Chapter

Bioactive Components of Magical Velvet Beans

Suresh S. Suryawanshi, Prajakta P. Kamble, Vishwas A. Bapat and Jyoti P. Jadhav

Abstract

The plant *Mucuna* is an annual climbing shrub with long vines that can reach over fifteen meters in length. About 100–150 *Mucuna* species are found in the tropic and subtropic regions of both hemispheres of the earth. The genus *Mucuna* belongs to the family Leguminosae. It is commonly known as Kewanch, velvet bean, cowhage and kappikachhu and is found widely in India as a hardy, herbaceous, vigorous, twining annual plant. The size and dimension of the *Mucuna* seeds, pods, platelets and leaves change from species to species. The hair present on pods is anthelmintic, which causes itching. People are seeking great attention towards *Mucuna* due to its several medicinal properties, including L-DOPA (L-3, 4-dihydroxyphenylalanine) along with supplementary antioxidants that are used for treating Parkinson's disease and many neurodegenerative diseases. Thus it is being used in about 200 medicinal formulations. The current chapter outlines the work that determines the influence of different nutritional, anti-nutritional and medicinal values and bioactive agents from different parts of the *Mucuna* species present in India and its importance in medicine.

Keywords: Legumes, *Mucuna*, Parkinson's disease, L-dopa, antioxidants

1. Introduction

Mucuna is a valuable genus of Leguminosae family; it has tremendous value in food and medicine. The genus *Mucuna* originated in Eastern India and China and then was transferred throughout tropical and subtropical regions of the world creating new populations [1]. Traditionally, *Mucuna* is known by different names including beans, buffalo beans, dopa bean, cowitch, kappikachhu and atmagupta. Out of 100 *Mucuna* species found worldwide, 8 species and 3 varieties of *Mucuna* are predominantly found in different localities of India [1–4]. The *Mucuna* plant is an annual perennial climbing shrub with long vines having a length of 15–25 m with trifoliate leaves and yielding long inflorescences with purple or pale yellow flowers. They produce green or brown pods covered with rigid hair, which causes intense itching [5]. Pods contain four to six ellipsoidal-shaped seeds that are rich dark brown or blotched [6] varying from species to species. *Mucuna* seeds are a rich source of nutritional, antinutritional and phytochemical compounds containing L-dopa as a prime constituent [7]. The content of L-dopa varies between from species to species and locality to locality. Among them, *M. pruriens* is the most exploited species as a remedy against Parkinson's disease [8]. Due to huge

international and national trade price and scarcity of *M. pruriens*, other *Mucuna* species are reported to be adulterants for *M. pruriens.*

Ancient reports of Ayurveda suggest that *Mucuna* seed powder contributes in reducing the risks of certain cardiovascular diseases and neurodegenerative disease and also as a remedy for snake bite. The seeds of *Mucuna* have gained increasing attention among food scientists, nutrition specialists and pharmaceutical expertise due to their rich source of antioxidant, phenolic, flavonoids, L-dopa, proteins, starch, micronutrients, dietary fiber and bioactive compounds that play a pronounced role in the traditional as well as modern medicine all over the world [9, 10]. The existing scenario shows ten reported *Mucuna* species that were studied recently by Pulikkalpura et al., from the Indian subcontinent [11], whereas Patil et al., also collected fourteen different species of *Mucuna* from various localities and further studied for their L-dopa content (anti-Parkinson's activity) [6, 12].

Mucuna grows best under moist, warm conditions and in areas with plenteous rainfall. It can propagate in any type of soil but sandy lome soil is mostly favorable with pH of 5.5–7.5. Several researchers have investigated different species having typical characteristics like size and shape of bracts, leaflets and pods, color, thickness, density as well as number of seeds in pod and flower, respectively [6]. The evaluation of genetic-level studies of *Mucuna* species from India was also carried out using inter-simple sequence repeat markers and randomly amplified polymorphic DNA [13]. The seeds show tolerance against different abiotic stress including low soil fertility and acidic pH and also grow in wet soils (Duke, 1981). Similar to different species, *Mucuna* also has 2n = 2x = 22 number of chromosomes with genome size ranging between 1281 and 1361 Mbp/C [14]. Due to wild fluctuating climatic and geographical distribution, these species show gigantic diversity in phenotype in the Indian subcontinent. Corresponding to the family *Leguminosae*, it also has the ability of atmospheric nitrogen fixation. It is also grown for the potential utility in animal feed and human food due to its rich source of nutritional content [15, 16]. Thus, it was consumed universally for the treatment of Parkinson's disease. Traditionally, in Ayurvedic science, *Mucuna* (velvet bean) plant is widely used to treat numerous diseases including parkinsonism [17–21] due to its L-dopa content as one of the principal constituents [9]. All parts of *Mucuna* have a great medicinal value in the ancient traditional medicinal system, and hence, it has a prodigious demand in the international and the Indian market [7, 22].

Mucuna is a superb source of protein and bioactive compounds that have increased consumption per capita after being considered as a functional food by the US [23]. The previous literature survey shows that the declining occurrence of numerous long-lasting disorders, namely neurological disorder, cardiovascular diseases, diabetes, obesity and cancer, has a positive correlation with the consumption of legume seeds [24]. Considering all the evident health profits, studying its bioactive compounds is of great importance. Among all the under-utilized *Mucuna* species, normally available and commonly used *Mucuna pruriens* seeds were studied enormously and have been reported in numerous of articles published till date. To avoid the burden on commonly available and used *Mucuna Purience,* various researchers are studying bioactive components and the use of other *Mucuna* species like *M. imbracata*, *M. bracteata*, *M. monosperma*, *M. macrocarpa, M. sanjappae,* M. atropurpurea, M. nigricans, M. gigantea, M. pruriens var *hirsuta, M. laticifera, M. yadaviana*, etc. in the treatment of various diseases [5–7, 9, 11–14, 17, 20, 22, 25–34]. Phytochemistry, toxilogicalogycal and food potential on the *Mucuna* species under study in the world were described by Lorenzetti et al. [35].

2. Bioactive compounds from various parts of *Mucuna* species

2.1 Bioactive compounds from seeds of *Mucuna*

Seeds of *Mucuna* are commonly used part of the plant, which are a rich source of nutritional and anti-nutritional compounds like L-dopa (anti-Parkinson's activity), antioxidants, phenolic, flavonoids, tannin, carbohydrates, starch, protein, micronutrients Sopanines and many more [9, 12, 26]. Antioxidant activities in this plant are mainly due to phenolic and various bioactive compounds present in the seed material [36, 37]. There are various extraction techniques, different solvents and processing methods that were used to extract the biologically active compounds from the seed of *Mucuna* [26, 31]. The prior study reports that *M. macrocarpa, M. sanjappae* and *M. atropurpurea* disclosed a higher level of L-dopa content, which also concludes that L-dopa content has a positive correlation to the protein content of seeds [12]. These high-yielding varieties of *Mucuna* can be commercially cultivated, which can thus serve to be a good option to lower the burden exerted on commonly used *M. prurience* variety [28]. LCMS analysis of four different species demonstrates the presence of diverse group of phenolics, alkaloids, flavonoids, different derivatives of gallic acid, L-dopa, catechin, alkaloids, quercetin, tannic acid, glycosides, saponins, tubastatin and a variety of amino acids in the seed extract [38]. Apart from that, it is also concluded that few anticancer compounds like *Spergualin,* sanggenon G, isopentenyl adenosine and spisulosine are also present in the seed extract [28, 38].

2.2 Bioactive compounds from leaves and roots of *Mucuna*

The root extract of *Mucuna* has various activities like stimulant, thermogenic, purgative, emollient, diuretic anthelmintic, emmenagogue and tonic; hence, they are used in the vitiated circumstances in Veda and Ayurveda [39]. L-Dopa content of leaves and roots is as much as 1% and 4–7% in *Mucuna* plant [40]. *Mucuna* plants release secondary chemical compounds called allelochemical in the form of L-3,4-dihydroxyphenylalanine (L-dopa) in the surrounding environment which show an impact on growth of nearby plants, either negatively or positively. These substances are produced through its roots, seeds or leaves [41]. These secondary chemical agents play a role in damaging root growth, terminating seedling growth, inhibiting plantlet growth or suppressing seed germination of other plants [42]. Plant-box bioassay explains that the secondary chemical compound produced from the root of *Mucuna* is L-dopa [40], which affects the cell and root of various plant seedlings [41]. Leaf extracts are used to treat various complications like Anticataleptic, antiepileptic, aphrodisiac, antimicrobial, tonic and ulcers are some applications in which *Mucuna* leaves were reported being used previously [8, 20, 43, 44].

2.3 Bioactive compounds from callus of *Mucuna*

Production of callus from *Mucuna* plant material is a new era in the advancement of biochemical engineering and industrial biotechnology, which has the potential to produce different biologically active agents from the explant [45, 46]. Their application in cost-effective industrially important product formation is helpful for humankind, which upshots effective drug formulations and upsurges the nutritional level of food [47, 48]. L-Dopa is a major component in different parts of *Mucuna* species [9]. This also helps in storing germplasm of endangered species, which in turn leads to regenerate new plantlets at any time. Production of callus from *Mucuna* species was done previously by the researcher at the lab scale [49]. An earlier study by Chattopadhyay et al. depicted the formation of callus culture of commonly used

Mucuna pruriens [50]. Media containing various concentrations of media components affects biologically active chemicals and growth of the callus [51, 52]. The use of different elicitors and precursors are studied by Nandeo and Patel et al. [53, 54]. Implementation of precursor in the media of callus enhances the phenolic content as reported in prior studies. The percentage of phenolic is greater in callus culture than in seeds, which is very helpful for industrial production [55, 56].

2.4 Bioactive compounds from cell suspension of *Mucuna*

Reactive oxygen species (ROS) and reactive nitrogen species (RNS) are stress-producing free radicals, but at usual level perform an important part in the physiology of the body [57] to accommodate the massive demands for L-dopa and other secondary metabolites. *In vitro* production of biologically active compounds from suspension culture is predominantly studied before in *Mucuna* plant by Chattopadhyay et al. [50]. The use of mevalonic acid and its precursor gibberellic acid affect the growth. L-Dopa in callus exhibits a declining trend in fresh weight with a rise in concentration of L-dopa as shown by Desai et al. [52]. The comparative study of production of L-dopa from cell suspension culture and effect of elicitor on two different species like *Mucuna pruriens* L. and *Mucuna prurita* H were also done previously [58]. Large-scale production of phytochemicals and L-dopa was done from *Mucuna pruriens* L. Commercial production of the drugs (L-dopa), phenolic flavonoids and antioxidants using cell suspension cultures is in extensive practice nowadays.

3. Use of different bioactive compounds from *Mucuna* in various application

3.1 Antioxidant activity of *Mucuna* species

Numerous studies on antioxidant activity and phytoconstituents content of *Mucuna* seeds, leaves and roots were performed previously [4, 7, 19, 30, 31, 59–62]. Optimization of different solvents for the extraction of antioxidants was done by Aware and Patil et al. [9, 10, 26]. They concluded that depending on solubility of antioxidant compounds present in different species of *Mucuna*, concentration of antioxidants differs. Most commonly, ethanolic extract of *Mucuna* shows good antioxidant activity due to high phenolic content [43]. Some reports also conclude that water is a universal solvent, which shows significant quantity of phenolic, flavonoids and strong antioxidants that can scavenge free radicals using different assays. Diseases like neurodegenerative diseases, cardiovascular diseases, aging, cancer, rheumatoid arthritis and inflammation are caused by oxidative stresses, which are protected by ROS and RNS [60]. LCMS report of four different species of *Mucuna* determines the presence of various components like phenolic, flavonoids and bioactive compounds, which are responsible for production of reactive species [38].

3.2 Antimicrobial activity of *Mucuna* species

There are several compounds in *Mucuna* that contribute for the antimicrobial activity as reported in a previous study [38, 43]. These compounds are responsible for the treatment of various infectious diseases and ulcers [63]. The study on various plant pathogens suggests that methanolic extract of *Mucuna pruriens* seeds showed highest antimicrobial activity [64] from all used solvents. A similar type

of study was done by Pujari *et al.*, who concluded that methanol extract of seeds of *Mucuna pruriens* was found to impart the best inhibiting activity among all scrutinized pathogens as compared to ethanol and acetone solvents. But alcoholic extract of *Mucuna pruriens* (L.) leaves has significant antioxidant and antibacterial activity, which has strongly recommended the use of *Mucuna* leaves and seed extract in traditional as well as modern medicine [65].

3.3 Protective effect against snake venom

Snakebite kills countless people annually since ancient days [66]. Various reports show the cross-reactivity between the enzyme of snake venom and protein from *Mucuna*, which determines the activity of *Mucuna* against snake venom [32, 67–69]. Betancur *et al.* in their review on therapeutics of antisnake venom explain the effectiveness of herbal plants, which act as coadjuvants and thus help to nullify the venom toxic action [68]. In recent literature, Kasturiratne *et al.* studied the global scenario of snakebite and deaths. They also elucidate that various traditional medicines were sometimes preferred with western drugs [70]. The protective effect of *Mucuna* in a study on mice or rat models proves that it has a good activity for curing snake bite, than few reported antivenom [71, 72].

3.4 Anti-Parkinson's activity of *Mucuna* species

Parkinson's disease (PD) was initially discovered by Dr. James Parkinson in 1817. It is a chronic neurological disorder triggered by a progressive loss of dopaminergic neurons present in the nigrostriatal part of the brain and found to be common in the US [73]. The major signs of the disease are complications in body movements, speaking, walking and many more complications arise as the disease progresses. Anti-Parkinson's potential of *Mucuna* is well known from ancient times due to its L-dopa content [7, 74]. L-Dopa is a precursor of dopamine used in the treatment of neurodegenerative disorders. Various scientists studied the potential of *Mucuna* to produce L-dopa as a source of anti-Parkinson's drug [8, 19, 75]. L-Dopa with other phytochemical compounds has a cumulative effect on the management of Parkinson's disease. Patil *et al.* describe that there is a correlation among the L-dopa, protein and carbohydrate content [12]. *Mucuna* is a rich source of antioxidant compounds, which performs a very important role in the physiology of the body mainly functioning in the inhibition of damage occurred because of free radicals [76]. There are hundreds of compounds that function as antioxidants in the plant system mainly vitamins, polyphenols, enzymes, flavonoids and metals like zinc, selenium, etc. [77]. The efficiency of the use of L-dopa and another dopaminergic agent in the treatment of Parkinson's disease is reviewed previously by Koller and Rueda [78]. The use of plants for the treatment is more beneficial than chemically manufactured medicines due to their infinitesimal occurrence of secondary complications by routine use and economical feasibility.

3.5 Use of *Mucuna* species in soil fertility

Cover crops have a role in the nitrogen-fixing bacteria and improvement of soil fertility by restoration of soil nutrients. Enormous use of chemical fertilizer and water in soil makes soil infertile, to overcome this problem, farmers are implementing traditional methods to enhance soil fertility. Mucuna is one of the best examples of a cover crop that has a rich source of biological natural products, which will increase the enhance soil fertility and fix atmospheric nitrogen [35].

4. Conclusion

Mucuna is a medicinally and biochemically valuable plant used from ancient days, having a large market value due to the presence of a large number of bioactive compounds. The content of phytochemical compounds and other bioactive agents present in *Mucuna* fluctuates from species to species. L-Dopa is a chiefly present amino acid found abundantly in *Mucuna* plant, which is used for the treatment of Parkinson's disease. It also contains a great amount of phenolics, flavonoids and antioxidants, which play a role in releasing oxidative stress. It also acts as a protein-rich diet. Due to all these properties, *Mucuna* has several applications in the pharmaceutical and food industries thereby uplifting the demand of *Mucuna* in day to day life.

Acknowledgements

Suresh Suryawanshi sincerely thanks the Indian Council of Medical Research (ICMR) for providing SRF fellowship [Award No. 45/6/2019/MP/BMS]. Vishwas A. Bapat thanks the National Academy of Sciences, India, for the honorary scientist fellowship. Prof. Jyoti P. Jadhav sincerely thanks the Department of Biotechnology, Government of India, for "Interdisciplinary Programme of Life Sciences for Advanced Research and Education (IPLS-Reference No: BT/PR4572/INF/22/147/2012)".

Conflict of interest

The authors declare no conflict of interest.

Author details

Suresh S. Suryawanshi[1], Prajakta P. Kamble[2], Vishwas A. Bapat[3] and Jyoti P. Jadhav[1,3*]

1 Department of Biochemistry, Shivaji University, Kolhapur, Maharashtra, India

2 Department of Microbiology, Shivaji University, Kolhapur, Maharashtra, India

3 Department of Biotechnology, Shivaji University, Kolhapur, Maharashtra, India

*Address all correspondence to: biochemjpj@gmail.com

References

[1] Wilmot-Dear CM. A revision of Mucuna (Leguminosae-Phaseoleae) in China and Japan. Kew Bulletin. 1984;**39**:23-25. DOI: 10.2307/4107853

[2] Wilmot-Dear CM. A revision of Mucuna (Leguminosae: Phaseoleae) in Thailand, Indochina and the Malay Peninsula. Kew Bulletin. 1992;**47**:203-245. DOI: 10.2307/4110664

[3] Ren S, Wilmot-dear CM, Browne SP, Browne ZP. About 100 Species: Worldwide; 18 Species (Nine Endemic) in China, Including Two Incompletely Known Taxa and One Possibly Extinct Species (*Mucuna* championii). 2010. pp. 207-218

[4] Aitawade MM, Yadav SR. Mucuna sanjappae, a new species from the north-Western Ghats, India. Kew Bulletin. 2012;**67**:539-543. DOI: 10.1007/s12225-012-9369-1

[5] Leelambika M, Sathyanarayana N. Genetic characterization of indian mucuna (Leguminoceae) species using morphometric and random amplification of polymorphic DNA (RAPD) approaches. Plant Biosystems. 2011;**145**:786-797. DOI: 10.1080/11263504.2011.610924

[6] Gaikwad SV, Gurav RV, Yadav SR. Karyotype studies in *Mucuna macrocarpa* Wall and *Mucuna sanjappae* Aitawade et Yadav (Fabaceae) from India. Chromosome Botany. 2017;**12**:52-55. DOI: 10.3199/iscb.12.52

[7] Kavitha C, Thangamani C. Amazing bean Mucuna pruriens: A comprehensive review. Journal of Medicinal Plant Research. 2014;**8**:138-143. DOI: 10.5897/jmpr2013.5036

[8] Lampariello L, Cortelazzo A, Guerranti R, Sticozzi C, Valacchi G. The magic velvet bean of mucuna pruriens. Journal of Traditional and Complementary Medicine. 2012;**2**:331-339. DOI: 10.1016/S2225-4110(16)30119-5

[9] Rane M, Suryawanshi S, Patil R, Aware C, Jadhav R, Gaikwad S, et al. Exploring the proximate composition, antioxidant, anti-Parkinson's and anti-inflammatory potential of two neglected and underutilized Mucuna species from India. South African Journal of Botany. 2019;**124**:304-310. DOI: 10.1016/j.sajb.2019.04.030

[10] Patil RR, Rane MR, Bapat VA, Jadhav JP. Phytochemical analysis and antioxidant activity of *Mucuna sanjappae*: A possible implementation in the parkinson' s disease treatment. Journal of Pharmaceutical and Medicinal Research. 2016;**2**:48-51

[11] Pulikkalpura H, Kurup R, Mathew PJ, Baby S. Levodopa in Mucuna pruriens and its degradation. Scientific Reports. 2015;**5**:2-10. DOI: 10.1038/srep11078

[12] Patil R, Aware C, Gaikwad S, Rajebhosale M, Bapat V, Yadav S, et al. RP-HPLC analysis of anti-Parkinson's drug l-DOPA content in Mucuna species from Indian subcontinent. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences. 2019. DOI: 10.1007/s40011-018-01071-9

[13] Patil RR, Pawar KD, Rane MR, Yadav SR, Bapat VA, Jadhav JP. Assessment of genetic diversity in Mucuna species of India using randomly amplified polymorphic DNA and inter simple sequence repeat markers. Physiology and Molecular Biology of Plants. 2016;**22**:207-217. DOI: 10.1007/s12298-016-0361-3

[14] Bairiganjan GC, Patnaik SN. Chromosomal evolution in Fabaceae. Cytologia (Tokyo). 1989;**54**:51-64. DOI: 10.1508/cytologia.54.51

[15] Tuleun CD, Patrick JP, Tiamiyu LO. Evaluation of raw and boiled velvet bean (*Mucuna utilis*) as feed ingredient for broiler chickens. Pakistan Journal of Nutrition. 2009;**8**:601-606. DOI: 10.3923/pjn.2009.601.606

[16] Harms RH, Simpson CF, Waldroup PW. Influence of feeding various levels of velvet beans to chicks and laying hens. The Journal of Nutrition. 1961;**75**:127-131. DOI: 10.1093/jn/75.1.127

[17] Sathiyanarayanan L, Arulmozhi S. Mucuna pruriens Linn.—A comprehensive review. Pharmacognosy Reviews. 2007;**1**:157-162

[18] Suresh S, Prakash S. Effect of *Mucuna pruriens* (Linn.) on sexual behavior and sperm parameters in streptozotocin-induced diabetic male rat. Journal of Sexual Medicine. 2012;**9**:3066-3078. DOI: 10.1111/j.1743-6109.2010.01831.x

[19] Yadav K, Mukesh PU, Purohit S, Pandey B, Shah H. Phytochemistry and pharmacological activity of *Mucuna pruriens*: A review. International Journal of Green Pharmacy. 2017;**11**:69-723. DOI: 10.22377/ijgp.v11i02.916

[20] Torabi M, Drahansky M, Paridah M, Moradbak A, Mohamed A, Owolabi FAT, et al. We are IntechOpen, the world' s leading publisher of Open Access books Built by scientists, for scientists TOP 1 %, Intech. 2016;**i**:13. DOI: 10.5772/57353

[21] Contin M, Lopane G, Passini A, Poli F, Iannello C, Guarino M. Mucuna pruriens in Parkinson Disease. Clinical Neuropharmacology. 2015;**38**:201-203. DOI: 10.1097/WNF.0000000000000098

[22] Buckles D. Velvetbean: A "New" Plant with a History Author(s): Daniel Buckles Published by: Springer on behalf of New York Botanical Garden Press Stable. Preserve and extend access to Economic Botany All use subject t. 1995;**49**:13-25. Available from: https://www.jstor.org/stable/4255685

[23] Luthria DL, Pastor-Corrales MA. Phenolic acids content of fifteen dry edible bean (*Phaseolus vulgaris* L.) varieties. Journal of Food Composition and Analysis. 2006;**19**:205-211. DOI: 10.1016/j.jfca.2005.09.003

[24] Troszyńska A, Estrella I, López-Amóres ML, Hernández T. Antioxidant activity of pea (*Pisum sativum* L.) seed coat acetone extract. LWT—Food Science and Technology. 2002;**35**:158-164. DOI: 10.1006/fstl.2001.0831

[25] Patil RR, Gholave AR, Jadhav JP, Yadav SR, Bapat VA. Mucuna sanjappae Aitawade et Yadav: A new species of Mucuna with promising yield of anti-Parkinson's drug L-DOPA. Genetic Resources and Crop Evolution. 2014;**62**:155-162. DOI: 10.1007/s10722-014-0164-8

[26] Aware C, Patil R, Gaikwad S, Yadav S, Bapat V, Jadhav J. Evaluation of L-dopa, proximate composition with in vitro anti-inflammatory and antioxidant activity of Mucuna macrocarpa beans: A future drug for Parkinson treatment. Asian Pacific Journal of Tropical Biomedicine. 2017;**7**:1097-1106. DOI: 10.1016/j.apjtb.2017.10.012

[27] Patil SA, Surwase SN, Jadhav SB, Jadhav JP. Optimization of medium using response surface methodology for l-DOPA production by Pseudomonas sp. SSA. Biochemical Engineering Journal. 2013;**74**:36-45. DOI: 10.1016/j.bej.2013.02.021

[28] Raina AP, Misra RC. Chemical evaluation of Mucuna species for L-dopa content—An anti-Parkinson's drug yielding medicinal plant from India. Indian Journal of Traditional Knowledge. 2018;**17**:148-154

[29] Sathyanarayana N, Pittala RK, Tripathi PK, Chopra R, Singh HR, Belamkar V, et al. Transcriptomic resources for the medicinal legume *Mucuna pruriens*: De novo transcriptome assembly, annotation, identification and validation of EST-SSR markers. BMC Genomics. 2017;**18**:1-18. DOI: 10.1186/s12864-017-3780-9

[30] Misra L, Wagner H. Extraction of bioactive principles from *Mucuna pruriens* seeds. Indian Journal of Biochemistry & Biophysics. 2007;**44**:56-60

[31] Vadivel V, Biesalski HK. Bioactive compounds in velvet bean seeds: Effect of certain indigenous processing methods. International Journal of Food Properties. 2012;**15**:1069-1085. DOI: 10.1080/10942912.2010.513466

[32] Pavan H. A new host record for Uromyces mucunae on Mucuna sanjappae. Plant Pathology and Quarantine. 2014;**4**:90-91. DOI: 10.5943/ppq/4/2/2

[33] Phylogeny L, Group W, Jeff J, Toby R, Michael J, Martin F, et al. Legume phylogeny and classification in the 21st century: Progress, prospects and lessons for other species-rich clades. Taxon. 2013;**62**:217-248. DOI: 10.12705/622.8

[34] Cilia R, Laguna J, Cassani E, Cereda E, Pozzi NG, Isaias IU, et al. Mucuna pruriens in Parkinson disease: A double-blind, randomized, controlled, crossover study. Neurology. 2017;**89**:432-438. DOI: 10.1212/WNL.0000000000004175

[35] Lorenzetti F, Macisaac S, Arnason JT, Buckles D. The phytochemistry, toxicology, and food potential of velvetbean (Mucuna Adans. spp., Fabaceae). Africa (Lond). 2010:1-11

[36] Biradar SP, Tamboli AS, Khandare RV, Pawar PK. Chebulinic acid and Boeravinone B act as anti-aging and anti-apoptosis phyto-molecules during oxidative stress. Mitochondrion. 2019;**46**:236-246. DOI: 10.1016/j.mito.2018.07.003

[37] Thiruvengadam M, Rekha K, Rajakumar G, Lee T-J, Kim S-H, Chung I-M. Enhanced production of anthraquinones and phenolic compounds and biological activities in the cell suspension cultures of *Polygonum multiflorum*. International Journal of Molecular Sciences. 2016;**17**:1912. DOI: 10.3390/ijms17111912

[38] Suryawanshi JPJSS, Rane MR, Kshirsagar PR, Kamble PP. Antioxidant, antimicrobial activity with mineral composition and LCMS based phytochemical evaluation of some Mucuna species from India. International Journal of Pharmacy and Biological Sciences. 2019;**9**:312-324

[39] Kumar S, Dobos GJ, Rampp T. The significance of ayurvedic medicinal plants. Evidence-Based Complementary and Alternative Medicine. 2017;**22**:494-501. DOI: 10.1177/2156587216671392

[40] Nishihara E, Parvez MM, Araya H, Kawashima S, Fujii Y. L-3-(3,4-Dihydroxyphenyl)alanine (L-DOPA), an allelochemical exuded from velvetbean (*Mucuna pruriens*) roots. Plant Growth Regulation. 2005;**45**:113-120. DOI: 10.1007/s10725-005-0610-x

[41] Guidotti BB, Gomes BR, Siqueira-Soares RDC, Soares AR, Ferrarese-Filho O. The effects of dopamine on root growth and enzyme activity in soybean seedlings. Plant Signaling & Behavior. 2013;**8**:1-7. DOI: 10.4161/psb.25477

[42] Soares AR, Marchiosi R, Siqueira-Soares RDC, Barbosa de Lima R, Dantas dos Santos W, Ferrarese-Filho O. The role of L-DOPA

in plants. Plant Signaling & Behavior. 2014;**9**:1-7. DOI: 10.4161/psb.28275

[43] Mastan SA, Ramayya PJ, Naidu LM, Mallikarjuna K. Antimicrobial activity of various extracts of *Mucuna pruriens* leaves. Biomedical and Pharmacology Journal. 2009;**2**:55-60

[44] Champatisingh D, Sahu P, Pal A, Nanda G. Anticataleptic and antiepileptic activity of ethanolic extract of leaves of *Mucuna pruriens*: A study on role of dopaminergic system in epilepsy in albino rats. Indian Journal of Pharmacology. 2011;**43**:197-199. DOI: 10.4103/0253-7613.77368

[45] Sree V, Aswani V, Babu R, Kumar P, Varma V, Birudu R. Advancements in the production of secondary metabolites. Journal of Natural Products Review. 2010;**3**:112-123

[46] Oksman-Caldentey KM, Inzé D. Plant cell factories in the post-genomic era: New ways to produce designer secondary metabolites. Trends in Plant Science. 2004;**9**:433-440. DOI: 10.1016/j.tplants.2004.07.006

[47] Smetanska I. Production of secondary metabolites using plant cell cultures. Advances in Biochemical Engineering/ Biotechnology. 2008;**111**:187-228. DOI: 10.1007/978-3-540-70536-9

[48] Hussain MS, Rahman MA, Fareed S, Ansari S, Ahmad I, Saeed M. Current approaches toward production of secondary plant metabolites. Journal of Pharmacy & Bioallied Sciences. 2012;**4**:10. DOI: 10.4103/0975-7406.92725

[49] Lalasangi SI, Hiremath L. Regeneration elicitation of bioactive compound extracted from endangered medicinal plant Mucuna pruriens and study of its inhibition activity using biomolecular simulation studies. Proj. Ref. No. 40S _ BE _ 2138. n.d

[50] Chattopadhyay S, Datta SK, Mahato SB. Production of L-DOPA from cell suspension culture of *Mucuna pruriens* f. *pruriens*. Plant Cell Reports. 1994;**13**:519-522

[51] Janarthanam B, Sumathi E. Optimization of biomass culture yield and l-dopa compound in the callus culture from cotyledonary leaves of *Mucuna pruriens*. Asian Journal of Pharmaceutical and Clinical Research. 2015;**8**:4-8

[52] Adam JI, Dampare SB, Addae G. Effect of culture conditions on L-dopa accumulation in callus culture of *Mucuna pruriens*. Journal of Chemical and Pharmaceutical Research. 2010;**2**:504-527

[53] Namdeo AG. Plant cell elicitation for production of secondary metabolites: A review. Pharmacognosy Reviews. 2007;**1**:69-79. DOI: 10.1016/ S0168-9452(01)00490-3

[54] Patel H, Krishnamurthy R. Elicitors in plant tissue culture. Journal of Pharmacognosy and Phytochemistry. 2013;**2**:60-65

[55] Simic SG, Tusevski O, Maury S, Delaunay A, Joseph C, Hagège D. Effects of polysaccharide elicitors on secondary metabolite production and antioxidant response in *Hypericum perforatum* L. shoot cultures. Scientific World Journal. 2014;**2014**:1-10. DOI: 10.1155/2014/609649

[56] Gadzovska S, Maury S, Delaunay A, Spasenoski M, Hagège D. The influence of salicylic acid elicitation of shoots, callus, and cell suspension cultures on production of naphtodianthrones and phenylpropanoids. Plant Cell Tissue and Organ Culture. 2014;**113**:25-39. DOI: 10.1007/s11240-012-0248-0

[57] Wong SP, Leong LP, William Koh JH. Antioxidant activities of aqueous extracts of selected plants. Food Chemistry. 2006;**99**:775-783. DOI: 10.1016/j.foodchem.2005.07.058

[58] Raghavendra S, Kumar V, Ramesh CK, Khan MHM. Enhanced production of L-DOPA in cell cultures of *Mucuna pruriens* L. and *Mucuna prurita* H. Natural Product Research. 2012;**26**:792-801. DOI: 10.1080/14786419.2011.553721

[59] Longhi JG, Perez E, de Lima JJ, Cândido LMB. In vitro evaluation of *Mucuna pruriens* (L.) DC. antioxidant activity. Brazilian Journal of Pharmaceutical Science. 2011;**47**:535-544. DOI: 10.1590/S1984-82502011000300011

[60] Murthy SN, Malgaonkar MM, Shirolkar AR, Pawar SD, Sangvikar S, Kulkarni YR. A comparative assessment of pharmacologically active principles and antioxidant activity of commonly occurring Mucuna SPS. in India. International Journal of Ayurveda and Pharma Research. 2015;**3**:8-13

[61] Yadav SK, Rai SN, Singh SP. *Mucuna pruriens* reduces inducible nitric oxide synthase expression in Parkinsonian mice model. Journal of Chemical Neuroanatomy. 2017;**80**:1-10. DOI: 10.1016/j.jchemneu.2016.11.009

[62] Oseni OM, Pande V, Nailwal TK. A review on plant tissue culture, a technique for propagation and conservation of endangered plant species. International Journal of Current Microbiology and Applied Sciences. 2018;**7**:3778-3786. DOI: 10.20546/ijcmas.2018.707.438

[63] Mohan VR. Antibacterial activity of *Mucuna pruriens* (L.) Dc. var. pruriens—An ethnomedicinal plant. Science Reserch Reporter. 2011;**1**:69-72. Available from: http://jsrr.in

[64] Rayavarapu KA, Kaladhar DSVGK. Evaluation of antimicrobial activity of mucuna pruriens on plant pathogens. Asian Journal of Biochemical and Pharmaceutical Research. 2014;**1**:593-600

[65] Pandey J, Pandey R. Study of phytochemical and antimicrobial activity of alcohlic extract of *Mucuna pruriens* (L.) leaves. International Journal of Applied Research. 2016;**2**:219-222

[66] Houghton PJ, Osibogun IM. Flowering plants used against snakebite. Journal of Ethnopharmacology. 1993;**39**:1-29. DOI: 10.1016/0378-8741(93)90047-9

[67] Kumar A, Gupta C, Nair DT, Salunke DM. MP-4 contributes to snake venom neutralization by *Mucuna pruriens* seeds through an indirect antibody-mediated mechanism. The Journal of Biological Chemistry. 2016;**291**:11373-11384. DOI: 10.1074/jbc.M115.699173

[68] Gómez-Betancur I, Gogineni V, Salazar-Ospina A, León F. Perspective on the therapeutics of anti-snake venom. Molecules. 2019;**24**:1-29. DOI: 10.3390/molecules24183276

[69] Guerranti R, Aguiyi JC, Neri S, Leoncini R, Pagani R, Marinello E. Proteins from *Mucuna pruriens* and enzymes from Echis carinatus venom. Characterization and cross-reactions. Journal of Biological Chemistry. 2002;**277**:17072-17078. DOI: 10.1074/jbc.M201387200

[70] Kasturiratne A, Wickremasinghe AR, De Silva N, Gunawardena NK, Pathmeswaran A, Premaratna R, et al. The global burden of snakebite: A literature analysis and modelling based on regional estimates of envenoming and deaths. PLoS Medicine. 2008;**5**:1591-1604. DOI: 10.1371/journal.pmed.0050218

[71] Shekins O. Anti-venom activity of *Mucuna pruriens* leaves extract against cobra snake (*Naja hannah*) venom. International Journal of Biochemistry Research & Review. 2014;**4**:470-480. DOI: 10.9734/ijbcrr/2014/10394

[72] Fung SY, Tan NH, Liew SH, Sim SM, Aguiyi JC. The protective effects of *Mucuna pruriens* seed extract against histopathological changes induced by Malayan cobra (*Naja sputatrix*) venom in rats. Tropical Biomedicine. 2009;**26**:80-84

[73] DeMaagd G, Philip A. Parkinson's disease and its management. Part 1: Disease entity, risk factors, pathophysiology, clinical presentation, and diagnosis. Pharmacology & Therapeutics. 1994;**40**:504-510. DOI: 10.1136/bmj.308.6923.281

[74] Katzenshlager R, Evans A, Manson A, Palsalos PN, Ratnaraj N, Watt H, et al. *Mucuna pruriens* in Parkinson's disease: A double blind clinical and pharmacological study. Journal of neurology, neurosurgery, and psychiatry. 2004;**75**:1672-1677. DOI: 10.1136/jnnp.2003.028761

[75] Lieu CA, Venkiteswaran K, Gilmour TP, Rao AN, Petticoffer AC, Gilbert EV, et al. The antiparkinsonian and antidyskinetic mechanisms of *Mucuna pruriens* in the MPTP-treated nonhuman primate. Evidence-Based Complementary and Alternative Medicine. 2012;**2012**. DOI: 10.1155/2012/840247

[76] Kasote DM, Katyare SS, Hegde MV, Bae H. Significance of antioxidant potential of plants and its relevance to therapeutic applications. International Journal of Biological Sciences. 2015;**11**:982-991. DOI: 10.7150/ijbs.12096

[77] Waris G, Ahsan H. Reactive oxygen species: Role in the development of cancer and various chronic conditions. Journal of Carcinogenesis. 2006;**5**:1-8. DOI: 10.1186/1477-3163-5-14

[78] Koller WC, Rueda MG. Mechanism of action of dopaminergic agents in Parkinson's disease. Neurology. 1998;**50**. DOI: 10.1212/wnl.50.6_suppl_6.s11