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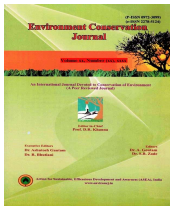

Necessity of genetic diversity study and conservation practices in chironji (*Buchanania cochinchinensis* (Lour.) M.R. Almedia)

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ABSTRACT

Chironji (*Buchanania cochinchinensis*) is an indigenous tree species of Indian subcontinent which belongs to the Anacardiaceae family. It has tremendous potential to uplift the socio-economic status of village dwellers and tribal people. It is used for various purposes including fruits, fuel, fodder and medicines. The species is facing severe ecological and anthropogenic pressures due to indiscriminate harvesting and illicit felling. IUCN has designated Chironji as a vulnerable species indicating that it may be on the verge of extinction if proper conservation measures are not taken very soon. The reports on its conservation and genetic improvement are very less. Hence, it is needed to devise the strategies to conserve its germplasm and genetically improve the species for higher fruit yield. The genetic diversity present in the species is also needed to be studied for effective conservation. Eco-distribution mapping and Molecular characterization using modern tools like molecular markers can give an accurate idea about the genetic diversity in lesser time and will also help in designing the breeding strategies and conservation of its diverse genotype. This review encompasses the researches done on Chironji till date detailing the importance of its genetic diversity and tries to indicate the future conservation and improvement strategies to be taken to fill up the remaining gaps.

Introduction

Buchanania cochinchinensis (Lour.) M.R. Almedia [Syn: *Buchanania lanzan* (Spreng.)] belongs to the family Anacardiaceae and originated in Indian sub-continent (Avani *et al.*, 2019). The tree is globally known as 'Almondette' or 'Little gooseberry tree' in English (Janick and Paull, 2006), but is most commonly called as 'Chironji' in its native regions like India, Nepal and Burma. The natural distribution of Chironji ranges from the foothills of western Himalayas, Sri Lanka, Bangladesh, China to Myanmar, Thailand, Laos and Vietnam. In India, it is known by several names varying with different regions and languages. In Hindi it is called as Achar, Char, Baruda, Priyala, Piyar; in Bengali it is known as Piyal, Chironji; in Gujarati & Marathi, Charoli, Pyalchar; in Tamil, Morala; in Telegu, Saarachettu, Morichettu; in Kannada, Charpoppu; in Malyalam, Mungapper; in Oriya, Charu; and in Sanskrit it is described as, Priyalam, Char, Rajadana, Dhanu etc. It is presumed that the foremost description of the tree Chironji was done by Francis Hamilton in 1798 as a small to medium-sized tree with a height up to 18 m (~ 55 ft) and girth up to 1.5 m (~ 5 ft). It is endemic to the tropical dry deciduous forests of India (Siddiqui *et al.*, 2014) and naturally found in the forests of central, north and west India along with hills of the peninsula, encompassing the states of Madhya

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Pradesh, Maharashtra, Gujrat, Rajasthan, Uttar Pradesh, Orissa, Jharkhand, Bihar, Chhattisgarh and parts of Andhra Pradesh and Karnataka up to an elevation of 1200 m from mean sea level (Singh *et al.*, 2010a). It is a very common associate of Sal (*Shorea robusta*), Kaldhi (*Anogeissus pendula*), Teak (*Tectona grandis*), Salai (*Boswellia serrata*) (Sharma, 2012) and Mahua (*Madhuca longifolia*).

Buchanania cochinchinesis is one of the neglected tree species in India, which may be at the verge of extinction very soon. The species is facing severe ecological and anthropogenic pressures due to indiscriminate harvesting and illicit felling. Poor attention and sheer negligence, degeneration of indigenous knowledge, high biotic and anthropogenic pressures, and over-exploitation by the natives are some of the major causes for the fast rate of depletion of the species. IUCN has already designated Chironji as a vulnerable (VU) species in its Red Data List (Prasad, 2020). It possesses medicinal properties and has tremendous potential to uplift the socio-economic status of village dwellers and tribal people. Hence, it is required to devise the proper conservation strategies to maintain the natural diversity and population distribution of this species, conserve its germplasm and genetically improve the species for higher fruit yield and kernel oil.

Morphological and Phenological characters of the species:

Chironji is naturally a dicot deciduous woody tree having a straight, cylindrical trunk and tomentose branches. The trunk has rough fissured bark which is dark grey or black in colour. The tree can be characterized by its signature dark-grey crocodile bark (Figure 1) (Siddiqui *et al.*, 2014). The trunk is reddish inside and gives a unique identifiable red blaze. The oblong or elliptic oblong leaves are coriaceous or leathery in upper texture and tomentose beneath with entire margin, obtuse apex and 1.5 – 2 cm long pubescent petioles (Figure 2). The flowers typically adhere to the characteristics of the family Anacardiaceae. Flowering starts with small, sessile greenish-white flowers on well-developed terminal and axillary pyramidal panicles in the month of January-February (Singh *et al.*, 2019). A single panicle can hold up to 5000 flowers (Figure 3). The flowers are hermaphrodite in nature. The flowers take around 16-20 days for complete development from when the buds start external growth. Singh *et al.* (2010b) conducted a detailed floral biology study in Chironji with 15 elite genotypes. They recorded the peak period of anthesis between 6 – 11 AM of the day. Chironji fruits are drupe by nature (Figure 4) and become perfectly ripe for harvesting in the month of April – June and the ripe fruits may remain on the tree for a long time (Singh *et al.*, 2010a). Fruits are alternate bearing in nature. Singh *et al.* (2006a) indicated that the immature fruits are green, but darken to black when ripe and moderately sweet in taste with juicy, acidic pulp. Interestingly, the fruit set and panicle length of the flowers were found to be positively and significantly correlated by the same authors.

Figure 1: *Buchanania cochinchinensis* in natural wild population with the signature crocodile bark

Economic importance of the species:

Chironji is a species that is less known in the global market for its economical uses, but it is uncontrollably exploited by the natives for the local markets. Its fruits are one of the most delicious wild fruits available in forests due to its pleasant sub-acidic flavour. Its seeds are crushed to powder to be used as a spice or flavouring substance in many local dishes. The nuts are often used in home-made sauces and stews to thicken the dish. Seeds can be

Figure 2: Juvenile leaves of *Buchanania cochinchinensis*

Figure 3: Flowering of *Buchanania cochinchinensis*

Figure 4: Fruiting of *Buchanania cochinchinensis*

used for making a traditional sweet dish known as "*Chironji ki burfi*" along with other sweets like *halwa* and *kheer* (Rajput *et al.*, 2018). Its kernels contain oil and can also be eaten raw or roasted. The kernels are the most economically valuable produce of Chironji. Kernels are used for preparation of puddings, and the juicy mesocarp is cherished by local children (Munde *et al.*, 2003). Sweet highly nutritious edible oil can be extracted from the kernels which can be used in cooking as a cheap substitute for almond or olive oil. Juices and beverages can be prepared from the pulp of Chironji fruits. In summer seasons, leaves of Chironji are used as a substitute to green fodder for the cattle. It produces a moderate quality of timber which have some natural resistance to termites. The timber is mainly utilized for making light furniture, boxes and crates, desks, match boxes, packing cases etc. The wood is very much cheap and hence can be utilized in timber industries after some treatments and modifications. Dried branches are generally used as fuel wood by local inhabitants. The bark consists good amount of tannin (around 14%) and can be used in tanning. Tewari (1995) reported that the gum exudates may also be used in textile industries as a colouring substance. The gum is also used in incense industries for adulteration of *Commiphora wightii* (Rajput *et al.*, 2018). The gum with good quality after treatments and refinements, may be used in soft drinks and making food colourings. It proves to be a good source of income and backbone of the daily economy for local dwellers and tribal people in many states like Chhattisgarh, Jharkhand, Bihar etc. (Avani *et al.*, 2019). Apart from these tangible economical values, it is a very suitable species for the reclamation of wastelands and has a high potential for commercial dryland horticulture. It can tolerate adverse climatic stresses and hence the cultivation can be established in any arid, semi-arid, resource-poor areas.

Ethno-medicinal uses of the species:

Indigenous and traditional knowledge (ITK) is very much important for proper and sustainable use of any resource. The plant species are not different from this. The livelihoods of native and tribal people are often dependent on Chironji. ITK reveals the immense medicinal value of almost every part of Chironji like leaves, roots, fruits,

seeds, gum etc. In Ayurveda and Unani systems of medicine, it is described as a plant from which various drugs and medicines can be prepared. The roots of Chironji are astringent, depurative, acrid, constipating and have cooling properties. They are used in the treatment of Diarrhoea. Extract of roots may also be used as an expectorant for curing several blood diseases and biliousness. The leaf juice contains 2.64% tannins, saponins, triterpenoids, flavonoids and different reducing sugars and can be used as an aphrodisiac, purgative, expectorant, blood purifier, thirst quencher (Rajput *et al.*, 2018). Leaf extract is used to cure digestive disorders. The leaves themselves have properties to heal minor wounds (Kala, 2009). Its seeds and kernels are very much palatable, nutritional and used in confectioneries as a substitute of almonds. The kernels are used by several tribal groups of Gujarat as brain tonic (Singh *et al.*, 2018). The seeds are also used as an expectorant tonic. The seed contains 34 – 47% of fatty oil which can be used for cooking. The oil extracted from seed kernels is natively known as '*Char*' and known to have medicinal values for curing skin diseases and removing spots and blemishes from the skin. The oil is non-toxic and safe for human consumption and also has non-repellent properties (Avani *et al.*, 2019). An ointment is made from this oil which is locally used to cure glandular swellings on several parts of the body (Dai *et al.*, 2002). The whole fruits of Chironji are also edible. They have some laxative properties and are used to relieve high body temperature, fever, cough, asthma etc. Even the bark of Chironji trunk have certain medicinal properties. Powder of Chironji bark and Malabar Plum (*Syzygium cumini*) bark is mixed together and used as a treatment of infantile diarrhea by the tribes of Southern Bihar (Rajput *et al.*, 2018). The bark and leaf paste of Chironji mixed with East Indian Ebony (*Diospyros melanoxylon*) dissolved in a glass of water at a dose of twice daily is reported to treat poisonous snakebite by Shukla *et al.* (2001). Chironji oozes water soluble gum from any cut on the bark or stem. The gum has tremendous medicinal values. It is an analgesic and is used to treat intercostals pain and diarrhea upon mixing with goat's milk (Shende and Rai, 2005). In some tribal areas of Andhra Pradesh, the gum dissolved in cow's milk is used as a cure to rheumatic pains.

Phytochemical importance of the species:

The genus *Buchanania* was always a species of interest for the chemists due to the varied range of phytochemicals available. Probably, the first and foremost phytochemical studies for Chironji was reported by Sengupta and Choudhary in 1977. They investigated the fatty acid composition in Chironji seed oil through gas liquid chromatography (GLC) and concluded that the seed oil contains 0.6% myristic acid, 33.4% palmitic acid, 6.3% stearic acid, 53.7% oleic acid and 6% linoleic acid. Triglyceride compositions were also determined and the oil is reported to be composed of 3.2% tri-saturated, 35.8% monounsaturated – disaturated, 45.5% disaturated – monosaturated and 15.5% tri-unsaturated glycerides. Interestingly, the Chironji seed oil contains 22.7% di-palmitoolein, 31% di-oleopalmitin and 11.3% tri-olein which may be denoted as an unique characteristic of Chironji seed oil (Mishra and Tiwari, 2018). The chemical compositions make Chironji seed oil as a promising commercial source of palmitic and oleic acids. Also, the oil yields a product with a slip point of 41.5°C upon directed inter-esterification, which has the potential to be used as a coating material for delayed action tablets (Sengupta and Choudhary, 1977). The lipid compositions of seed oil were determined by Hemavathy and Prabhakar (1988) and they reported the total lipids contain neutral lipids (90.4%), glycolipids (3.4%) and phospholipids (6.2%). Tri-acylglycerols (82.2%), free fatty acids (7.8%), small amounts of di-acylglycerols, mono-acylglycerols and sterols mainly formulate the neutral lipids. In this study, the researchers identified and reported three glycolipids and six phospholipids.

Potential anti-inflammatory and anti-oxidant activities of methanolic extract of Chironji kernel extract (BLK-ME) were evaluated by Warokar (2010) and total polyphenolic content was reported to be 16.82 ± 23 mg of GAE/100. The author concluded that the presence of several phytochemicals like saponins, tannins and triterpenoids probably be the cause for BLK-ME to show such anti-inflammatory and antioxidant activities. Simultaneously, Mishra *et al.* (2010), investigated the antioxidant activities of dried fruits of Chironji along with other edible fruit species through different biochemical assays. The total phenolic content was estimated using Folin-

Ciocalteu reagent assay. In this method, EC_{50} values were calculated to evaluate the antioxidant activities and it was concluded that Chironji fruits also have significant antioxidant properties. Khatoon *et al.* (2015) have evaluated the nutraceutical potential of Chironji and reported that there are huge opportunities to develop value-added products, dietary supplements and phototherapeutic compounds from Chironji. Tripathi *et al.* (2016) have tried to standardize the methods of phytochemical investigation and pharmacogenetic studies on Chironji seeds. Recently, there have been a lot of investigations on the phytochemistry of Chironji as the evaluation equipment and scientific methods have advanced at a rapid pace. Siddiqui *et al.* (2016) evaluated phytochemicals, physio-chemical properties and antioxidant activities in gum exudates of Chironji. Pawar and Singh (2020) investigated for antioxidant and anti-cancerous potential of Chironji through an *in-vitro* study of antioxidant activity of various extracts from Chironji leaves and concluded that chemicals extracted from Chironji have tremendous potential to be used as a cure for cancer in near future. Niratker and Sailaja (2014) evaluated antimicrobial activities of Chironji leaf-extract and reported that it has high potential antimicrobial activities against three bacterial species namely *Escherichia coli*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* and two fungal species namely *Aspergillus Niger* and *Penicillium* sp.

Species variation and genetic diversity:

Chironji is a highly heterozygous cross-pollinated tree which resulted in high variation in a natural population (Singh *et al.*, 2010a). Around 20 species under the genus *Buchanania* have been identified so far, among which seven species are reported to be found in India. *B. cochinchinensis* (Syn: *B. lanzan* / *B. latifolia*) and *B. axillaries* are the two main species producing edible fruits in India. *B. axillaries* (Syn: *B. angustifolia*) is a dwarf species that is reported to produce good quality edible kernels. *B. lanceolata* is found in the evergreen forests of Kerala and is marked as an endangered species. *B. Platyneura* is also reported to be edible, but found only in the islands of Andaman (Chauhan *et al.*, 2012). The other minor species reported in India are *B. lucida*, *B. accuminata* and *B. glabra*. Among all the Chironji species, *B. cochinchinesis* is the most widely distributed and found throughout the country (Kirtikar and Basu, 1918). Cytogenetic studies of the genus *Buchanania* is very much scarce and at a very nascent state. Very recently, cytogenetic analysis on root cells of *Buchanania cochinchinensis* through the chromosome splash technique revealed that the species is diploid in nature with chromosome number 2n = 18 (Singh *et al.*, 2019).

Being a highly heterozygous and cross-pollinated tree species, Chironji exhibits a high degree of genetic diversity and variation in its natural population. However only a handful of works have been done till date to exploit the genetic variation and resources of Chironji in India. Chironji is still not cultivated for commercial purposes and hence the importance of releasing superior high-yielding variety is not felt at a large scale. Although researchers are now engaged in studying the genetic diversity of the species and a few improved cultivars are available. A detailed study is required including germplasm collection from the range of its distribution, genetic diversity assessment and genetic improvement through the breeding programs are needed for the commercial utilization of the species.

One of the foremost surveys was carried out by Rai (1982) in Uttar Pradesh for investigating the extent of variability in terms of morphological characters and yield attributes present in the species. They reported a high degree of variability in seed size, fruit yield and chemical compositions of fruits in the study area. Later several surveys were carried out for assessing the genetic diversity present in its growing areas throughout the country by several researchers like Singh and Chaturvedi (1983) and Chadhar and Sharma (1997). Singh *et al.* (2006b) conducted an extensive survey during 2004 – 2005 in Gujarat for exploring its genetic diversity under semi-arid conditions. They identified thirty (30) candidate plus trees (CPTs) of the species which were propagated vegetatively and utilized under tree improvement programs (Singh *et al.*, 2016). Out of identified CPTs, CPT1, CPT5, CPT10, CPT15, CPT17, CPT19 and CPT22 showed early flowering (first week of February) while CPT13 showed late flowering (last week of February). Variation in the panicle lengths was also observed as the longest length (35.11 cm) in CPT1 and the

shortest length (14.20 cm) in CPT18. The highest fruit yield recorded was 28 kg / plant in CPT7 whereas the highest protein content of 30.70% was observed in CPT2. All these data indicated the presence of wide variation and diversity in natural population. National Bureau of Plant Genetic Resources (NBPGR), New Delhi also conducted a survey in the states of Rajasthan, Chhattisgarh, Madhya Pradesh and Gujarat and collected 74 different accessions (Malik *et al.*, 2010). Another important landmark survey for the exploration of genetic diversity and germplasm collection of Chironji was carried out by Malik *et al.* (2012) in the states of Gujarat, Madhya Pradesh and Rajasthan. They collected 72 diverse accessions of Chironji with a wide range of genetic variations and preserved them.

Conservation approaches:

Chironji is a wild tree that is facing high biotic and anthropogenic pressure leading to severe genetic erosion. Abrupt deforestation in the areas where a wide range of genetic variations of Chironji could be found, is one of the major causes. As a counter measure, both *in-situ* and *ex-situ* conservation strategies should be taken up for maintaining the genetic diversity of Chironji in India. Due to the rapid depletion of genetic diversity, immediate *ex-situ* conservation accompanied by proper *in-situ* conservation is to be considered the most appropriate measure for germplasm conservation (Rajput *et al.*, 2018). Moreover, presence of a hard seed coat and association of several pathogen fungi like *Curvularia, Trichothecium, Fusarium, Alternaria, Aspergillus, Mucor, Penicillium* etc. poses a problem in the regeneration of Chironji (Sharma *et al.*, 1998) which greatly contraints the conservation and area expansion procedures for this species. To overcome such problems, *ex-situ* field gene banks for Chironji are established at Godhra, Gujarat and Lucknow, Uttar Pradesh by the Indian Council of Agricultural Research (ICAR) for the conservation and development of advanced propagation practices of superior cultivars. Moreover, the germplasms collected from all over India, consisting of 127 accessions of Chironji, representing the genetic diversity and variation explored so far are cryopreserved as a base collection at NBPGR, New Delhi (Malik *et al.*, 2012). For enhancing the conservation of Chironji, modern biotechnological and tissue culture tools are being used recently. Rapid clonal techniques for multiplication through profuse shooting and rooting to supplement the establishment of *in vitro* gene banks for Chironji have been developed by Shende and Rai (2005).

Future Prospects in conserving the genetic diversity of the species:

Chironji is mainly multiplied through seed propagation which ensures variability within the population. Hence, selection can prove to be a very useful tool for the improvement of the species. Selecting the desirable traits like good quality seeds, kernels, high yield will help in developing improved cultivars. A detailed survey in the areas with rich diversity to select the promising elite genotypes is a must for this. These elite genotypes may be evaluated and propagated to produce true to the type cultivars as a preliminary step in developing improved varieties. Hybridization may be another approach for the improvement programmes. Crossing with elite genotypes may become useful for producing improved cultivars with high yield, good resistance and short height in near future. Some future prospects and thrusts may be enumerated as:

- Research on the genetic resources across the country should be undertaken for studying the genetic diversity.
- The proper genetic structure of Chironji is yet to be discovered, detailed study can be done for exploring the genome of the species.
- The selection of promising genotypes with good tolerance to several abiotic and biotic stresses can lay a path to the release of improved cultivars.
- Model nurseries for preservation and propagation for the species may be established.
- A standardized package of practices for commercial cultivation of Chironji is yet to be published.
- Other aspects like maturity indices, harvesting time, grading and preservation of produce are also to be standardized throughout the country.
- Research on integrated pest and pathogen management for Chironji is also a need for the hour.
- Proper dispersal of information about new improved varieties, processing and value addition techniques, demand and supply in

local as well as international markets about Chironji is very much necessary to improve and popularize the species throughout the country.

Conclusion

Buchanania cochinchinensis or Chironji has a high potential for being used as a commercial horticultural crop which can uplift the socio-economic status of the native inhabitants and tribal people. Over-exploitation and unscientific harvesting practices hinder the sustainability of the species which is leading the species to extinction. Urgent conservation measures and scientific researches are in dire need for the species to prevent these threats. Standardization of proper cultivation practiced along with modern molecular and biotechnological approaches should be taken for conservation and improvement of the species, unless we can lose this native species of India in the very near future.

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Conflict of interest

The authors declare that they have no conflict of interest.

References

Avani, P., Bauri, F. K., & Sarkar, S. K. (2019). Chironji: a golden nut fruit of Indian tribes. *Acta Hotic., 1241*, 37-42. https://doi.org/10.17660/ActaHortic.2019.1241.6

Chadhar, S. K., & Sharma, M. C. (1997). Trends in fruit production in *Buchanania lanzan* trees. *Vaniki Sandesh*. 211–213.

Chauhan, P. S., Jitendra, S., & Kavita, A. (2012). Chironjee: A promising tree fruits of dry subtropics. *HortFlora Research Spectrum*, *1*(4), 375–379.

Dai, Y., Ye, W. C., Wang, Z. T., Matsuda, H., Kubo, M., & But, P. P. H. (2002). Antipruritic and antinociceptive effects of Chenopodium album L. in mice. *Journal of Ethnopharmacology*, *81*(2), 245–250. https://doi.org/10.1016/s0378-8741(02)00096-x

Hemavathy, J., & Prabhakar, J. V. (1988). Lipid composition of Chironji (*Buchanania lanzan*) kernel. *Journal of Food Composition and Analysis*, *1*(4), 366–370. https://doi.org/10.1016/0889-1575(88)90037-3

Janick, J., & Paull, R. E. (2006). *The encyclopedia of fruits and nuts* (pp. 14–15). CABI Publishing.

Kala, C. P. (2009). Aboriginal uses and management of ethnobotanical species in deciduous forests of Chhattisgarh state in India. *Journal of Ethnobiology and Ethnomedicine*, *5*(1), 20. https://doi.org/10.1186/1746-4269-5-20

Khatoon, N., Gupta, R. K., & Tyagi, Y. K. (2015). Nutraceutical potential and phytochemical screening of Buchanania lanzan, an underutilized exotic Indian nut and its use as a source of functional food. *Journal of Pharmacognosy and Phytochemistry*, *4*(1).

Kirtikar, K. R., & Basu, B. D. (1918). *Indian medicinal plants.* Ed. Lalit Mohan Basu (2nd ed). III. pp 1964–1965.

Malik, S. K., Chaudhury, R., Dhariwal, O. P., & Bhandari, D. C. (2010). *Buchanania lanzan* (Chironji). In *Genetic resources of tropical underutilized fruits in India* (pp. 25–35). NBPGR.

Malik, S. K., Chaudhury, R., Panwar, N. S., Dhariwal, O. P., Choudhary, R., & Kumar, S. (2012). Genetic resources of Chironji (*Buchanania lanzan* Spreng.): A socio-economically important tree species of central Indian tribal population. *Genetic Resources and Crop Evolution*, *59*(4), 615–623. https://doi.org/10.1007/s10722-012-9801-2

Mishra, N., Dubey, A., Mishra, R., & Barik, N. (2010). Study on antioxidant activity of common dry fruits. *Food and Chemical Toxicology*, *48*(12), 3316–3320. https://doi.org/10.1016/j.fct.2010.08.029

Mishra, S., & Tiwari, S. (2018). Spatial distribution of Buchanania cochinchinensis in Jharkhand. *Biobrio*, *5*(3&4), 344–353.

Munde, V. M., Shinde, G. S., Sajindranath, A. K., Prabu, T., & Machewad, P. M. (2003). Correlation and path analysis studies in charoli (*Buchanania lanzan* Spreng.). *South Indian Horticulture*, *50*, 517–521.

Niratker, C., & Sailaja, D. (2014). Preliminary phytochemical screening and evaluation of antimicrobial activity of *Buchnania lanzan* (chironji) from Chhattisgarh. *World J Pharmaceu Res*, *3*(9), 514–522.

Pawar, B. R., & Singh, G. (2020). Studies on in vitro antioxidant activity of various extract of Buchania Lanzan leaves. *European Journal of Molecular and Clinical Medicine*, *7*(9), 284–291.

Prasad, S. (2020). Chironji (*Buchanania lanzan*): A Retreating Valuable Resource of Central India. *International Journal of Bioresource Science. IJBS*: *7*(1): 01-04.

Rai, Y. C. (1982). *Buchanania lanzan* Spreng. - Studies on Methods of Propagation and Estimation of Fruit Yield. *Indian Forester*, *108*(7), 501–511.

Rajput, B. S., Gupta, D., Kumar, S., Singh, K., & Tiwari, C. (2018). *Buchanania lanzan* Spreng (Chironji): A vulnerable multipurpose tree species in Vindhyan region. *Journal of Pharmacognosy and Phytochemistry*, *7*(5), 833–836.

SenGupta, A., & Choudhury, S. K. (1977). Triglyceridecomposition of *Buchanania cochinchinens* in seed oil. *Journal of the Science of Food and Agriculture*, *28*(5), 463–468. https://doi.org/10.1002/jsfa.2740280510

Sharma, A. (2012). Scientific harvesting for quality seed collection of *Buchanania lanzan* Spreng for its conservation and sustainable management – case study of Chhindwara, Madhya Pradesh, India. *International Journal of Bio-Science and Bio-Technology*, *4*(1), 65–74.

Sharma, N., Ghosh, R., & Nigam, M. (1998). Toxigenic fungi associated with stored fruits of chironji. *Indian Phytopathology*, *51*(3), 284–286.

Shende, S., & Rai, M. K. (2005). Multiple shoot formation and plant regeneration of a commercially useful tropical pla... *Buchanania lanzan* Spreng. *Plant Biotechnology*, *22*(1), 59–61. https://doi.org/10.5511/plantbiotechnology.22.5...

Shukla, K. M. L., Khan, A. A., Khan, S., & Verma, A. K. (2001). Traditional phototherapy of Ma...kal rang... and plateau of Pendra district Bilaspur MP. India... *Advance... in Plant Sciences*, *14*, 11.

Siddiqui, M. Z., Chowdhury, A. R., Prasad, ... (2016). Evaluation of phytochemicals, physico-chemical properties and antioxidant activity in gum exudates of *Buchanania lanzan*. *Proceedings of the National Academy of Sciences, India Section B*, *86*(4), 817–822. https://doi.org/10.1007/s40011-015-0539-4

Siddiqui, M. Z., Chowdhury, A. R., Prasad, N., & Thomas, M. (2014). *Buchania lanzan*: A species of enormous potentials. *World journal of pharmaceutical sciences*, 374–379.

Singh, A. K., Bajpai, A., & Ravishankar, H. (2010a). Enriching fruits basket in India: Biodiversity in underutilized fruits. *Indian Horticulture*, *55*(3), 53–56.

Singh, R. P., & Chaturvedi, O. P. (1983). Primary production of a deciduous forest at Varanasi. *Indian Forester*, *109*(5), 255–260.

Singh, S., Singh, A. K., & Apparao, V. V. (2006b). Genetic diversity in chironji [*Buchanania lanzan*] under semi-arid ecosystem of Gujarat. *Indian Journal of Agricultural Sciences*, *76*(11), 695.

Singh, S., Singh, A. K., Apparao, V. V., & Bhargava, R. (2016). Genetic divergence in chironji [*Buchanania lanzan*] under semi-arid ecosystem of western India. *Indian Journal of Agricultural Sciences*, *86*(4), 550–555.

Singh, S., Singh, A. K., Apparao, V. V., Bagle, B. G., & Dhandar, D. G. (2006a). Phsio- biochemical changes during fruit development in chironji (*Buchanania lanzan* Spreng.). National Symposium on underutilized horticultural crops 8th and 9th June, 2006 at IIHR, Bangalore p. 7/8.

Singh, S., Singh, A. K., Joshi, H. K., Kanak, L., Sisodia, P. S., & Bagle, B. G. (2010b). Floral biology studies in *Buchanania* under semi-arid ecosystem of western India. *Indian Journal of Horticulture*, *67*(2), 161–168.

Singh, S., Singh, A. K., Mishra, D. S., Saroj, P. L., & Appa Rao, V. V. (2018). Chironji is promising fruit for tribal. *Journal of Indian Horticulture*, *63*(5), 37–41.

Singh, S., Singh, A., Mishra, D. S., & Rao, V. V. (2019). Chironji. In *Breeding of horticultural crops*, *2* (Eds. V A. Parthasarathy, Sanjay Kumar Singh,S Vinoth, C. Aswath). Publisher: Today and Tomorrow's Printers and Publishers. New Delhi.

Tewari, R. K. (1995). Bulletin on *Buchanania lanzan* (Chironji) (Indian Council of Forest Research and Education), p. 1–6.

Tripathi, M. K., Kumar, A., Mishra, M. C., & Singh, R. (2016). Preliminary phytochemical investigation and pharmacognostic study of seeds of *Buchanania Lanzan* Spreng. *Journal of the Indian Botanical Society*, *95*(3and4), 246–255.

Warokar, A. S., Ghante, M. H., Duragkar, N. J., & Bhusari, K. P. (2010). Anti-inflammatory and Antioxidant Activities of methanolic extract of *Buchanania cochinchinensis* Kernel. *Indian Journal of Pharmaceutical Education and Research*, *44*(4).