

Exotic ancient plant introductions: part of Indian ‘Ayurveda’ medicinal system

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Abstract

India is home to some of the oldest civilizations, during which period the local communities domesticated indigenous plant species for food and agriculture and medicinal uses. In this process, they also bio-prospected and/or absorbed potentially valuable exotic plant species, making them integral part of Indian culture, including the traditional medicinal system, the *Ayurveda*. The present paper discusses the absorption of 26 plant species of exotic origin, before 8th century, as evidenced by archaeological sculptural or botanical remains and documentation of such plants in Sanskrit, the *Vedic* language. Occurrence and/or introduction of such plants at such distant places in ancient times is visualized as a result of geographical continental fragmentation followed by drift, natural or man-made transoceanic movement, and cultural and trade exchange of plant material over time and space.

Keywords: ancient plant introduction, archaeological, archaeobotanical, ayurveda, sanskrit

Introduction

The Indian Subcontinent has been the host to some of the oldest ancient civilizations of the world. During these civilizations, the local communities had high level of interaction with natural resources for potential use. Additionally, following the *Vedic* doctrine that good practices, products and resources should be welcomed and absorbed from all sides without discrimination, they also culturally absorbed a large number of plant species from various parts of the world. Ancient Indians bioprosppected the nature and natural resources, including plants and examined them not only for food, but for diverse requirements, including wellness, health and for treatment of ailments/diseases. Consequent to this a number of indigenous and exotic plant species were domesticated and/or introduced for food and agriculture, including pharmacological uses from the very beginning of their social communalization. Most of our knowledge regarding the extent and depth of Indian medicinal heritage is obtained from written

texts. We know a great deal of information scattered in *Vedic* literature and other erudite and comprehensive treatises of *Ayurveda*, written in Sanskrit. Also, there are written and unwritten (archaeological) records to help constructing the Indian medicinal science history. However, investigators confront various difficulties, such as lack of knowledge of oriental language and task of identification and verification of Latin synonyms of plant species. The knowledge about the medicinal potential of plants was generated on the basis of utility, evolved from simple trial and error. It continued to grow over time both in volume and excellence. It is from this nebulous beginning that Ayurvedic conception of medical knowledge as comprehensive science and philosophy of life evolved. This process continued with significant contributions during Buddhist period. Experts such as *Jivak* discovered that all plants have medicinal properties, parallel to ancient (Charaka Samhita, 1949) and the current belief is that all plants as well as seeds possess medicinal properties.

Ayurveda (2000 BC) probably is the oldest repository of human knowledge regarding the human body, body systems, their functioning, diseases and related ailments, and medicinal herbs that can be used in treatment of diseases

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and ailments. It is a part of *Atharvaveda* (1600–100 BC), the last of four Vedas. Sixty-seven species are mentioned in *Rigveda*, 81 in *Yajurveda* and 290 in *Atharvaveda*. *Ayurveda* is also credited with the first-time documentation of the plant species of medicinal value with pharmaceutical properties in the three legendary and authoritative classical texts, namely *Charak Sambita* (700 BC) for 1100 plant species, *Sushruta Sambita* (200 years BC), for 1270 plant species and *Astang Hridayam* (AD 700) 1150 plant species (Singh *et al.*, 2012). Though the dates of these works are still debated, most accept them to be several centuries before the Christian era. In the recent times, Kapoor (2001) brought out the descriptions of approximately 250 plants, which are being commonly used in constitution of herbal medicine of prevailing *Ayurveda* system.

A perusal of the list of the plants listed in these treatises reveals that a number of plant species are of exotic origin. They were either present or got introduced into Indian Subcontinent in ancient times. The possible causes may be geographical forces, such as continental fragmentation and drift (resulting in distant occurrence); natural forces, such as transoceanic movement, air current, etc.; and/or biological forces, such as interaction between different civilizations through social, cultural or religious exchange and trade (particularly involving Africa, Asia and Mediterranean region), etc. During these times the world in general and India in particular was still evolving. Most of these plant species have acclimatized/naturalized and adapted to diverse ecological conditions offered by the Indian Subcontinent to such an extent that many of them appear natural/native to the land, such as *Cannabis sativa*, *Trigonella foenum-graecum*. Whereas, the others have thrown enormous genetic diversity, making India either a secondary centre of diversity for many crop species, such as *Allium*, *Aloe*, *Annona*, *Carthamus*, etc. or regional centre of diversity for species such as *Ananas*, *Argemone*, *Vitis*, etc.

Evidences to support

The evidences, which support the inference on ancient presence/introduction of plant species have been drawn from diverse investigations carried in specific fields, and information and/or knowledge gained from diverse sources. They can be:

- Archaeological remains: The hard data available in the form of archaeological remain in the form of architectural monuments in caves, temples, etc.
- Archaeobotanical remains: The plant material remains discovered/obtained from various archaeological excavation sites with possible carbon dating of their age, etc.

- Literary: Reference in the literary writings from ancient times belonging to those days, particularly with vernacular name in Sanskrit, the ancient *Vedic* language.
- Pre-medieval: Based on the above evidence, assignment of dates to presence of species populations/existing species populations and listing of only those falling into the category of pre-medieval period, i.e. 8th century and before.

Possible mode for common occurrence and introductions and the routes

The occurrence of plant species, native to American continent during ancient period for bioprospecting and use in the *Ayurveda* medicinal system with names in Sanskrit (the *Vedic* language) can be visualized both on the basis of physical and biological forces.

- (1) Common occurrence/distribution of a plant species in distant continents is possible, as a consequence of the presence of species populations during bi-hemispheric continental times, on either sides of the ocean. These bi-hemispheric continents got separated into present continents on fragmentation, followed by further drifting apart. This might have caused the presence of these species populations on distant landmasses (continents).
- (2) The transoceanic inter-continental seed-movement (Sorenson and Johannessen, 2004), carried them to such distances through oceanic currents. As few seeds are equipped with structures like buoyant seeds of *Morinda citrifolia* with wings and air-sac (Singh Anurudh *et al.*, 2011), others have capacity to survive long while floating (coconut).
- (3) The wind flow of the wind carried the seeds long distances, as some are very light to travel great distances (*Tagetes* spp.).

In addition to transoceanic movement, the introduction is possible through human movement for settlement, cultural exchange and/or trade from the regions separated by oceans, but connected with Indian Subcontinent by contiguous landmass, such as Africa, Mediterranean region, Central Asia and China. Possibly this is how it occurred between Africa and India. It could have possibly followed different routes for different plant species, which could be either: (i) from main land Africa to North Africa, Egypt to the Near East to Iran to North-western India; or (ii) through Sabaean Lane, along the Red Sea or along the southern edge of the Arabian Peninsula and then, either via coasting or crossing the sea; or (iii) through open sea movement between the East Africa and western coast of India.

During ancient times contiguous landmass, such as India, China, Central Asia and Far East were culturally and economically connected by a network of trade routes, referred as the

Silk Route/Road. It connected the East and the West, predominantly China and India with the Mediterranean Sea, both via Himalayan passes and coasting across the Arabian Sea, Indian and Pacific Oceans, facilitating exchange of materials, including plants. The contributions of Buddhist and their scholars in spreading medicinal knowledge and material on this route are well documented.

Further, there are species, which naturally extended their distribution during ancient times, such as *Cannabis sativa*, *Trigonella foenum-graecum* and attracted the attention of local communities. They bio-prospected and brought them in use and cultivation, resulting into geographically independent domestication (polyphyletic). In other cases, wild taxa accompanied the other plant species or human and were bio-prospected by the local Indian communities and brought into use under *Ayurveda* system and cultivated, as proposed by Hymowitz (1972) under trans-domestication hypothesis.

Ancient introduced 'Ayurveda' plant species

Agave americana L., *American aloe*

It is a native of America, but naturalized and widely distributed in India. It has Sanskrit names such as *Kantala* (Nadkarni, 1914; Watson, 1868; Torkelson, 1999) and *Kalakantala* (Pullaiah, 2002). Therefore, it appeared to have been introduced in ancient times when Sanskrit was the common language of the subcontinent.

It appeared to have been introduced as ornamental, but has long history of traditional medicinal use. Roots have flavonoids and saponins, which have therapeutic value (Kadam *et al.*, 2012). Roots with sarsaparilla in form of decoction and juice of leaves are used in syphilitic complaints. Fresh juice is a good external application on bruises and contusions. Gum from leaves used to cure toothache, while slices as tonic and poultice (ICMR, 2004, 1:362–374).

Allium cepa L., *Onion*

The Central Asia region is considered as primary centre of origin of onion, while near east and Mediterranean regions as the secondary centres. The earliest records of its cultivation come from Egypt. In India, its reference is found in 6th century BC writings (Bhava Mishra, ca.1600 AD, 1995) with several Sanskrit names, *Palandu*, *Yavaneshta*, *Durgandha*, *Mukhdushak*. Archaeobotanical remains of *Allium cepa* have been recorded in Middle Gangetic Plains [Waina, Ballia, Raja-Nala-Ka-Tila, Uttar Pradesh (UP)] (Saraswat, 2005), confirming its ancient cultivation.

The medicinal use of onion by Emperor Ashok (ca. 268–232 BC) have been historically documented [Divyavadan (200 AD), 1959]. Onion bulbs contain an acrid volatile oil,

while the active principle is reported to be glycolic acid (Chopra *et al.*, 1969). The bulbs are stimulant, diuretic, expectorant, rubefacient, aphrodisiac and antiseptic (Chopra *et al.*, 1982). It is used to clear obstructions of intestines, prolapse of the anus and as sedative (Aiyegoro *et al.*, 2008). Onion juice is applied as liniment with mustard oil over painful joints, inflammatory swelling and skin diseases (ICMR, 2004, 2:1–89). Onion and garlic extracts have antibacterial properties (Purseglove, 1972).

Allium sativum L., *Garlic*

Maab and Klaas (1995) suggest, west to middle Asia to be the primary centre of origin and the Mediterranean as the secondary centre of origin. Further, they indicated that the garlic of subtropical region might have originated independently from *Allium longicuspis* Regel, in North India. The trade relationship between Mesopotamia, Egypt and the Indian Subcontinent during 'Mohenjo-Daro period', about 3000 BC, probably led to its introduction to India. Later, the bulbs were brought as seed and grown. Arabian traders and the Greeks (Alexander 300 BC), 'Yavans', brought garlics into cooking as a condiment and into *Ayurveda* as medicine. It has several Sanskrit names, *Mabaushadha*, *Lasbunaba*, *Granjnaba*, *Aristaba*, *Mabakandaba*, *Rasonakaba* and *Amarkosha*. It was possibly documented for the first time in Amarsingh's '*Amarkosha*' brought out in 600 AD at the time of king Vikramaditya (Amarsimha, 2001). Additional Sanskrit names, *Uragandha*, *Malechakanda* and *Yavanishta* were also recorded (Garga, 1969). Three cloves of *A. sativum* were found carbonized at Balu, Haryana, a Harappa site (Saraswat and Pokharia, 2002), confirming its ancient cultivation and use.

Onion and garlic finds are mentioned in *Charaka-Sambhita*. The garlic cloves/buds have stimulant, carminative, emmenagogue, anti-rheumatic and alterative action (Chopra *et al.*, 1982). The juice and essential oil showed protective action against fat-induced increase in serum cholesterol and plasma fibrinogen, and decrease in fibrinolytic activity, as well coagulation time (Bordia and Bansal, 1973; Bordia *et al.*, 1974). Garlic and onion are effective in controlling the hyperglycaemic effect of glucose feeding (Jain *et al.*, 1973). *Allicin* (diallyl thiosulfinate or diallyl disulfide), the biologically most active compound is antimicrobial. It was first chemically isolated in the 1940s. Externally garlic juice is used as rubefacient in skin diseases, and as ear-drops for ear-ache (Kapoor, 2001). It is also anthelmintic (ICMR, 2004 2:1–89).

Aloe barbadensis Mill; *syn. A. vera* L., *Aloe*

It is a native to Mediterranean region of Southern Europe (Spain) and North Africa. Its antiquity was first discovered

in 1862 in an Egyptian papyrus, dated 1550 BC with Queens being associated with its use for their physical beauty. Alexander conquered the island of Socotra in the Indian Ocean to secure supplies of Aloes to treat the battle wounds of his soldiers. This plant came to India, through human trade and migration. The Hindus derived their knowledge about aloe from the *Rig Veda*, where it was recommended for use in reproductive disorders, liver disease and against parasites, and referred to as *Gbrita Kumari* in Sanskrit.

Aloes contains anthraquinone C-glycosides, which are responsible for purgative properties. It has stomachic action in small quantity and purgative in large quantity, and indirectly emmenagogue and anthelmintic too. Dried juice is cathartic, while fresh is cooling. Pulp helps in menstrual suppression (Chopra *et al.*, 1956). Juice in the form of ointment in Vaseline hastens healing of wounds of thermal burns and radiation (Singh *et al.*, 1973). Aloe compound are very useful in case of functional sterility and disturbed menstrual function (Gupta, 1972). Known for laxative properties of *aloin* and its gel, it is being increasingly used as skin moisturizing and anti-ageing. Ayurveda drug prepared from this, '*kumari asava*' is used in diverse ailments (ICMR, 2004 2:101–115).

Ananas comosus (Stickm.) Merr., Pineapple

It is a native of Brazil, cultivated for a long time in Central America. It was introduced into India, probably by the 5th century AD via Middle East. It has Sanskrit names, *Anamnasam* and *Babunetrapphalam* (Pullaiah, 2002). Sculpture depicting the fruit on the *vanamala* of Vishnu in his *Varaha avatara* in the Udayagiri cave temples, Madhya Pradesh (MP), dated ca. 5th century AD (Gupta, 1996) has been found. This could not have been possible without locals and artisans being familiar with the plant. Other places with such depiction is at Moti-ShahKa-Tuk, Shatrunjaya Hill complex, Palitana, Gujarat, which is believed to be more than 1000 years old, confirming its presence during ancient times.

Pineapple fruit contains digestive ferment, bromelin, closely related to trypsin, while plant has arsenic properties. It has febrifuge, alterative and bitter tonic action. Ripe fruit juice is antiscorbutic, diuretic, diaphoretic, aperient, refrigerant and helps in digestion of albuminous substances. Unripe fruit is acrid, styptic, diuretic, anthelmintic, emmenagogue and abortifacient (Chopra *et al.*, 1982). Garg *et al.* (1970) reported that unripe fruit juice showed antifertility activity.

Annona spp. – Annona cherimola Mill., Large Annona, Custard apple

It is a native of the highlands of Colombia, Ecuador, Peru, it is also found in Mesoamerica. As per Balfour Edward

(1871–1873), the tree was introduced into India in 1820. However, the fruit of *A. cherimolia* is shown held by a sculpted goddess figure on a wall of a Hoysala Dynasty temple in Karnataka State, India, dated to 13th century (Johannessen and Wang, 1998). Thus, indicating its introduction much earlier to reach this stage of cultural, social and religious recognition.

Fruit has great antioxidant potential and contains bioactive compounds, carotenoids and vitamins (Albuquerque *et al.*, 2016). Most prominent poly-phenolic antioxidants recorded is Annonaceous acetogenins. Acetogenin compounds such as *asimicin*, *bullatacinare*, etc., are cytotoxic (anticancer), anti-malarial and anthelmintic. Fruit is also a good source of vitamin C, B-complex, especially pyridoxine that helps keep-up high level of glutamate (GABA), the neuro chemical in the brain, which calms down nervous irritability, tension and headache ailments (www.nutrition-and-you.com/cherimoya.html).

Annona reticulata L., Bullock's Heart, Custard apple

It is another species, native of tropical America and naturalized in India to an extent that some authors have considered it as a native. It has Sanskrit names, *Rama Sita* (Balfour Edward, 1871–1873), *Rampbal* (Pullaiah, 2002), *Luvunee* (Watson, 1868), *Rampbala* (Chopra *et al.*, 1956; Torkelson, 1999) and *Krishnabeejam*. As most names are associated with Lord Rama, it indicates its connection with ancient Indian legends. It has been displayed on sculptures at the Bharhut Stupa of 2nd century (Cunningham, 1879). Fruit pieces and seeds have been recovered from Sanghoi, Punjab and Tokwa and Raja-Nala-Ka-Tila, UP (Saraswat *et al.*, 2008), confirming its ancient presence.

Annona squamosa L., Sugar apple

It is the main cultivated fruit species, also native of tropical America. It grows wild in MP and naturalized to southern parts of India, thriving well in Karnataka and Maharashtra. It is mentioned in writings dated beginning of the present era and Ramayana, ca. 2000–1000 BC up to AD 200. Its Sanskrit names, [*Shubbā* and *Suda* (Nadkarni, 1914), *Sitaphalam* (Torkelson, 1999), *Gandagatra* and *Sitaphala* (Chopra *et al.*, 1956), and *Sitaphalam*, *Gandbagathra* and *Shubba* (Pullaiah, 2002)]. Association of these names with Lord Rama and his wife, Sita, suggests that they probably used this fruit during exile (Bhishagratna, 1907). Cunningham (1879) described its fruit sculptured at Bhārhut Stupa, 2nd century BC and Watt (1889) at Ajanta Caves, while Gupta (1996) reported it in the hands of various deities in temples situated

in various parts of the country. Fruit pieces and seeds of these two species have also been found at Sanghol, Punjab and at Raja-Nal-Ka-Tila and Tokwa UP, dated ca. 1700/1600 to 200 BC (Saraswat *et al.*, 2008). These evidences are indicative of its ancient cultivation, contradicting De Candolle (1882) suggestion of its introduction by the Portuguese in the 16th century.

A. reticulata fruit is rich in nutrients. Acetogenins present in *A. reticulata* possess more potent antitumour and cardio protective activity (McLaughlin, 2008). *Annona squamosa* fruit is rich in vitamin C. Aporphine alkaloids, anonaine, roemerine, noreorydine, corydine (from root; anti-cancerous), norisocorydine, isocorydine and glaucine have been isolated from it (Bhakuni *et al.*, 1972). It has astringent, tonic, anthelmintic, purgative and diuretic action. The seeds have little oxytocic activity. Ripe fruit of *Annona* species, bruised and mixed with salt are applied on malignant tumours. Leaves paste are applied to ulcers (Kapoor, 2001).

Argemone Mexicana L., Prickle poppy

It is a native of Mexico, grows as weed all over India. It is mentioned in the Indian medicinal writings dated 1st or 2nd century AD, such as *Susbruta Sambhita*. It has several Sanskrit names (Bhava Mishra, ca.1600 AD, 1995), *Brahmadandi* (Nadkarni, 1914), *Srigāla kamīā* and *Brahmadandi* (Watt, 1889), *Srigāla-kantaka* (Chopra *et al.*, 1956), *Satyamasi* (Torkelson, 1999) and *Swarnakshiri* and *Bbramadendi* (Pullaiah, 2002). Charred seeds of this plant were found at a site in Punjab, radiocarbon dated to 1100 and 1060 BC (Pokharia and Saraswat, 1999). It is also recorded at Narhan, UP belonging to the Black-and-Red-Ware phase (ca. 1300–800 BC) and the Black-Slipped-Ware phase (ca. 800–600 BC) (Saraswat *et al.*, 1994), confirming its ancient cultivation and medicinal use.

All the plant parts have pharmacological actions. The stem and roots contain 0.125% of total alkaloids having 0.041% berberine and 0.084% of protopine (Willaman and Li, 1970). The seeds yield 22–33% nauseous, bitter nonedible oil (Bose *et al.*, 1963). Root is diuretic, anodyne and hypnotic. Seeds are laxative, emetic, expectorant, demulcent and narcotic. Oil is purgative, narcotic and demulcent. Plant juice is diuretic and alterative, given in dropsy, jaundice, skin diseases and gonorrhoea. Juice is also applied to blisters, rheumatic pains, ulcers, scabies, herpetic eruptions and warts (Kapoor, 2001). Also, it shows anthelmintic, anti-inflammatory, wound healing, anti-bacterial and antifungal activities (Bhattacharjee *et al.*, 2006).

Bixa Orellana L., Achiote (Anotto)

It is a native of Brazil, naturalized to India to such an extent that initially Indian botanists considered it of Indian origin.

It appeared to have reached India via Pacific islands and Southeast Asia. In Sanskrit, it is called *Sinduri* (Pullaiah, 2002), *Brabmi* (Balfour Edward, 1871–1873) and *Raktabeeja*, *Rakhtapushpa*, *Sukomata* (Bhava Mishra, ca.1600 AD, 1995), indicating introduction no later than 1000 AD.

It is well known for its reddish orange dye, produced on aril portion of its seed, which is widely used for colouring dairy, confectionary and bakery products, as cosmetic pharmaceutical ointments, and for dyeing leather (Chattopadhyay *et al.*, 2008). The leaves have marked effect on urinary system, reduce benign prostrate hyperplasia and have anti-tumour activity due to antioxidant activity of the carotenoid compounds, Bixin and Norbixin. Methanolic extract of Bixa leaves exhibited neuropharmacological, anti-convulsant, analgesic, antidiarrheal activities (Shilpi *et al.*, 2006) and diuretic activity (Radhika *et al.*, 2010).

Canna edulis Ker Gawl.; syn. C. indica L., Indian shot

It is a plant of North western and South American origin, cultivated for its edible starchy rootstock. The stock is pictured in ceramic effigies and also drawn on pots in coastal Peru. It has Sanskrit names, *Sarvajayā* and *Silarumba* (Watt, 1889), *Silarumba* (Balfour Edward, 1871–1873), *Sarvajaya* (Nadkarni, 1914) and *Devakuli* (Pullaiah, 2002), indicating ancient cultivation in India. It is a common ornamental plant all over gardens.

Tuber is eaten and the rhizome extracts are traditionally used against headaches, diarrhoea, yaws, acute hepatitis, traumatic injuries, as a diuretic and against nose bleeding (ICMR, 2007 5:300). It is also used in waste water treatment (Neralla *et al.*, 1999). Recently, antioxidative properties have been reported by Mishra *et al.* (2011).

Cannabis sativa L., Hashish (Marijuana)

A native of western and central Asia. Found wild in the western Himalayas, including Kashmir. The Indian variant has been referred as *C. sativa* subsp. *indica* (Lam.) E.Small & Cronquit/*C. sativa* L. var. *indica* (Lam.) Wehmer. Therefore, either it is a case of independent geographical domestication after extended distribution or evolution of ancient introduction. It has Sanskrit names, such as *Vijayā* and *Siddhapatri* (Nadkarni, 1914), *Ganjika* and *Bhanga* (Chopra *et al.*, 1956), and *Matulani*, *Madini*, *Jaya* (Bhava Mishra, ca.1600 AD, 1995). Flattened seeds have been found in archaeological remains of Kunal, Haryana (Saraswat and Pokharia, 2003) and wood charcoal at Senuwar, Middle Ganga plain (Saraswat, 2004), corroborating ancient cultivation.

Cannabis has a long history of use as a psychoactive drug in Asia, consequent to which its cultivation is restricted. However, for the same property, it is used in treatment of numerous diseases and pain relief. Over 60 different compounds have been identified, collectively referred as cannabinoids (Robson, 1997). The most abundant and primary psychoactive constituent is delta-9-tetrahydrocannabinol (THC) isolated in 1964 (Hirst *et al.*, 1998). Additionally, it contains cannabidiol (Grlic, 1976), which has multiple pharmacological actions, including anxiolytic, antipsychotic, antiemetic and anti-inflammatory (Bergamaschi *et al.*, 2011). The resin content in crude, leaves and stem are 29.23, 7.25 and 3.25%, respectively. It relaxes the muscles, produce initial excitement followed by depression with psychotomimetic effect (Bose *et al.*, 1964). Hemp seed oil is a complete nutrition source, with all essential amino and fatty acids, measurable amounts of terpenes, cannabinoids and phenolic, without negative effects (Leizer *et al.*, 2000).

Carthamus tinctorius L., Safflower

Genus *Carthamus* is distributed from Spain and North Africa across the Middle East to North India. A majority of evidence suggests its origin in an area bound by the eastern Mediterranean and Persian Gulf (Knowles, 1969). However, based on variability and production in ancient culture, Vavilov (1935) proposed India as one of its centres. From the Middle East, where it was used for colouring textiles, the safflower probably spread into India by the Arab traders and trans-domesticated as an oilseed crop. In ancient *Sanskrit* literature, safflower has been described as *Kusumbha*. Achene of safflower has been found in archaeological remains at sites such as Imlidih-Khurd, UP and Middle Gangetic Plains (Saraswat *et al.*, 1994; Saraswat, 2005). Grains were found at Savalda (ca. 2300–2000 BC) in western Maharashtra, confirming its ancient cultivation.

Flowers have been used in Ayurveda medicines preparation. They are reported to cure several chronic diseases, like hypertension, cardiovascular diseases, arthritis, spondylosis and sterility in both men and women (Li and Mundel, 1996). They are also used to treat menstrual pains. Externally, they are applied to bruising, sprains, skin inflammations, wounds, etc. Seed is diuretic, purgative and tonic, used in the treatment of rheumatism and tumours, especially inflammatory liver tumour, while seed oil helps to reduce blood-cholesterol (Nagaraj, 1993; Liu *et al.*, 2016).

Catharanthus roseus G.Don, Periwinkle

It is a native of Madagascar. It is generally believed to have been introduced into India by the Portuguese in the 18th

century. However, presence of Sanskrit names, *Nitya Kalyani* and *Sadapushpi*, and use in treatment of diseases in Ayurveda system, suggest that it might have been introduced during ancient times. Though, there is no archaeological evidence to support its presence in ancient India, it grows wild all over India as an escape.

The leaves contain alkaloids, vindoline and catharanthine. Vinblastine and Vincristine are the two anticancer drugs used in the treatment of acute leukaemia and Hodgkin's disease (Noble, 1990). Leaf and root bark are the source of ajmalicine, used in treatment of high blood pressure, as tonic, stomachic, hypotensive, sedative and tranquilizer (Kurz *et al.*, 1981). Flowers are used to treat asthma. Plant extract can help treat dysentery and diarrhoea (ICMR, 2007 5:813–859). For further details see Kulkarni *et al.* (2016).

Datura spp.

Although opinions vary, most consider Central America as home of this genus (Sorenson and Johannessen, 2004). There are two basic species, *Datura metel* L. (syn. *Datura meteloides*, *Datura innoxia*, *Datura fastuosa*, *Datura alba*) and *Datura stramonium* L. (syn. *Datura tatula*, *Datura patula*) found growing naturalized in waste lands throughout India, particularly in the arid and semi-arid regions of Punjab, Haryana, Rajasthan, Gujarat and Tamil Nadu. They appear to have been introduced 2–3 millennia ago either via a single transoceanic boat passage that brought both the species, or by separate voyages to different destinations as reflected by the ancient literature and archaeological finds. Chopra *et al.* (1958) reported *Datura innoxia*, a native of Mexico, growing in the western parts of the Deccan Peninsula and a few other places. At least eight Sanskrit names, *Dhustura* and *Dhattura* (Nadkarni, 1914; Chopra *et al.*, 1956; Torkelson, 1999), *Madakara* (Pullaiah, 2002), *Khrishna-dhattura* (Watson, 1868) and *Unmatta*, *Kanaka* and *Shivapriya* (Bhava Mishra, ca.1600 AD, 1995) are known. Pokharia and Saraswat (1999) excavated specimens of *Datura* (exact species not determinable) in Punjab, dating to the 1st–3rd centuries AD.

Lancaster (1965) lists *Datura* as one of the species whose flowers were sacred in India. In Ayurveda, *Datura* plant parts are used to treat various disorders, including asthma, skin disorders, jaundice, piles and diabetes (Dash and Kashyap, 1991). Smoking seeds for asthma treatment was known in the *Vedic* period. Also, mentioned for use in suicidal and homicidal purposes (ICMR, 2009). The total alkaloid content in *Datura* varies from 0.02 to 0.52%, and scopolamine from 0.0029 to 0.32% on dry weight basis (Vitale *et al.*, 1995). Hyoscyamine, hyoscyne and meteloidin are used as pre-anaesthetic in surgery and childbirth,

ophthalmology and prevention of motion sickness. The active constituents in *Datura* include scopolamine, atropine, hyoscyamine, withanolides and other tropanes. Withanolide compounds have shown significant antitumor, cytotoxic, anti-inflammatory, antibacterial, hepatoprotective, sedative, cytostatic and immunosuppressive activities (Maheshwari *et al.*, 2013). Isolectins have been isolated from *Datura stramonium* seeds. Two of these lectins are homodimers made up of either A/B subunits, while the third is a heterodimer composed of either (Broekaert *et al.*, 1987).

Lagenaria siceraria (Monila) Standl., Bottle gourd

It is one of the oldest cultivated plants, originated from wild population in Southern Africa. It might have been carried from Africa to Asia by oceanic drift during summer monsoon or in the course of human migration. Genetic research on archaeological samples published by the National Academy of Sciences (December 2005) suggested that it may have been domesticated earlier than food crops and livestock. Based on the analysis of archaeological samples, two unrelated domestications: one 8–9000 years ago in Asia and other 4000 years ago in Egypt are indicated. Old Indian scripts and the fossil records indicate its culture even before 2000 BC. It is cultivated nearly all over India as backyard garden crop from ancient times. It has several Sanskrit names such as *Alābu* (Nadkarni, 1914) and *Kutukumbi* (Pullaiah, 2002), confirming its ancient cultivation.

In Ayurveda, bottle gourd is advocated for treatment of diabetes mellitus, hypertension, flatulence, cooling properties, liver diseases, weight loss, congestive cardiac failure (CCF) and other associated benefits. It is part of complementary and alternative therapy, which is widely prevalent in India (Prajapati *et al.*, 2010; Milind and Kaur, 2011; ICMR, 2012). Pulp boiled in oil is used to treat rheumatism and insomnia (ICMR, 2015). The chemical compounds isolated include sterols, terpenoids, flavonoids and saponins (Prajapati *et al.*, 2010).

Mimosa pudica L., Touch-me-not

It is a native of tropical America, possibly Brazil. It was introduced into India probably two millennia ago via transoceanic movements. It is now naturalized to most of tropical and sub-tropical India. The sensitiveness property of the touch-me-not plant is described in Ayurveda. It has Sanskrit names, *Anjalikarika* and *Lajja* (Torkelson, 1999), *Ajālikalika Namaskāri* (Nadkarni, 1914) and *Lajjala Namaskari* (Pullaiah, 2002), confirming its ancient introduction and use.

In Ayurveda, its root is recorded bitter, acrid, cooling, vulnerary, alexipharmic, used in the treatment of leprosy,

dysentery, vaginal and uterine complaints, and inflammations, burning sensation, asthma, leukoderma, fatigue and blood diseases. Decoction of root is used as gargle to reduce toothache. It is very useful in diarrhoea, amoebic dysentery, bleeding piles and urinary infections (Joseph *et al.*, 2013).

Mirabilis jalapa L., Four-o'clock

Four-o'clock is a native of South America and is cultivated in gardens. It is widely cultivated in India, corroborating its ancient introduction. Recorded as '*Gulambasa*' in Ayurveda, has several other Sanskrit names, *Sandhya-rāga* (Nadkarni, 1914), *Krisbnakeli* (Chopra *et al.*, 1956; Torkelson, 1999), *Ttrisandbi*, *Krsnakeli* and *Sandhya-Raga* (Pullaiah, 2002) and *Babu-Bumi*, and *Sundia-ragum* (Balfour Edward, 1871–1873).

It is medicinally used widely in Himalayan region. Root of the plant is used as a diuretic, purgative and for vulnerary wound healing purposes. Leaves are used as anti-inflammatory, antiviral, anti-bacterial, anti-fungal, antispasmodic and anti-inceptive agents (Shishir *et al.*, 2008).

Mucuna pruriens (L.) DC, Velvet Bean

It is a native of the Americas, present in Polynesia and the Malay region in prehistoric times. Others believe, it occurs commonly throughout the tropical regions of the Americas, Africa and India. In India, it is mentioned in texts dated before the rise of Buddha, including Ayurveda. It has Sanskrit names, *Atmaguptā*, *Kapikachchbu* (Nadkarni, 1914; Torkelson, 1999) and *Atmagupta*, *Vanari* (Pullaiah, 2002).

Seeds are considered as a strong aphrodisiac and roots as a tonic in India. Seeds contain alkaloid, L-dihydroxy-phenylalanine (Damodaran and Ramaswamy, 1937), which is a sedative drug used for the treatment of Parkinson's syndrome (Nath *et al.*, 1981), and in kidney and dropsy ailments. Also, it has been found to reactivate the antioxidant defence system, necessary for maintaining homeostasis within the body. For further details, see Sathyanarayana *et al.* (2016).

Nicotiana tabacum L., Tobacco

It is a native of the Americas, as per *Materia Medica*, tobacco was introduced into India in 1605 AD. Others believe that tobacco began in the New World and was carried to India after its introduction into Europe (Ashraf, 1985). However, the use of the water-cooled smoking device, '*hooka*', is shown in pre-Columbian art of India, along with its medicinal references in traditional medical practices. Its Sanskrit name is *Tamakhu* (Chopra *et al.*, 1956; Torkelson, 1999). Archaeologically, a temple in Himachal

Pradesh dated to 1422–1424 AD depicts the use of the *booka*. Photographic documentation of this depiction is also available from other temples through the Archaeological Survey of India, indicating its ancient presence and use.

The *Materia Medica* of India considers tobacco an agricultural crop (product), used in treatment of some ailments and medicines. Tobacco leaf contains several pyridine alkaloids, the principal one is a liquid alkaloid, nicotine (Kishore, 2014). Nicotine is used for treatment of Alzheimer's diseases, Parkinson's disease, depression and anxiety, schizophrenia, attention deficit hyperactivity disorder, pains and obesity (Binorkar and Jani, 2012), besides several other associated uses.

Papaver somniferum L., Opium poppy

The centre of origin of opium poppy is Western Mediterranean region of Europe, wherefrom it spread through Balkan Peninsula to Asia Minor (Morton, 1977). Beginning of cultivation of opium in India is a researchable issue. It has been mentioned as *soma* plant in *Rig Veda*, which dates back to 1500 BC or more as per Indian scholars. *Soma* in Sanskrit means moon, describing the shape of the bulb and emission of sap, visible in moon light. Other Sanskrit names are *Abiphenam*, *Aphukam* (Farooqi *et al.*, 2005). It has been visualized that Sumerians were the earliest users of the opium poppy or Greek, who knew about opium during Hippocrates time or Alexander, introduced opium into India around 330 BC. Archaeologically, a flattish piece of some cake-like structure is recovered in carbonized state (1900–1400 BC) from Sanghal, Punjab (Saraswat, 1997).

Dwarkanath (1965) described the properties of opium from Ayurveda, as one of the oldest and important medicinal plant, best known as painkiller drug. The sap of the poppy plant contains opium and oxalic acid. It has around 25 alkaloids, morphine is the major constituent, followed by noscapine, codeine, thebaine and papaverine (Shukla *et al.*, 2006). Pharmacologically opium has analgesic and narcotic action due to morphine followed by codeine and thebaine.

Psidium guajava L., Guava

Guava is native of tropical America. The site of Caral in the Supe Valley of Peru has yielded remains of guava, dated between 2627 and 2020 Cal BC. It is naturalized and cultivated throughout India. It has several Sanskrit names such as *Mansala* (Chopra *et al.*, 1956), *Péràlà* (Nadkarni, 1914), *Amruta-phalam* (Chopra *et al.*, 1958) and *Perukab* and *Mansala* (Pullaiah, 2002), *Peruka* or *Paravata* (Kumari *et al.*, 2013). It finds mention in *Charaka Sambhita*,

indicating that it was introduced not later than the 4th century. Probably it was present considerably earlier, negating the common belief that it was introduced by the Portuguese in 17th Century.

Guava fruit is rich in dietary fibre, protein, minerals, vitamins A, b1, b2, b3, C and folic acid. Active factors are ursolic acid, oleanolic acid, arjunolic acid and glucuronic acid (Chang, 1982). Huge amounts of β -sitosterol glucoside, brahmic acid and polyphenolics, including gallic acid, ferulic acid and quercetin (Peng and Hsieh, 2006) and triterpenoids (Chen *et al.*, 2010) exist in guava leaves, which are effective against various diseases. Pharmacological activities of its major components indicate it as potent anti-diarrhoeal, antihypertensive, hepatoprotective, antioxidant, antimicrobial, hypoglycaemic and anti-mutagenic (Joseph & Mini Priya, 2011). It is also rich in antioxidant and protects cell damage (Kumari *et al.*, 2013).

Ricinus communis L., Castor

Domesticated in West-Central Africa, castor spread to Egypt (4000 BC) and then reached India (2000 BC). In Sanskrit, it is called, *Eranda*, *Gandbarva hasta* and *Rakta-erund*; *Sbukla-erund* (Bhava Mishra, ca.1600 AD, 1995). The earliest archaeobotanical record of castor in India was found at the Harappan site of Hulas (Saraswat, 1993) dated between 1800 and 1300 BC. Since then it has been recorded both in Indus valley and Gangetic plains (Saraswat, 1992, 2004, 2005).

In the Indian medicine system, the leaf, root and seed oil of castor have been used for the treatment of inflammation and liver disorders, and for hypoglycaemic, laxative activities (Kensa and Yasmin, 2011). Flavonoids, kaempferol-3-O-beta-drutinoside and kaempferol-3-O-beta-d-xylo pyranoid (Chen *et al.*, 2008) and tannins (Khafagy *et al.*, 1979) have been isolated from the leaves, and Indole-3-acetic acid from the roots (Kang *et al.*, 1985). Seeds contain toxic proteins Ricin A, B and C and ricinus agglutinin. The pericarp of the fruits contains alkaloid ricinine (Ferraz *et al.*, 1999). These components impart, antioxidant, anti-implantation, anti-inflammatory, antidiabetic, central analgesic, antitumour, larvicidal (insecticidal) and adult emergence inhibition, antinociceptive and anti-asthmatic activities (Rana *et al.*, 2012).

Tagetes erecta L., T. patula L. (dwarf), Marigold

It is a native of South-central Mexico, though some believe in African origin (Pandey, 2000). It arrived in India, while Sanskrit was the active language. It has four Sanskrit names, *Zanduga* (Chopra *et al.*, 1956; Torkelson, 1999) and *Sandu*, *Sthulapushpa*, *Ganduga* (Pullaiah, 2002). The use of *Tagetes* spp. in decoration and colouring is

associated with Hindu religious ceremonies. There is substantial evidence to suggest its cultivation in India since ancient times with essentially similar use as in Mexico.

The essential oil extracted from marigold in Ayurveda has been listed with moisturizing and gentle heating energies. The oil has antispasmodic, vulnerating, hypotensive, tranquilizing, anti-inflammatory, alterative and antiseptic properties, and contains antioxidants (Perez Gutierrez *et al.*, 2006). The most popular use of marigold is as an insect repellent. In India, it has been used in agriculture to suppress plant parasitic nematodes for centuries (Khan *et al.*, 1971).

Trigonella foenum-graecum L., Fenugreek

It is a native of eastern Mediterranean region. It was brought into cultivation in the Near East as indicated by the charred fenugreek seeds recovered from Tell Halal, Iraq dating back to 4000 BC. It occurs wild in Kashmir, Punjab and the upper Gangetic Plains, suggesting either India as another centre of origin or very early spread of its cultivation in India to get naturalized and appear indigenous. In Sanskrit, it is called by *Babupatrika*, *Ballari*, *Babubeeja*, *Bodhini*, *Chandrika*, *Deepani*, *Gandbaphata*, *Medhika*, *Metbika* (Bhava Mishra, ca.1600 AD, 1995), confirming ancient cultivation. Single partly broken seed, somewhat oblong with a deep groove between the radicle and the cotyledon has been identified as *Trigonella cf. foenum-graecum* in initial archaeobotanical remains. Seeds have also been recorded in early and mature Harappan phases at Kunal and Banawali in Haryana and Rohira in Punjab (Saraswat, 1986; Saraswat *et al.*, 2000; Saraswat and Pokharia, 2003).

Seeds help lowering blood sugar and cholesterol (Toppo *et al.*, 2009). Seeds contain alkaloid, trigonelline, choline and saponin; essential and fixed oil, prolamin, mucilage, bitter and colouring substances (Chopra *et al.*, 1982). It is source for extraction of diosgenin (Seshadri *et al.*, 1973). It has demulcent, emmenagogue, aromatic, diuretic, nutritive, tonic, lactation, emollient, astringent, carminative and aphrodisiac actions (Chopra *et al.*, 1982). A poultice of herb is applied to reduce swelling; a pessary or lint saturated with its decoction is used to treat leucorrhoea (Kapoor, 2001). The leaves relieve indigestion and bilious disorders. Boiled or roasted seeds are eaten in dyspepsia, diarrhoea, dysentery, colic, flatulence and rheumatism, enlargement of liver and spleen, and chronic cough. Seed paste is applied to reduce inflammation, as a skin-cosmetic (Kapoor, 2001).

Vitis vinifera L., Grapes

It is a native of Eurasia. It is thought to have been domesticated first in Southwestern Asia during the Neolithic period. In Asia, the earliest evidence of cultivation of grapes for wine making is from Iran and Baluchistan, dated before

2000 BC, wherefrom cultivation spread slowly into India and China with the beginning of Christian era. It is listed under Ayurveda plants, and possesses Sanskrit names, such as *Draksba*, *Drakerfi*, *Swaduphala*, *Madhuras* (Bhava Mishra, ca.1600 AD, 1995). Two pyriform seeds in carbonized state have been found at Balu and Kunal from mature Harappan stage (Saraswat and Pokharia, 2002).

Grape fruit is known worldwide for its spectrum of biological properties (www.fruit-crops.com/grape-vitis-spp/), assimilated in Ayurvedic tonic *Draksba-Aasav*. Grapes contain 70–80% water, sugars, organic acids; phenolic, nitrogenous and aroma compounds; minerals, pectic substances and bioflavonoids. The main biologically active and well-characterized constituent of the grape is resveratrol, which is known for medicinal properties in human diseases (Yadav *et al.*, 2009).

Table 1 presents a summary of evidences to support the presence of these exotic medicinal plants, introduced into Indian Subcontinents, before 8th century and used in *Ayurveda*. It presents archaeological evidences gathered by the Birbal Sahni Institute of Palaeobotany, Lucknow, discovering archeobotanical remains of many of these plant species at various sites in India (Saraswat and associates). Also, the Sanskrit names used for these plants in various writings, including X edition of *Bhavaprakash Nighantu* (Indian *Materia Medica*) (Bhava Mishra, ca.1600 AD, 1995), provide hard evidences for their ancient cultivation and use in India.

Discussion

It is difficult to reconstruct historical chronology of events and facts, in relation to any subject. Same is true with visualization of the presence/period of introduction of exotic plant species that became the integral part of Indian medicinal system, *Ayurveda*. Archaeological evidence in the form of plant remains, the documentation for the presence of a plant species in the form of sculptures on the stones either in caves and/or temples, and in ancient Sanskrit writings are very strong foolproof evidences to support cultivation and of these plants in ancient times and their medicinal use. Nevertheless, it may be difficult to obtain the corroborating evidences from all lines of investigations. There may be inherent difficulties in relation to certain plant species, such as presence of archeobotanical remains in case of vegetatively propagated and leafy plant species and lack of information for some others. Poor or no documentation may be, because of non-appreciation of economic/medicinal potential of the plant species by the primitive communities/societies or civilizations in the country of origin.

The perusal of literature with regard to plants species of exotic origin used in *Ayurveda* medicinal system, reveal their presence in archaeobotanical remains at various

Table 1. Summary evidences from archaeological remains, literature and Sanskrit names on exotic plants used in 'Ayurveda' from ancient times

Species	Archaeological remains	Sanskrit name	Centre of origin	Introduction/cultivation time
<i>Agave Americana</i> , Agave		<i>Kantala & Kalakantala</i>	Central Americas	Before AD 1000
<i>Allium cepa</i> , Onion	Seeds; stem	<i>Durgandha, Mukhdushak</i> , etc.	Central Asia	800–1600 BC
<i>Allium sativum</i> , Garlic	3 cloves	<i>Aristaha, Lashunaha</i> , etc.	Central Asia	2500 BC; during Harappa period
<i>Aloe barbadensis</i> , Indian Aloe		<i>Chrita Kumari</i>	North Africa and Spain	Vedic period
<i>Ananas comosus</i> , Pineapple	Sculptured fruit	<i>Anamnasam, Bahunetrphalam</i>	Brazil, Central America	5th century AD
<i>Annona cherimolia</i> , Large Annona	Sculptured fruit		Colombia, Ecuador Peru	Before 13th century AD
<i>Annona reticulata</i> , Bullock's heart/ Custard apple	Sculptured fruit; Fruit pieces and seeds	<i>Rama Sita, Ramphala</i> , etc.	Tropical America	By 2nd century BC
<i>Annona squamosa</i> , Sugar apple	Sculptured fruit; Fruit pieces and seeds	<i>Gandagatra, Shubhâ, Sitaphalam</i> , etc.	Tropical Americas	Mid of 3rd millennium BC
<i>Argemone mexicana</i> , Prickle poppy	Charred seeds	<i>Brahmadandi, Satyanasi, Swarnakshiri</i> , etc.	Mexico	Before 1100 to 800 BC
<i>Bixa Orellana</i> , Achiote		<i>Raktabeeja, Sinduri</i> , etc.	Brazil	1000 AD
<i>Canna edulis</i> , Indian shot		<i>Devakuli, Silarumba</i> , etc.	Northwestern South America	Before AD 300
<i>Cannabis sativa</i> , Marijuana	Flattened seeds and wood charcoal	<i>Bhanga, Ganjika, Madini</i> , etc.	Central Asia	AD 100
<i>Carthamus tinctorius</i> , Safflower	Achene and grains	<i>Kusumbha</i>	Eastern Mediterranean and Persian Gulf	Chalcolithic period (1300–600 BC) from middle east
<i>Catharanthus roseus</i> , Periwinkle		<i>Nitya kalyani & Sadapushpi</i>	Madagascar island	Ancient times
<i>Datura metel</i> ; <i>D. stramonium</i> , Datura	Plant and seeds	<i>Dhattura, Madakara, Madan, Shivapriya</i> , etc.	Central America	2–3 millennia ago
<i>Lagenaria siceraria</i> , Bottle gourd	Fossil	<i>Alâbu & Kutukumbi</i> , etc.	Africa	Earlier than 10,000 BP
<i>Mimosa pudica</i> , Touch-me-not		<i>Anjalikarika, Lajja</i> , etc.	Tropical America	2 millennia ago
<i>Mirabilis jalapa</i> , Four-o'clock		<i>Gulambasa, Krishnakeli</i> , etc.	South America	2000 year ago
<i>Mucuna pruriens</i> , Cowhag		<i>Atmagupta, Vanari</i> , etc.	Americas	Early first centuries AD
<i>Nicotiana tabacum</i> , Tobacco	Sculptured hooka	<i>Tamakhu</i>	Americas	By AD 1000
<i>Papaver somniferum</i> , Opium poppy	Piece of cake	<i>Soma, Ahiphenam</i> , etc.	West Mediterranean	300 BC or earlier
<i>Psidium guajava</i> , Guava		<i>Amruta-phalam, Mansala</i> , etc.	Tropical South America	2000 years ago
<i>Ricinus communis</i> ; Castor bean	Wood	<i>Eranda, Gandharva hasta</i> , etc.	West-central Africa	2000 BCE; Chalcolithic time (1300–600 BC)
<i>Tagetes erecta</i> ; <i>T. patula</i> ; Normal/ dwarf marigold	Association with Hindu ceremonies	<i>Ganduga, Sthulapushpa, Zanduga</i> , etc.	South-central Mexico	When Sanskrit was an active language
<i>Trigonella foenum-graecum</i> ; Fenugreek	Seeds	<i>Bahupatrika, Maithika</i> , etc.	Mediterranean	Ancient introduction with medicinal use
<i>Vitis vinifera</i> ; Grapes	Seeds	<i>Draksha, Madhurasâ</i> , etc.	Eurasia, South-Western Asia	2000 BC

excavation sites in Indian Subcontinent. Graphic depiction of some plants or plant parts, such as flowers, fruits in caves and temples, particularly from Neolithic-Chalcolithic period in Harappa, Gangetic Plains and other parts of the subcontinent, including South India. References to most in ancient literature, particularly the *Vedic* literature, and treatises like *Charak Sambita* and *Susbruta Sambita*, with vernacular names in Sanskrit, unambiguously indicate their presence during ancient times (Table 1). They were present in wild and/or cultivated, and used in *Ayurveda* medicinal system.

In several cases, these evidences dispel the prevailing perception visualized by the Western historians regarding their introduction and use with the arrival of Western colonial powers (8th–18th century CE). For example, in case of *Annona* spp., *Catbaranthus roseus*, guava, tobacco, etc. evidences demonstrate their presence during ancient times and use in *Ayurveda*. In few of these cases Indian Subcontinent appears to be another centre of geographical domestication/origin. The plant species might have reached the Indian Subcontinent, through their natural spread or migration in wild, causing extended distribution, followed by domestication. This probably happened in case of *Canabis sativa*, *Trigonella foenum-graecum* and *Vitis vinifera* or their cultivated forms spread. Whereas, in several other cases, particularly the species of American origin, such as *Agave*, *Aloe*, *Annona* spp., *Argemone*, *Bixa*, *Canna*, *Datura*, *Mimosa*, *Mirabilis*, *Mucuna*, *Tagetes* etc., common occurrence in two distant continents was probably either caused with the separation plant species population's with geographical continental fragmentation and drift or the transoceanic movement between the Americas and the Indian Subcontinent, followed by domestication. Introduction through transoceanic movement may also apply to species like *Legenaria siceraria*, *Catbaranthus roseus*, from southern Africa, because of the distance/absence of the intermediate lands. It was probably followed by their independent geographic domestication and use in food and agriculture and *Ayurveda*.

There are other cases, where a wild or cultivated form was introduced with a different usage, but they were transdomesticated for medicinal purpose by Indians. This probably happened in case *Carthamus tinctorius*, *Ricinus communis*, etc. as visualized by Hymowitz (1972) in the case of *guar*/cluster bean.

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