International Journal of Advanced Research in Biological Sciences
ISSN: 2348-8069
www.ijarbs.com
DOI: 10.22192/ijarbs Coden: IJARQG (USA) Volume 8, Issue 5 -2021

Review Article

DOI: http://dx.doi.org/10.22192/ijarbs.2021.08.05.005

Boswellia serrata - Propogation and uses - A Review

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Abstract

Boswellia serrata Roxb. Commonly known as 'Salai Guggal', is an important and multi-use tress species. The tree is used for fodder, timber, medicinal, religious and in cosmetics. The plant is good source of oleo-gum-resin, which show medicinal properties. *Boswellia serrata* is economical important species. The *Boswellia serrata* is endangered species because it shows poor seed germination in natural condition. To improve seed germination of an endangered important forest species, the different pre-treatment was used. The best pre-treatment for seed was GA_3 with 750ppm concentration for 36 hrs and after 30 days it shows 88 percent germination rate. The clonal propagation also done by plant cuttings and shows 80 percent success rate. The *in-vitro* propagation technique also used to propagate the plant species. The various work tried by using plant tissue culturing through cotyledon node segment, embryo, and leafy nodal explants. The propagation through cotyledon node segment with IBA (0.5 mg dm^{-3}) with IAA (0.25 mg dm^{-3}) shows 80 percent rooting in media. The *in-vitro* embryo germination shows 96 percent germination rate. The fully developed seedlings show 94 percent success rate when established in soil. The micropropagation method were used for culturing cotyledonary node and leaf node. The cotyledonary node explant shows best result with BA (2.5 µM) and 91 percent of explant producing shoot. Along with leaf node, also shows best result with BA (2.5 µM) and 91 percent of explant producing shoots. Hardening and accumulation shows 76.5 percent of survival rate when plantlets were transferred to field condition.

Keywords: *Boswellia serrata* Roxb, medicinal properties, *in-vitro* propagation, germination rate.

Introduction

Boswellia serrata Roxb. commonly known as Indian frankincense tree, belongs to *Burseraceae* family, holding both trees and shrubs of tropical and sub-tropical geographical distribution, with approximately 700 species originating from 18 genera. The genus *Boswellia* was named in an honour of Johann Boswell (1719-80) who has described 25 species of *Boswellia*; some of them, however, appear now as synonyms of the 21 known species. The genus *Boswellia* has mostly found in Africa (Sudan, Eritrea, Ethiopia, Somalia, and Kenya), southern Arabia (Oman and Yemen), and India **(Watson, L. and Dallwitz, M.J., 1992; Langenheim, J.H., 2003).**

S.No	*Bosewellia* Species	Geographical Location
1.	*B. sacra*	Oman, Yemen
2.	*B. serrata/B. thurifera/B. glabra*	India
3.	*B. ovalifoliolata*	India
4.	*B. pirottae*	Ethiopia
5.	*B. carterii*	Somalia
6.	*B. frereana*	Somalia
7.	*B. globose*	Somalia
8.	*B. ogadensis*	Ethiopia
9.	*B. neglecta/ B. elegans/ B. hildebrandtii/ B.Microphylla/ B. campestris/ B. holstii/ B.multifoliolate*	Ethiopia, Somalia, Kenya
10.	*B. rivae/ B. boranensis/ B. ruspoliana*	Ethiopia, Somalia, Kenya
11.	*B. papyrifera/ B. chariensis/ B. occidentalis*	Ethiopia, Eritrea, Sudan
12.	*B. odorata*	Niger, northern Nigeria, and eastern Cameroun
13.	*B. dalzielii*	Northern Nigeria
14.	*B. madagascariensis*	Madagascar
15.	*B. popoviana*	Socotra
16.	*B. nana*	Socotra
17.	*B. bullata*	Socotra
18.	*B. dioscorides*	Socotra
19.	*B. ameero*	Socotra
20.	*B. elongate*	Socotra
21.	*B. socotrana*	Socotra

In India, *Boswellia serrata* mainly established in the region of the States of Andhra Pradesh, Gujarat, Madhya Pradesh, Jharkhand and Chhattisgarh **(Siddiqui, M.Z., 2011)**. The botanical origin and vernacular names of *Boswellia serrata* are given in table and Regionally, it is also known by different names **(Monograph *Boswellia serrata*, 1998)**.

Botanical Origin		**Vernacular Names of *Boswellia Serrata***
Division:	Spermatophyta	English: Indian Olibanum or Indian Frankincense
Sub- division:	Angiospermae	Hindi: Kundar, Salai
Tribe:	Rosopsida	Bengali: Kundar, Salai
Sub-tribe:	Rosopsida	Gujarati: Dhup, Gugali
Over-class:	Rutanae	Kannada: Chiita, Guguladhuph
Class:	Anacardiales	Malayalam: Parangi, Saambraani
Family:	Burseraceae	Tamil: Parangi, Saambraani
Genus:	*Boswellia*	Telugu: Phirangi, Saambraani
Species:	*serrata*	Sanskrit: Ashvamutri, Kundra, Shallaki.

Ancient Literature

Boswellia serrata is one of the ancient and most valued herbs in Ayurveda. "*Gajabhakshya*", a Sanskrit name sometimes used for *Boswellia*, as name suggests that elephants enjoy this herb as a part of their diet **(Sharma, S *et al.*, 2004)**. Three famous ancient texts form the pillars of classical Ayurvedic Science, which has its roots in India: Charaka's *Charaka Samhita* (B.C. 700), the first fundamental medical text; Susruta's *Susruta Samhita* (B.C. 600), which attempted to amass the entire medical knowledge, with special focus on surgery; and the two-volume book comprising *Astanga Samgraha* and *Astanga Hridaya* (130-200 A.D.), written by Vagbhata the Elder and Vagbhata the Younger, which synthesized the works of Charaka and Susruta and summarized the eight parts of Ayurveda in prose and verse forms.

The first two pillars of Ayurveda describe the anti-rheumatic (anti-arthritis) activity of *gugguls*-the gum-resins of trees **(Kirtikar, K.R. and Basu, B.D., 1935; Chattarjee, G.K. and Pal, S.P., 1984; Khare, C.P., 2004; MHFW, 2006).**

In addition to its beneficial use for arthritis, this gummy resin is also mentioned in traditional Ayurvedic and Unani texts as an effective remedy for diarrhoea, dysentery, ringworm, boils, fevers (antipyretic), skin and blood diseases, cardiovascular diseases, mouth sores, bad throat, bronchitis, asthma, cough, jaundice, haemorrhoids, vaginal discharges, hair-loss, syphilitic diseases, irregular menses and stimulation of liver. It is also diaphoretic, astringent, diuretic and acts both as internal and external stimulant. Modern medicine and pharmacology strongly point out to its use as an antiarthritic, anti-atherosclerotic (anticoronary plaque), anti-inflammatory, analgesic (pain-reliever) anti-hyperlipidemic (controls blood lipids), and hepatoprotective (protects the liver) **(Sharma, S *et al.*, 2004; Dhiman, A.K. 2006; Hostanska, K. *et al.*, 2002; Lemenith, M. and Teketay, D., 2003; Mathe, C. et al., 2004).**

Phenology

Boswellia serrata phenological event starts from month of June in which initiation of new leaves starts and tree fully covered with leaves from July to Mid-November. In mid of November tree leaf shedding initiated and tree becomes leafless in December. Inflorescence primordia appear on trees due to shedding. *Boswellia serrata* flowering period starts in January which ends in March and flowering peak observed in February. Fruiting period starts in month of March and that's end in mid of May. The Seed dispersal from plant appears in May. The species is self-incompatible and the self-crossed pollen tubes are inhibited soon after their entry into the stigma. Cross-pollinated flowers allowed normal pollen germination and pollen tube growth, and resulted in fruit- and seed-set **(Sunnichan, V.G., *et al* 2005)**. But poor fruit setting (2.6 to 10%) under open pollination, inadequate production of viable seeds **(Joshi, H.B., *et al,* 1981)** and scanty seed germination (10–20%) restrict the distribution and therefore limits its natural source **(Purohit SD *et al,* 1995; Ghorpade, R.P., *et al,* 2010)**. On the other hand, the tree is harvested to extract the sap and to utilize the pulp in paper industries. Such problematic regeneration and the destructions have resulted in declining of the natural abundance and the species has been classified under threatened **(Saha, D. *et al,* 2015)**. Therefore, development of mass multiplication technique for conservation and sustainable utilization of this species has become a serious concern.

The studies carried out on the phenology, floral biology, pollination ecology and breeding system of Salai Guggal. Their study shows the tree remains leafless for 2-3 weeks prior to flowering and during the entire period of flowering and fruiting. During the flowering season, on average each branch produces 7.2 ± 2.3 inflorescence and each inflorescence produce 20-90 flowers. The flower opening lies between 12.30 to 15.00 h, with opening 5.9±4 flowers open per inflorescence each day. The pollen grain average diameter from large size anther is 68.5± 2.0 um, on other hand small sized anther is 60.5± 1.7 um. The pollen grains gradually lost their viability within 7 days, under the laboratory condition.The stigma pollinated, 48 hours before anthesis did not assist in pollen adhesion and germination. Only those stigma support pollen adhesion and germination, those are pollinated before 24 hours. For the determination of self-incompatibility, both self- and cross pollination were carried out. *Boswellia serrata* is self-incompatible and self-pollen tubes are inhibited son after their entry into stigma. Self-pollen tubes develop a characteristic 'isthmus' as a result of enlargement of the tube soon after emergence through the narrow germ pore. Cross-pollinated flowers allowed normal pollen germination and pollen tube growth, and resulted in fruit and seed-set. Under open pollination fruit-set was only about 10%. Although manual cross-pollinations increased fruit set, it was only up to about 20%. Low fruit set appears to be the result of inadequate cross-pollination and other constraints, presumably limitation of available nutrients. The cross pollination resulted in fruits and seeds, while pollen germination is high in self-pollinated pistils. The study eliminates out the wind pollination in the *Boswellia serrata*. The effective pollinators are insect specifically by the giant Asian honey bee (*Apisdorsata*) and *A. ceranav*ar. *indica* (Indian honey bee) (**Sunnichan, V. G. *et al.*, 2005)**.

Chemical constituents

The identification of thirty-five constituents in yellow volatile oil of *Boswellia serrata* done by hydrodistalliation of bark of *Boswellia serrata*. The *Boswellia serrata* bark oil prevalently contains monoterpenoids which includes α-Pinene (73.28 %),

β- Pinene (2.05 %), *cis*-Verbenol (1.97 %), *trans*-pinocarveol (1.80 %), borneol (1.78 %), myrcene (1.71 %), verbenone (1.71 %), limonene (1.42 %), thuja-2,4(10)-diene (1.18 %) and *p*-cymene (1.0%), while α -copaene (0.13 %) was the only sesquiterpene identified in the oil **(Kasali, A.A. *et al*., 2002)**

The oleo-gum-resin have major fraction of higher terpenoids (25-30%). The confirmed the structure of methyle ester of acetyle- β- boswellic acid found in 1995. In addition to Boswellic acid, several other tri-terpenoid have also been isolated from the gum resin. This compound includes α- amyrins, 3 hydroxyl urs-9, 11-keto- α- boswellic acid, 11- dien-24-oic acid (**Handa, S.S, 1995)**. Tetracyclic triterpenoic acid compound also found in *Boswellia serrata* essential oil (**Pradhy, R.S. *et al*., 1978)**.

Gum production

Boswellia serrata is a gum yield plant species frequently found in the tropical dry deciduous forest patches of India, having medical values. The comparative studies of gum producing capacity and find out a relationship between the girth size and gum producing capacity of these two plants. The result indicates that the plant was found to attain gum producing ability reaching a girth at breast heigh of 38.1 cm. the gum producing capacity get stabilized after attaining a girth of 86 cm (**Mishra, S. *et al*., 2012)**.

Germination studies

The study on seed germination or a threatened endangered medical plant species *Boswellia serrata* was conducted**.** The study was aim to develop protocol for seed germination of *Boswellia serrata* and also effect of different pre-treatment on seed. In this investigation fruit of species were collected from trees growing in natural environment in Pune and nearby area with help of forest department research garden Pune. In experiment with pre-treatments such as hot water, GA_3, IAA, KNO_3, H_2SO_4 and Thiourea were given. The hot water treatment was conducted for 15 minutes and 30 minutes at 85°C, followed by several washing. In case of hormone GA_3 500 ppm and 750 ppm for 36 hrs and IAA 500 ppm and 750 ppm are used. The pre-treatment with 1% of KNO_3 and Thiourea also perform in which seed are soaked in solution for 15 and 30 minutes. Similar treatment given to H_2SO_4 solution for 15 min & 30min. Mechanical scarification is also conducted because it's a quickest and economical method. The results indicate that the treatment with hot water for 30 min show 63 percent seed germination. The mechanical scarification shows results of 68 percent seed germination against 20 percentage of seed in control. The H_2SO_4, 1 percent thiourea and 1 percent KNO_3 pre-treatment show 75 percent, 76 percent and 78 percent of seed germination respectively when seed soaked in solution for 30 min. The highest rate of germination appeared in hormonal treatment of GA_3 and IAA 750 ppm for 36 hours. The 88 percent seed germinate in GA_3 and 83 percentage in IAA. The Table mentioned below shows germination at different days **(Khan, M.R., 2015)**.

The propagation of *Boswellia serrata*, also done through seed. The fruit are directly collected from trees and sterile seed was quash by immersing them in water where they will float. The selected seed were sown immediately and warm water pre-treatment was given for 24 hours. The seed show germination after 7-15 days and it can be transplanted after 10-12 weeks. The cutting propagation shows 80% of success rate. **(Bedi, Y, et al., 2011)**.

The conducted study over different forest plant species which are available in Uttarakhand region for showing their improved nursery practices. They collected *Boswellia serrata* seed in the month of June. Through propagation methods, they show very good germination result about 60-65%, after 10-12 days of sowing under the shade net. The polybags seedlings show high mortality rate and low morality rate is observed through vegetative propagation of branch cutting **(Rawat, R.B.S, et al., 2015)**.

Propagation by cutting

The propagation of *Boswellia serrata* done through cutting. In this 10 and 180 cm of cutting are buried in the ground at around 50 cm depth, approximately two months before rainy season.It shows 80 percent success rate **(Bedi, Y. et al., 2011)**.

The study on clonal propagation of depleted threatened species *Boswellia serrata* Roxb. through branch cuttings was conducted. This experiment was performed to standardize the propagation technique of the species transferable to nurseries. The poor fruiting (2.6 to 10 percent) was observed under open pollination, inadequate production of viable seeds and scanty seed germination (10–20 percent). That's become one major people of the plantation of species.

So, they design protocol for clonal propagation. The branches and mature fruits were collected from trees of *Boswellia serrata* Roxb from Kawardha forest division, Chhattisgarh, India in the month of April (1st week). From each tree, five cuttings of 25 cm length and different thickness (1–2 cm diameter) were prepared and after that surface sterilization with Bavistine fungicide. In next step those were treated with Indole-3-Acetic Acid (IAA) and Indole-3-Butyric Acid (IBA) of 500 ppm, 1000 ppm, 2000 ppm and 4000 ppm concentration respectively. The 25 cm long sized cuttings show no growth or differentiation after 50 days of planting. All planted seeds germinate and grow but not more than the state of small plantlets. In another propagation, Three out of five 1 m length branch cuttings of thick diameter survived and first bud was initiated after 12 days of planting. After 22 days, first leaf differentiation was observed, shoot proliferation was observed after 47 days. After 65 days of planting the establishment of rooting was confirmed. The successful rooting from the large size (thicker >4 cm and long >1 m) branch cuttings and small number of cuttings also shows positive response **(Vaishnav, V &Janghel, U. 2018)**.

Plant tissue culture technique

The *in-vitro* propagation procedure of *Bosweillia serrata* Roxb was developed using cotyledonary node segments. On average 4 shoots per node were development on Murashige and Skoog's (MS) medium containing 0.5 mg dm^{-3} 6-benzylaminopurine (BAP) and 0.05 mg dm^{-3} Naphthalene Acetic Acid (NAA) within 22 days. Shoots cutting could be rooted on MS medium containing ¼ salts, 1% saccharose, and a combination of 0.5 mg dm^{-3} IBA and 0.25 mg dm^{-3} IAA. For prevention of browning of culture antioxidants (PVP) and ascorbic acid is added in media. Seedlings was grown on MS medium and Cotyledonary nodes was used because it is better explants than epicotyledonary nodes for shoot induction. The cotyledonary nodes inoculated on MS medium without growth regulator produced no shoots. The kinetin was given to culture at lower concentrations (0.1 - 1.0 mg dm^{-3}) which induced 2 shoots per node with a maximum length of 1.5 cm in 22 days after inoculation. Increased concentrations of kinetin (5.0 mg dm^{-3}) could not enhance shoot multiplication. BAP when used individually produced 6 - 8 shoots per node at lower concentration (0.5 - 1.0 mg dm^{-3}). A maximum of 15 shoots per node (1.5 cm length) could be produced on MS medium containing 0.5 mg dm^{-3} BAP in 44 days of inoculation (with one subculture of 22 days). Higher concentrations of BAP produced lesser number of shoots. For improvement in shoot elongation, BAP was combined with kinetin in different concentrations. And cytokinins also combined for improvement in average shoot length upto 3.5 cm on 0.5 mg dm^{-3} each of cytokinins but there was no improvement shown in number of shoots/ nodes. NAA is better than auxin as compared to IAA to help elongation of shoots upto mean length of 3.9 cm. It was observed that medium containing 0.5 mg dm^{-3} BAP and 0.05 mg dm^{-3} NAA was best combination result in which 13 shoots (length 3.9 cm) could be produced per node and 90 - 100 shoots were obtained in 88 days (involving 3 subcultures). NAA is also help in later stages of shoot growth. The antioxidant also prevents the culture from browning which affect the health and growth of shoot. The rooting stage was conducted with three type of auxins such as NAA, IAA and IBA in which only IAA and IBA inducing rooting in the shoots in the concentration range of 0.5-2.0 mg dm^{-3}. The 50 percent of shoots shows rooting in 30-35 days on medium which contain 0.5mg dm^{-3} IAA. The maximum (40 percent) rooting response observed with 1.0 mg dm^{-3} IBA in medium. Further rooting was improved by the combination of IAA (0.5mg dm^{-3}) and IBA (0.25 mg dm^{-3}) in the rooting medium and maximum 80 percent of rooting observed in shoots with reduce in concentration of salt to $1/4^{th}$ and saccharose to 1%. Hardening and acclimatization of obtained plant from culture bottle showed 70 percent survival at pot level. It was observed that without saccharose, plant shows stress, compelling to become partially autotrophic (**Purohit, S.D. *et al.*, 1995)**.

The study was conducted to develops an efficient protocol for development of seedlings through plant tissue culturing. Researcher took experimental mature green fruits naturally from growing trees on hillock in Vetal hills in Pune city. In this experiment, collected seed was used in study before that seed was sterilized and cleaned with sterilized water multiple times. By mechanically cutting on fruit wall and seed coat by using sterile blade, embryos were exercised out aseptically. This study also shows the effect of wet heat treatment, acid scarification and plant growth regulator. Researcher also check the Embryo viability by using Tetrazolium (TZ) test. The viability of mature was observed as 80 percent embryos elongated and grow in the medium. In this investigation dry seed are also taken and dry seeds show only 4 percent of germination. The different concentration of sucrose was given to dry fruits but no sign of germination

appeared. However, the data was obtained from green seed shows 91 percent of germination. Among these germinated embryos, 64 percent developed into seedlings and 36 percent failed to develop into seedlings. The different types of media did not show any significant response in the embryo germination. But different concentration of sucrose show promotion in germination. The antioxidant PVP did not induce seed germination in embryos obtained from dry seeds. But there was an increase in germination in green embryos (96 percent) and 82 percent in seedling development. In the presence of 200 mg l^{-1} PVP, the optimum growth of embryo and less browning of root and shoots was observed. As compared to control experiment, 96 percent germinated embryos produce longer shoots (2.3±0.1) and roots (1.6 ± 0.1 cm) after four weeks. The embryo obtained from the dry fruit treated with wet heat, acid scarification, auxins, cytokinins and GA_3, did not show any sign of germination when it transferred to nutrient medium. On other hand, green mature seeds show maximum frequency of germination that was up to 91 percent on MS medium lacking PVP and 96 percent on MS medium containing PVP. The development of germinated embryos into seedling was 64 percent and 82 percent respectively. Different culture media, type of growth regulator and their concentration and PVP concentration in medium helps the seedling in survival and now it transferred to soil and field condition. All well-developed seedlings were transferred directly to soil and showed yellowing of leaves, followed by defoliation within 5-7 days. However, 94 percent of the seedlings derived from *in vitro* germinated embryos on MS medium containing 3 % sucrose together with PVP and lacking of growth regulator survived when transferred to the sand soil mixture (1:1). They were further maintained for four weeks under glasshouse conditions. After 4 weeks of glass house acclimatization, 500 seedlings were transferred to field conditions. Among these 94 percent seedlings survived and were morphologically identical to those that grew in the seed source plantation area **(Ghorpadel, R. P. *et al.*, 2010)**.

The reported protocol that can be used for conservation and exploitation of in vitro production of *Boswellia serrata* was based on Micropropagation and non-steroidal anti-inflammatory and anti-arthritic agent boswellic acid production in callus culture of *Boswellia serrata Roxb*. The root, stem, cotyledon and leaf explants *Boswelllia serrata* was tended to produce roots with little or no callus growth on medium containing 2.5 µM to 10.0 µM IAA (Indole-3-Acetic Acid) and 2.5 to 5.0 µM NAA (α-Naphthaleneacetic acid); while nodal explants responded for shoot regeneration on medium with 0.5 to 10.0 µM BA (6-Benzyladenine), Kin (Kinetin) and TDZ (Thidiazuron). In adding 2.5 µM BA with 200 mgl^{-1} PVP (Polyvinylpyrrolidone) was highly effective for induction of shoot were shown, with increasing mean number of shoots per explant and shoot elongation as well. A maximum of 8.0 shoots/cotyledonary node and 6.9 shoots/leafy node explant was produced in 91 percent and 88 percent cultures respectively, which is statistically better than Kin and TDZ. The shoots were treated with 2.5 µM IBA showed highest average root number (4.5) and the highest percentage of rooting (89 percent). The shoots were treated with 1.25 µM NAA shows average root number (3.0) and highest percentage of rooting (47 percent). (**Nikam, T. D. *et al.*, 2013**).

Uses

1. Anti-Inflammatory

Boswellia serrata show effect on acute inflammatory parameter and tumour necrosis factor-α in complete freund's adjuvant-Induced animal model of Rheumatoid arthritis (**Kumar, R. *et al.*, 2019)**. The Rheumatoid arthritis (RA) is an inflammatory condition of synovial tissue leading to the destruction of joints and muscles pain **(Lee DM and Weiblatt M.E, 2011).** When this tissue remains constantly inflamed, it leads to deformity by loosening joint ligaments and joint destruction by eroding nearby cartilage and bones **(Matsumoto, I *.et al.*, 2002).** The currently available therapy for RA includes nonsteroidal anti-inflammatory drugs corticosteroids, disease-modifying anti-rheumatic drugs but all of these have harmful effect. The *Boswellia serrata* as herbal drug, have been reported to possess anti-inflammatory activity. The experimental study aims to evaluate and study the anti-arthritic activity of *Boswellia serrata* extract (BSE) in Complete Freund's adjuvant (CFA)-induced arthritis in rats. In this investigation 36 Wistar rats was divided into six equal groups for study of RA. RA was induced by intradermal injection of 0.1 ml CFA in hind paw. Body weight, ankle diameter, paw volume, arthritic index, tumor necrosis factor-α (TNF-α), and histopathological examination were assessed. The effective dose of BSE was found at 180 mg/ kg that show statistically significant improvement in body weight and decrease in ankle diameter and arthritic index ($P < 0.05$) and insignificant change in paw volume ($P = 0.056$) was observed. This improvement was comparable with Indomethacin. The level of

TNF-α did not show any statistically significant change (P = 0.076). The result of histopathological also exhibited a reduction in inflammatory parameters (**Kumar, R. *et al.*, 2019)**.

Physical burns and their consequences are one of important cause of death around the world. Healing of burning wound is a process which is performed by the coaction of tissues, cells and different factors **(Brunicardi FC and Schwartz SI. 2006)**. The healing of wounds takes times and it is delayed because of the inflammation or the insufficient blood vessel formation. Use of herbal medicines is documented against the burning wound. The World Health Organisation (WHO) estimated that approximately 80% of the population of several African and Asian country use herbal medicines in primary health care **(Sahinfard, N. *et al.*, 2015)**. The performed study over *Boswellia serrata* as herbal medicine in promoting burn injuries healing in laboratory mice. The *Boswellia serrata* has anti-inflammatory activity and also speedup the blood vessel formation in body. In this experimental investigation, the burn wound was created by placing a 1.5cm^2 hot plate on the back side of lab mice. Investigation is carried over 54 mice and divided into four group of equal members i.e. 14 mice in each group. The *Boswellia* 2%, vaseline and silver sulfadiazine two times per day for 21 days treatment were given to three group of mice and the last group of mice taken as control group. Experimental result indicates that the 2% *Boswellia* shows 95.29 percent wound recovery on day 21 as compared to Vaseline (80.76 percent), Silver sulfadiazine (76.24 percent) and Control (75.30 percent). The histopathological evaluation of sample showed that, In assessment to the control group, the group acquired *Boswellia* better in reconstruction of the epithelial cells, the fibrotic reaction was more extended and less bleeding was noticed within burn wounded area on day 7 and 14 **(Sahinfard, N. *et al.*, 2015)**.

2. Anti-Diabetic

Boswellia serrata is one of the herbal and medicinal plants that used to treat various diseases, including diabetes. The periclinal evidence against antidiabetic effects of *Boswellia serrata* gum resin. They evaluated antihyperglycemic and lipid-lowering effects of *Boswellia serrata* gum resin in type 2 diabetic patients. This investigation was carried over 56 diabetic patients that was randomly selected. The dose of 250 mg of the *Boswellia serrata* gum resin or placebo twice daily for 8 weeks in addition to their routine antidiabetic treatments. Throughout the investigation a considerable reduction after the intervention in the field of fasting blood sugar, glycosylated haemoglobin, and triglyceride in the *Boswellia serrata* gum resin group, no significant difference was observed in all outcome measures between patient. The current study showed that 8 weeks of complementary use of *Boswellia serrata* gum resin with a daily dose of 500 mg had no better glucose and lipid-lowering effect than placebo in diabetic patients **(Mehrzadi, S. *et al.*, 2018)**.

3. Anti-Microbial

The *Boswellia serrata* extract exhibit anti-bacterial and anti-fungal activities **(Weckesser, S. *et al,* 2007)**. In another study on *in-vitro* screening of antimicrobial activity of *frankincense* of *Boswellia serrata*. Clinically isolated Gram positive (*Bacillus subtilis*, *Streptococcus pneumonia* and *Staphylococcus aureus*) and Gram negative (*Escherichia coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Proteus vulgaris*, and *Enterobacter aerogenes*) microbes were treated different concentration (25, 50, 75 and 100 mg /ml). Inhibition zones were evaluated and compared with antibiotic Ciprofloxacin (5µg/ml) as positive control and DMSO was used as a negative control. Results demonstrated antimicrobial property of *Boswellia serrata*. The highest antimicrobial activity was observed in zone of inhibition *E. coli* (21.87±0.98) and the lowest effect was on witha zone of inhibition (11.67±1.00 mm). In another hand, Standard result showed highest activity against *E. aerogenes* (30.27±1) and lowest activity against *S. pneumoniae* (20.07±0.74). The sequential order of inhibitory activity of extract against different microorganisms is: *E. coli*> *S. aureus*> *B. subtilis*> *S. typhi*> *K. pneumoniae*> *S. pneumoniae*>*E. aerogenes*> *P. vulgaris*. The order of inhibitory activity of standard against different microorganisms are summarized as *P. vulgaris*> *E. coli*> *S. aureus*> *E. aerogenes*> *P. aureginosa*> *B. subtilis*> *K. pneumoniae*. In this experimental assay shows extracts of *Boswellia serrata* showed antimicrobial activity comparable with standard. It can be used in prevent the bacterial infested diseases caused by the studied bacterial strains and in drug development **(Ismail, S.M. *et al.*, 2014)**.

4. Anti-Viral

The β-boswellic acid (BA) are the important active constituents of the *Boswellia serrata* oleo-gum-resin (BSE) of the plant *Boswellia serrata* which has been used in treating diverse skin alignments infection. To utilize its medicinal potential, the anti-viral property of β-boswellic acid against Herpes Simplex Virus 1 (HSV-1) were investigated. Under this experiment, Cytotoxic Concentration (CC_{50}) and antiviral activity is analysed by plaque reduction and MTT assay, followed by the determination of median concentration (EC_{50}). The results indicate that BSE and BA potently inhibited wild-type and a clinal isolated HSV-1 (EC_{50} 5.2-6.2 and 12.1-14.63 µg/ml), with nearly-complete inhibition (EC_{99}) at 10 and 30 µg/ml, respectively. The inhibitory effect of BA and BSE was significant at 1h post-infection and effective up to 4h. Based on investigation, they analysis the inhibition of NF-κB which is essential for virus replication and observed significant down regulation of NF-κB and p38 MAP-kinase activation, with reduced expression of tumour necrosis factor (TNF)-α, Interleukin (IL)-1β and IL-6, involved in scheming NF-κB signalling. Their obtained results support the ethnomedicinal use of BSE in skin infection by HSV-1 **(Goswami, D. *et al.*, 2018)**.

Similar types of anti-viral investigation are was conducted**.** In this experiment, two pharmacological active compound of curcumin and *Boswellia serrata* gum resin extract (AKBA - acetyl-11-keto-β-boswellic acid) were tested against Chikungunya virus (CHIKV). In many developing countries chikungunya virus infects millions of people and cause chikungunya fever. Chikungunya virus is a mosquito-transmitted alphavirus. The curcumin and *Boswellia serrata* gum resin compound inhibited CHIKV infection and blocked the entry of CHIKV Env-pseudotyped lentiviral. The both compounds show antiviral activity, so they might be used as lead structure to develop more effective antiviral drug (**von Rhein, C. *et al.*, 2016)**.

5. Anti-Tumour

In the current scenario, traditional herbal medicines and their phytoconstitutents draw attention of many researcher because of their usefulness in complementary as adjuvant to chemotherapy in various cancer. The triterpenoidal fraction present in *Boswellia serrata* which contains boswellic acid is responsible for the antitumour properties **(Khan, M.A *et al,* 2016)**.

The first examine of boswellic acid against leukemia, which include four types of triterpene acid named as β-boswellic acid, 3-*O*-acetyl-β-boswellic acid, 11-keto- β-boswellic acid and 3-*O*-acetyl-11-keto-β-boswellic acid. All four chemical compound evaluated for their antileukemic activity *in vitro.* The different doses of these compound were evaluated against leukaemia and it inhibited the synthesis of DNA and RNA, as well as protein formation in human leukemia HL-60 with IC_{50} (half maximal inhibitory concentration) range of 0.6 to 7.1 µM. Among all these screened compound, 3-*O*-acetyl-11-keto- β -boswellic acid induced the inhibitory effects on DNA, RNA and protein synthesis with IC50 values of 0.6, 0.5 and 4.1 µM, respectively. this compound generates irreversible effect on DNA synthesis. The compound inhibited the HL-60 cell proliferation significantly, without affecting the viability of cell **(Shao, Y. *et al.*, 1998)**.

The formulation of Pentacyclic triterpendiol (*Boswellia serrata*) into solid lipid nanoparticles (SLNs). SLNs showed remarkable improvement in antitumor potential i.e 40-60% than the parent drug as evident IC_{50} values, proapoptotic protein expression, extent of apoptosis and DNA damage and Poly (ADP) Ribose Polymerase (PARP) cleavage in HL-6 cells **(Bhushan, S. *et al.*, 2013)**.

The investigation conducted on *in vivo* antitumour and *in vitro* cytotoxic activity of 3-α-acetyl-11-keto-α-boswellic acid (AKBA) in chemoresistant androgen-independent PC-3 prostate cancer cell. AKBA caused mitochondrial cytochrome c release and DNA fragmentation, and also inhibited NF-κB signalling through IKK. AKBA was active at a very low dose of 10 µM. Apoptosis is also induced apparently through activation of caspase-3 **(Syrovets, T. *et al.*, 2005)**. AKBA also shows its activity, *in vivo* anti-proliferatory and proapoptotic activity in prostate cancer cell xenotransplanted on to the chick chorioallantois membrane **(Buchele, B. *et al.*, 2006)**.

6. Immune System Boost

The tested humoral antibody synthesis in the serum from mice treated with sheep erythrocytes by determining the hemagglutinating antibody titres. The result was found that a single oral dose of a mixture of β-boswellic acid (BAs) (50–200 mg/kg) on the day of sensitisation produced a dose related reduction (10.4–32.8 percent) in primary hemagglutinating antibody titres on the fourth day. A significant drop in antibody

production was obtained with 100 and 200 mg/kg doses. On the other hand, the secondary antibody titres were significantly enhanced at lower doses and the effect dose prominent at 50 mg/kg. Azathioprine as a reference compound regulate following the same schedule resulted in only 10.4 percent inhibition of primary antibody synthesis and show no effect on the secondary antibody production. This also used complement fixing technique, it is the method for analysing antigen and antibody titres, oral administration of a mixture containing BAs (25, 50, 100 mg/kg) for 5 days around the time of immunization resulted in a substantial decrease in primary and secondary complement fixing antibody titres at 100 mg/kg **(Sharma, M. L. *et al.*, 1996)**.

The researcher also observed, a marked increase (15.38–26.92 percent) in antibody production on 7th day, when a BA mixture (25–100 mg/kg) was given orally for 5 days systematically for immunization. The effect was more noticeable at a dose of 25 mg/kg than at 50 or 100 mg/kg. The secondary antibody titres were only slightly increased. There are no significant effects on primary as well as on secondary antibody titres by Azathioprine treatment (100 mg/kg). In experimental treatment in mice was initiated 7 days prior to immunization, BAs (25–100 mg/kg) produced a dose related increase (37.93–63.79 percent) in the primary humoral response without significantly affecting the expression of the secondary response **(Sharma, M. L. *et al.*, 1996)**.

They also investigate on the effect of an undefined mixture of BAs on phagocytosis.in this experiment, result shows enhanced phagocytotic function preincubation of peritoneal macrophages of adherent macrophages with different concentrations of Bas (1.95–125g/ml) and observed the maximal effect occurring at 62.25 g/ml **(Sharma, M. L. *et al.*, 1996)**.

Researchers also worked on the complement system consists of a variety of plasma proteins which together attack extracellular pathogens. In this experiment, they studied about activation of the complement system by antigens through classical way or by surface pathogens finally leads to taxis of inflammatory cells, opsonisation of pathogens and destroy of pathogens. The significant results were obtained at the concentration range between 5 and 100 µM, in this range Inhibition of the guinea pig complement system by β-boswellic acid and β -boswellic acid was noticed **(Wagner, H. *et al.*, 1987)**.

The Anticomplementary activities of a mixture of Basin shows, BAs inhibited the in vitro immunohaemolysis of antibody-coated sheep erythrocytes by pooled guinea-pig serum. The classical complement pathway show reduction in immunohaemolysis due to inhibition of C3-convertase. The threshold concentration for inhibiting C3-convertase was observed at 100µg per 0.1 ml diluent buffer added to the assay. The complement system was weakly inhibited by Bas. Thus at least in vitro BAs can suppress the conversion of C3 into C3a and C3b and therefore its proinflammatory/lytic actions **(Kapil, A. and Moza, N. 1991)**.

The studied on the extract of the oleo gum resin of *Boswellia serrata* consisting of AKBA along with other constituents such as KBA and acetyl-β-boswellic acid for anti-anaphylactic and mast cell stabilising activity. They utilized Passive paw anaphylaxis and compound 48/80 as inducer of mast cell degranulation as study model. The extract inhibited passive paw anaphylaxis in rats in a dose-dependent manner (20, 40 and 80 mg/kg, p.o.). In the case of dexamethasone (0.27 mg/kg, p.o.), it taken as positive control for the extract proved to be superior. A noteworthy, dose-dependent inhibition (20, 40 and 80 mg/kg) in compound 48/80-induced degranulation of mast cells was also observed and showing mast cell stabilising activity. The positive control disodium cromoglycate (50 mg/kg, i.p.) afforded maximum protection against degranulation as compared to the extract containing 60% AKBA. The results suggest promising anti-anaphylactic and mast cell stabilising activity of the extract of *Boswellia serrata* **(Pungle, P. *et al.*, 2003)**.

Conclusion

The *Boswellia serrata* is one of important economical forest species. The Boswellia serrata also has religious value in some part of India. The plant had hard wood which is used in the timber industries and its other parts uses as fodder for animals. The oleo-gum-resin is used in cosmetic and perfumery. It is one of most ancient herbs in Ayurveda. The *Boswellia serrata* is recommended for osteoarthritis, juvenile rheumatoid arthritis and soft tissue fibrosis without any side effect. In present scenario, the *Boswellia serrata* chemical constituent also shows anti-cancer, anti-viral, anti-bacterial and anti-inflammatory properties. All these properties of plantincrease market demand in present time which leads to increase in harvesting of tress. Due to increase in market demand, the population of *Boswellia serrata* decline tremendously which makes

it endangered species in India. The propagation of tress under natural condition is very low. It is not easy to germinate plantfrom seed. The most effective way for seed germination is, pre-treatment with GA_3 and IAA in 750ppm concentration for 24 hours. The clonal propagation of *Boswellia serrata* through cutting shows 80 percent success rate with 10 to 180cm of cutting were buried in the ground, approximately two months before rainy season. The *In-vitro* propagation of *Boswellia serrata* done by using cotyledonary node segments. The propagation through cotyledon node segment with IBA (0.5 mg dm^{-3}) with IAA (0.25 mg dm^{-3}) shows 80 percent rooting in media. Around 70 percent survival rate is observed at Hardening and accumulation stage. The *in-vitro* germination of plant through zygotic embryo from green mature seed shows highest frequency of embryo germination rate (96 percent). Fully developed seedling was successfully transferred to soil with 94 percent survival rate. The micropropagation method were used for culturing cotyledonary node and leaf node of *Boswellia serrata*. The response for roots, shoots and callus formation were varied in cotyledonary and leaf node explant from *in-vitro* germinated seeds, If inoculated on MS medium along with cytokinins and auxins alone or together. The best result obtained with 2.5 µM of BA and 200 mgl^{-1} PVP shows 91 percent of explant producing shoot. Along with leaf node, also shows best result with BA (2.5 µM) and 91 percent of explant producing shoots. The shoots treated with 2.5 µM IBA showed the highest percentage of rooting i.e. 89 percent and well rooted plantlets were acclimatized and 76.5 percent of the plantlet showed survival in transfer to field condition

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DOI:10.22192/ijarbs.2021.08.05.005	

How to cite this article:
Anuj Soni and N.K. Bohra. (2021). *Boswellia serrata* - Propogation and uses - A Review. Int. J. Adv. Res. Biol. Sci. 8(5): 35-46.
DOI: http://dx.doi.org/10.22192/ijarbs.2021.08.05.005