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An overview of resurrecting herb 'Sanjeevani' (*Selaginella bryopteris*) and its pharmacological and ethnomedicinal uses

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Abstract
Resurrection plants are nature's wonder with a unique water stress tolerant capacity. In recent years some of these species has drawn attention of scientific community to study their physiological mechanism and genetic makeup during water stress and hydrated conditions with a possibility to utilize them as a viable genetic tool to develop drought tolerance species to combat global climate change. This study is an overview of resurrection plant *Selaginella bryopteris*, a pteridophyte with lithophyte habitat, its distribution, characteristics, constituents and physiological mechanism during dehydrated and rehydrated conditions. Most of the characters except few find this species close to the mythological 'Sanjeevani booti'. Further, its scope in the field of genetic engineering, pharmacology and medicines are also analysed. More research is required to identify various other similar plant species with a potentiality to prepare drug formulations to fight chronic diseases and to develop engineered plant with drought tolerance capacity.

Keywords: Resurrection plants, sanjeevani, physiological mechanism, pharmacology, ethnomedicine

1. Introduction
Selaginella bryopteris (L.) Bak, commonly known as 'Sanjeevani', a pteridophyte with remarkable resurrection capabilities, being able to survive even without water reported to be distributed in Kailas and Rishabh mountain in the Himalayan region, and also from Dronagiri Hills Joshimath and Kumaon [1] and Garhwal in Uttaranchal. Some studies reported the species from Arawali Mountain terrains running east to west [2], Uttar Pradesh, Orissa [3] and even in Madhya Pradesh from Nimar [4] Satpura Hills mainly Hoshangabad, Amarkantak, Jabalpur, Mandla, Chhindwara, Betul and Sehore regions [5]. The herb does not die, even under water stress condition and just curls up and loses colour, turning to brown in the absence of moisture and regain its original color within hours of coming in contact with water (Fig. 1).
In recent years several investigations has been carried out to correlate this species with 'Sanjeevani booti' (Life giving herb) a wonder herb mentioned in great epic 'Valmiki Ramayana' [3, 6, 7] that exists in Mount Rishabha Indian Himalayas with unique bioluminescence and resurrection property. According to the available literature the plant existed in four categories Mrithasanjeevani (Sanjeevani that restores life), Vishalyakarini (arrow remover), Savarnyakarani, (color restorer that reset fractured bones and enhances skin glow) and Sandhanakarani, (fame restorer) (Valmiki Ramayana, Yuddh kand- Sarga 74).
The archeological sciences believes the existence of the herbs as a group of ferns known to belong to Carboniferous period, about 300 million years back, and were the first vascular plants pioneered on the earth [3]. The evaluation of a series of herbs existing in hilly tracts with lookalike features [8] makes this species closer to the original one. Although several researcher strongly condemn this hypothesis as the species do not exhibit bioluminescence property [7], however the distribution, morphology and physiological similarities increases possibility for this pteridophyte and other allied species [8] to make ease for the existence of miracle herb 'Sanjeevani booti'.

a

b

Fig 1: Dry (a) and hydrated (b) fronds of S. *bryopteris* collected from satpura region, Madhya Pradesh

2. Chemical composition and Resurrection properties

2.1 Chemical composition

The resurrection plants generally survive under water stress conditions showing various adaptations such as increases in sugar contents sucrose, galactinol and raffinose that prevent death of the tissues from dehydration and osmotic stress. These plant also contains several types of sugar acids and sugar alcohols protecting them from detrimental effects of cell destruction [9]. The herb shows remarkable variation in chemical compositions. The species in Northeast India contains two known and three new bioflavonoids, whereas in southern India eleven known and one new bioflavonoids of the amentoflavone- and hinokiflavone-type were isolated [10]. However, the important natural compounds in this species are characteristic flavonoid-dimers, 'biflavonoids' [6]. Spectroscopic technique circular-dichroism determined absolute configurations of chiral biflavonoids with flavanone subunits [10] and Tandem mass spectrometry isolated tetrapeptide from the fronds of this plant [11].

2.2 Water stress tolerance capacity

Resurrection plants have capacity to tolerate desiccation of vegetative tissues [12] and survive even loss of most of its cellular water (>95%) [13], regain structure after rehydration [14, 15] depending on the regulated expression of various genes [14]. Resurrection plants are rare in Pteridophytes [16] showing herbaceous life-form distributed in deserts or temperate regions. Several studies have been carried out to detect how this plant adapts and survives in the dry phase. Most species of *Selaginella* survive severe drought conditions due to the presence of a unique disaccharide, trehalose [6]. The cellular mechanism studies reveals the expression of stress-associated genes and high levels of protective metabolites that express themself in the absence of stress, and also to transcriptome and metabolome reconfigurations that occurs instantly during drought stress phases, making it to tolerate extreme drought stress condition [9]. Several other species tolerate desiccation using a wide range of metabolites like aromatic amino acids, osmoprotectant betaine and flavonoids. These species shows higher levels of c-glutamyl amino acid that are linked with glutathione metabolism used in the detoxification of reactive oxygen species, followed by nitrogen remobilization resulting rehydration [17].

2.3 Impact on physiological and biochemical processes

Resurrection plant shows a unique morphological, biochemical, physiological, and genetic protective mechanisms to resist under extreme desiccation [18]. The plant shows physiological and biochemical changes during desiccation and rehydration. Most of the proteins that are synthesized during dehydration are present in chloroplasts and plays significant roles in the protection of photosynthetic structures and recovery in resurrection species [19]. During this phase the net photosynthesis inhibits, PSII shows more photochemical efficiency, dark respiration proceeds even at 10% relative water content, but burst after rehydration, thus requiring protection mechanisms [20]. Proteome studies of detached fronds reveals differentially expressed with highest quantity of transport, targeting and degradation proteins during desiccation phase, and a very little change in electrolyte leakage, dehydrated and rehydrated fronds. The plant performs only respiration and there was decline in Fv/Fm values and fluorescence and photosynthesis activates after rehydration, which seems as a physiological advantage of this resurrection plant [21].

Desiccation shows a very little variation in chlorophyll content, decrease in sucrose and starch contents, however reactive oxygen species, lipid peroxidation, proline deposition, anti-oxidative enzymes like ascorbate peroxidase, superoxide dismutase, and catalase and soluble acid invertase increases. The plant further exhibits complete recovery after rehydration even in these circumstances of photo inhibitory or thermal injury to PSII making it tolerance during drought stress [20]. The intermediates of the processes like glycolysis, gluconeogenesis and tricarboxylic acid cycle, and antioxidant vanillate along with sugar alcohols, sugar acids and polyunsaturated fatty acids, increases in the hydrated state. During dry state condition nitrogen-rich and nucleotide catabolism products (e.g. allantoin), UV-protective compounds like 3-(3-hydroxyphenyl) propionate, naringenin and apigenin, and γ-glutamyl amino acids like citrulline, and lipids like choline phosphate are produced more playing a crucial role in membrane hydration and stabilization [22]. The research on desiccated Selaginella bryopteris plants using two dimensional gel electrophoresis identified 500 protein spots and among these nine of them shows significant changes in abundance, eight were up regulated and one being down-regulated thus protecting photosynthetic activity [23].

3. Scope in genetic engineering

Resurrection plants the desiccation tolerance involves an integration of molecular genetic mechanisms, antioxidant and metabolic systems [24]. This specificity can be exploited using molecular biological engineering strategies for improving plant drought tolerance in crops [25]. The plants also have potentiality to be exploited in drug industry. Most predictable, during desiccation phase the science of genetic engineering can be employed to synthesize secondary compounds from

the plant that possess medicinal properties. However, this is mere a hypothesis whether the extracted compound alone or engineered genetically in combination with other compound to be an efficient drug [9].

4. Pharmacological uses of *S. bryopteris*

This epilithic plant is a wonder herb with varied pharmacological uses. During desiccation phase the metabolites like sugars, phenolic compounds, and polyols present in the frond cell helps to protect against abiotic stresses and increases oxidative stress tolerance and these properties can be efficiently exploited to prepare novel drug with antibacterial, anticancer, antifungal, and antiviral activities and can also be used in cosmetic industries [9]. The herb also possesses chemo-preventive and anti-carcinogenic property [26, 6]. Chemoprevention biomarkers like proliferative index and status of cell-cycle regulatory protein assessment reveals chemopreventive potential of this herb in 7,12-dimethyl benz (a) anthracene-mediated skin papilloma agenesis and benzopyrene-induced lung carcinogenesis resulting unperturbed cell-cycle regulation, inhibition of DNA fragmentation, maintenance of intracellular antioxidant defence, prevention of stress-induced senescence, anti-inflammatory activity, and genoprotective effects against methyl isocyanate carcinogenicity [26].

The studies on neuromodulator propensity of S. delicatula by chemically inducing neurodegenerative diseases in rodents and Drosophila that modulates redox status and inhibits mitochondrial functioning making it a possible candidate in treating oxidative stress-mediated neurodegenerative diseases like Parkinson's disease [6]. The researches have also concluded that 10% aqueous extract of *S. bryopteris* on cultured insect Spodoptera frugiperda (Armyworm) and mammalian mouse macrophage protects cells against oxidative stress-induced cell death 41% and 78%, and heat-induced cell death 40-50%, respectively, thus making it a promising drug against stress-induced complications mainly due to heat shock [27]. The herb with biflavonoids like amentoflavone and hinokiflavone also possess antiprotozoal activity against *Plasmodium falciparum, Trypanosoma cruzi, Trypanosoma brucei rhodesiense* and *Leishmania donovani* strains [28].

5. Ethnomedicinal and other uses

The herb possess unique ethnomedicinal properties and is generally used to treat heat stroke and burning sensation during urination [29] Gonorrhoea [5], menstrual irregularities wounds, uterine disorders and other internal injuries [29] minimize labor pain, Jaundice [6, 29] skin cell's damage due to sun's rays [9] chronic trachitis [6] stomach disorders [30, 3] and human growth tonic [3].

The Indian tribal communities mainly use it as a strength tonic in improving fitness and to extend lifespan [2, 29]. The tribal women of Gond, Bhil, Korku, Mauria, Maria, Baigas, Bharia, Bhatara and Paria, communities of Pachmarhi in Madhya Pradesh uses pteridophytes specially *Sanjeevani* for gynecological problems in treating gonorrhea and other venereal diseases like spermatorrhoea and leucorrhoea [31]. In various part of this region the dried plant along with tobacco, are smoked by tribal people for inducing hallucinations used as witch craft and worship [32]. In hilly tract in Nagaland state in North Eastern India the tribal people uses this plant to cure liver disorder and epilepsy [33]. The Baiga Tribes of Amarkantak region, of Madhya Pradesh uses leaf paste in stomachache and urinary tract inflammation in children and gonorrhea, spermatorrhoea and leucorrhoea in adults [34]. The species is also ecologically significant as evidence from the studies conducted on various lycophytes in Eastern and Western Ghats regions showing arbuscular mycorrhizal colonization thus contributing in restoration of natural ecosystems [35].

6. Conclusion

It can thus be concluded that *S. bryopteris* with unique resilience property has a wide pharmacological uses and can be well exploited to prepare drug formulations for certain incurable diseases. There are also the possibilities of its use as a viable genetic tool to be engineered into drought tolerant plant for combating global warming and climate changes phenomenon.

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