects are less understood (McKenna et al., 2011). However, the neurological activity of many plants may be less associated with the isolation of one single high-potency molecule, and rather a complex complement of synergistic phytochemicals including neuroregulators, neurohormones and neurotoxins (Cao et al., 2006). For example, melatonin and serotonin have been found in many neurologically-active medicinal plants (Murch et al., 1997; Murch et al., 2004), and it has been hypothesized that these compounds can improve mental health (Fernández-Mar et al., 2012; Murch et al., 2009; Murch et al., 2004). These studies represent a new approach to understanding the impact of plant chemicals on human neurological health that has been made possible by advances in chemical analysis techniques and metabolomics that allow new approaches to understanding complex interactions (Brown and Murch, 2012).

Discovering candidate species for further investigations of complex neurochemistry requires correlating data from many different sources and methods to identify clusters of over-utilized taxa of activity in the traditional knowledge. Several different research approaches and statistical methods have been used to analyze ethnobotanical databases including Residual, Binomial, Bayesian and Imprecise Dirichlet Model (IDM) analysis (Bennett and Husby, 2008; Frei et al., 1998; Leduc et al., 2006; Moerman, 1991; Moerman and Estabrook, 2003; Weckerle et al., 2011, 2012). Residual analysis is used to calculate the expected number of species to be utilized for a specific family size, found within a specific plant population (Moerman, 1991; Moerman, 1996). The method is based on the calculation of the deviation from the expected frequency (residual) in order to describe over or under-utilization of a given plant family. Alternately, Binomial (Bennett and Husby, 2008), Bayesian (Weckerle et al., 2011), and IDM (Weckerle et al., 2012) statistics have been suggested. All of these methods hypothesis that the proportion of species utilized in the total flora is equal to the proportion of species utilized for a given family, and that any deviation from this value will lead to statistical significance. However, Bayesian and IDM analysis do not consider the proportion of utilized species as fixed, instead they consider uncertainty surrounding counts for medicinal flora and the total flora, and use probability distribution to determine the proportion of utilized species (Weckerle et al., 2011, 2012).

North America (north of Mexico) is home to a mosaic of healing practices used by Native American and First Nations peoples. Generally, treatments involve some combination of the following: teas, purification ceremonies, herbs, special foods, prayer, chants, dancing, sand painting, and therapeutic activities such as singing (Portman and Garrett, 2006). Much of the traditional knowledge of the North American indigenous peoples has been curated in Moerman's Native American Ethnobotany Database and some interesting examples include: The consumption of infusions made from *Gutierrezia* Lag. (Asteraceae) species by the Keresan in order to induce vomiting and/or purging during ceremony (White, 1945). The burning of roots of *Ligusticum canbyi* J.M. Coult & Rose (Apiaceae) by the Okanagan-Colville people in order to revive those considered ceremonially unconscious or possessed by the Blue Jay spirit (Turner et al., 1980). The use of leaves of *Clematis occidentalis* var. *occidentalis* (Hornem.) DC. (Ranunculaceae) by the Blackfoot for protection from ghosts or to remove from supernatural objects shot by ghosts (also known as 'ghost bullets') (Hellson, 1974). The use of the roots of *Angelica dawsonii* S. Watson (Apiaceae) as a religious power medicine (Hellson, 1974). The Winnebago used *Artemisia* L. (Asteraceae) species to drive away evil influences (Gilmore, 1919). The Cherokee chewed on the roots of *Cicuta maculata* L. (Apiaceae) to determine the longevity of one's life (Hamel and Chiltoskey, 1975). The Seminole used the roots of *Eryngium yuccifolium* Michx. (Apiaceae) as an emetic to purify after death (Sturtevant, 1954), and the Ditidaht burned seeds of *Lomatium nudicaule* (Pursh) J.M. Coult & Rose to protect themselves against illness or bad spirits (Turner et al., 1983). The physiological mechanisms underlying many of these uses have not been fully elucidated.

We hypothesize that the report of use of specific North American plant species in ceremony or spirituality indicates the presence of neurologically active constituents in the plant family. The objectives designed to test this hypothesis were: (1) to compare Residual, Bayesian, Binomial and IDM analyses of ceremonial and spiritual uses of plants reported in the ethnobotanical data; (2) to determine the frequency and distribution of spiritual and ceremonial uses within plant families and (3) to identify genera that are good candidates for the discovery of novel psychoactive compounds.

## 2. Materials and methods

### 2.1. Acquisition of ethnobotanical and flora data

Moerman's online Native American Ethnobotany Database, was accessed on July 3, 2012 (http://herb.umd.umich.edu/). The online database holds a repository of ethnobotanical data for 3618 species and consists of 47,000 items describing uses of North American flora for purposes such as food, drug, dye, and fiber among 291 Native American groups (Moerman, 2009; Moerman, 2012). All ceremonial taxa were identified using Cronquist (1981) via the USDA's PLANTS Database (http://plants.usda.gov/java/). The database was queried with the following format "Family Name **AND** Ceremonial **OR** Spiritual" for 263 North American botanical families (Moerman and Estabrook, 2003). Spiritual/Ceremonial data were exported and sorted into two categories: (1) species identified as 'ceremonial medicines' (incense, smudges, scrubs, smoking tobacco, snuffs, teas, topical rubs, washes) or (2) species identified as 'ceremonial items' (ceremonial masks, charms, paints (including ash), prayer sticks, rattles, statues, symbolic items, tools). The total number of species for each family was based on the data collected by Moerman and Estabrook (2003). The metadata on the Apiaceae and Asteraceae were acquired from the USDA's Plants Profile (USDA, 2012).

### 2.2. Residual analysis and ranking

Residual analysis was performed in Excel using methods outlined in Moerman (1991, 1996). In brief, each family was plotted with dependent values equal to the number of species found within a given family and independent values equal to number of species utilized for spirituality/ceremony, item or medicine. Linear regression analysis was used to identify the number of expected species for each family. Residual values were then calculated by subtracting the observed value from the expected value. The families were then ranked from largest to smallest residual to determine the 10 most over- and under-utilized families.

### 2.3. Binomial analysis and ranking

Binomial analyses were conducted using methods described by Bennett and Husby (2008). The null hypothesis was that the proportion of spiritual plants in the total flora was equal to the proportion of spiritual species in each family. The alternative hypothesis was that the proportion of species used in spirituality within each family is either (1) greater or (2) less than the total proportion found within the flora. Significance was tested using