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Therapeutically Important Phytochemicals and Traditional Uses of *Satyrium Nepalense* D. Don: A Comprehensive Review

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Abstract: Orchids have been highly valued for their aesthetically pleasing blossoms, as well as their therapeutic properties. *Satyrium nepalense* D. Don is a terrestrial Orchid that is distinguished as the only species with two varieties: *Satyrium nepalense* var. ciliatum, which has pink blossoms, and *Satyrium nepalense* var. nepalense, which has white flowers. This orchid is remarkable because it is among the few species found in both the Himalayas and the Western Ghats. This orchid is versatile, offering medicinal, nutritional, and cosmetic advantages as well as a pleasant perfume. Plant juice is used to treat wounds, fever, and cuts, whereas dried tubers are used as a preventive measure against dysentery. Their existence is jeopardized by natural factors, such as habitat degradation from undulating terrain and landslides induced by excessive precipitation. Anthropogenic development projects have fragmented and destroyed ecosystems, leading to the displacement of species. The plant's survival is occasionally questioned due to overgrazing and indiscriminate collection for fodder in certain areas. The multiplication of this species using conventional and micropropagation techniques, together with its reintroduction into natural habitats and specific locations, would constitute a substantial conservation endeavor.

Keywords: *Satriyum nepalense*; orchid; phytochemistry; orchidaceae; pharmacological activity.

1. Introduction

India has a vast collection of undiscovered medicinal plants and a wealth of related information that must be effectively used. The extensive range of species across the nation is closely correlated with significant ecological differences and changes in altitude. Thorough scientific exploration of untapped natural resources and their subsequent commercialization has the potential to provide advantages for everyone involved. It may also play a pivotal role in drug development initiatives [1].

Orchids, which belong to the family Orchidaceae, are the largest, most diversified, oldest, and most unique families of flowering plants. There are approximately 763 genera and 28,000 presently recognized species, accounting for approximately 10% of all angiosperms [2]. Organisms display a wide range of physical characteristics, growth patterns, life cycles, and habitats, often linked to variations in the physiology and physical features of the environment [3, 4].

Orchids can be readily identified from other blooming plants because of their distinct characteristics, including highly modified petals (labellum), zygomorphic resupinate flowers (bent back with the face upright), exceedingly tiny seeds, and fused carpels and stamens. Orchids are found in many climatic settings, from tropical to alpine, making them among the most widely distributed plant species across different latitudes [5].

Epiphytes, terrestrials, and semi- or full parasites are the three primary life forms of orchids. Orchids are the most diverse monocot family, with roughly 1,000 genera and 25,000-35,000 species. Their flowers have a wide range of sizes, shapes, and colors. Orchidoideae, Epidendroideae, Cypripediodeae, Vandoideae, Aspostariodeae, and Spiranthoideae are the five subfamilies of the Orchidoideae family [6].

Most orchids were found in epiphytic environments. Although many orchids are widespread, others are rare and are threatened with extinction. It has also been noted that certain orchid species exhibit high endemism. There is a great deal of variation in the size, color, and form of the orchid blossoms. Fungal symbiosis facilitates the development of the tiny seeds that orchids generate. Numerous factors, including overexploitation, habitat loss, and climate change, pose a danger to the survival and variety of orchids. It is of ethnobotanical importance for orchids [7].

Orchids can be found in both tropical and temperate locations, and their range is extensive. India is one of the hotspots for orchid biodiversity. Many different plant species are found in the Himalayas, the Eastern and Western Ghats, and the northeastern states of India. Among these species are orchids, many of which are unique to the region. India is home to approximately 1,300 orchid species across 180 genera. In India, several orchid species are used both medicinally and as nourishment for various ailments. Numerous orchid species, including those used in Ayurveda, Unani, and Siddha, are used as treatments for certain diseases or conditions in traditional medical systems [8, 9].

Despite improvements in our knowledge of the orchid family, threats to its survival are worsening every day. 948 (3.3%) of the world's orchid species have been classified as endangered on the IUCN Red List of threatened species. Discovering biology, evolution, taxonomy, cytology, chemistry, hybridization, and culture, among other aspects of the family, is receiving considerable attention worldwide. Orchids inhabit a wide range of habitats, including terrestrial, epiphytic, and subterranean environments, and can be found on all vegetated continents. Orchids are not found in polar or arid environments [10]. Similar to the environment, orchids display a wide range of flowering patterns. However, the period of maximal flower abundance is from June to August, with the greatest number of species blooming in July, which is in the middle of the summer. Although orchids have a wide distribution, they are often found in specific local areas and are uncommon [11].

The only known species of terrestrial orchid is *Satyrium nepalense* D. Don. It has two varieties: Satyrium nepalense var. ciliatum, with pink blossoms, and Satyrium nepalense var. nepalense, with white blossoms. One of the multipurpose orchids is the fragrance orchid, which has therapeutic benefits and may be used as a nutritional supplement [12].

2. Literature Search Methods

Scientific search engines like Scopus, Science Direct, Web of Science, Wiley Online, the Scientific Electronic Library Online (SciELO), Google Scholar, Springer Link, ISI Web of Science, PubMed, and SciFinder, as well as a number of patient offices (e.g., WIPO, CIPO, and USPTO), were utilized in collecting all of the literature surveys.

3. Plant Profile

3.1. Habit and habitat.

S. nepalense has great medicinal value and has been extensively obtained from its native environment, which has led to a significant decline in natural populations [13]. To prevent *S. nepalense* from becoming extinct in the future, this study aimed to establish an economical in vitro multiplication procedure for this species. In addition to aiding the preservation and growth of this significant medicinal orchid, this procedure may be able to meet the growing needs of the pharmaceutical industry.

3.2. Ecology.

S. nepalense is a widespread species. It is not an extensively trafficked herbal item; however, for long-term conservation and use, the local community must be aware of sustainable harvesting practices. The two biggest concerns are overgrazing and habitat loss caused by human activities. People primarily eat the tubers and stems of *S. nepalense*, although they can readily regenerate in their native environment. If plants are removed, the entire colony persists. Mahendran *et al*. [13] described a process for mass multiplication of *S. nepalense* for conservation. These initiatives will assist with both in-situ and ex-situ conservation as well as *S. nepalense* production and use [13].

3.3. Distribution and status.

S. nepalense D. Don., sometimes known as Nepal Satyrium, is found in the Indian Himalayan Region from Shimla eastward, the Khasia Mountains, and the Deccan Peninsula surrounding Travancore generally between 1800-2300 m. It is a remarkable orchid because it is one of the few with a distribution that spans both the Himalayas and the Western Ghats. Furthermore, the genus is found throughout Asia, namely, in Pakistan, India, Nepal, Bhutan, northern and southern India, Sri Lanka, Myanmar, northern Thailand, and China [14, 15].

A specialized microhabitat is required for growth and proliferation. These plants require acidic soil and are frequently encountered in nearly gregarious environments. We have occasionally observed Satyrium var. ciliatum growing in lithophytic habitats, although it is uncommon for var. ciliatum and C. nepalense to coexist in the same habitat [16].

4. Classification of *S. nepalense* D. Don.

S. nepalense is classified as a member of the Plantae Kingdom and belongs to the family Orchidaceae. Order is Asparagales; Phylum Magnoliophyta; Class Liliopsida; Subfamily Epidendroideae; Tribe Coelogyneae; Sub tribe Coelogyninae; Genus *Satriyum* [16].

5. Synonyms of *Satriyum nepalense* D. Don.

Satriyum nepalense has been given numerous names in different languages [16]. *Satyrium nepalense* D. Don.: *Satyrium albiflorum* a. Rich.; *Satyrium pallidum* a. Rich.; *Satyrium nepalense* Var. nepalense; *Satyrium neilgherrensis* Fyson; *Satyrium wightianum* Lindl., *Satyrium nepalense f. albiflorum* (a. Rich.) Tuyama; *Satyrium perrottetianum* a. Rich.; *Satyrium henryi* Schltr. *Satyrium nepalense* Var. ciliatum (Lindl.) Hook. F.: *Satyrium tenii Schltr*.; *Satyrium mairei* Schltr.; *Satyrium ciliatum* Lindl.; *Satyrium setchuenicum* Kraenzl.; *Satyrium aceras* Schltr.; *Satyrium tschangii* Schltr.

6. Vernacular Names of *Satriyum nepalense* D. Don.

Satyrium nepalense D. Don.: niao zu lan (Chinese), Salam misri (Hindi), Mishri, Thamni (Nepali), Nepal Satyrium (English). *Satyrium nepalense* Var. ciliatum (Lindl.): yuan mao zu lan (Chinese).

7. Morphological Features and Botanical Description

The plants varied in height from 20 to 70 cm, and the oval-shaped tubers measured 2-5×0.5-1.5 cm. The altitudinal range was 1200-4500 m. The leaves were covered with a protective sheath and had pointed, elongated, and lance-shaped bases. They are broadly ovate, widely spaced, alternate, basal and subopposite, or sometimes cauline, lanceolate-oblong, or ovate-lanceolate, with margins somewhat crisped, slightly fleshy, apex acuminate, or acute [17].

The fruit is capsule and spindle-shaped, approximately 2-6 mm in length. Pinkish to deep red or reddish-brown when ripe, and the roots are adventitious, arising from the base of the rhizome (fibrous). Stem cells are present in 1-3 membranous sheaths at the base [18]. Flowers are widely spread in fragrant, pink, whitish, or pale purple colors. They are hermaphroditic or have reduced stamens. The only distinguishing factor among the blossoms was their color. Satyrium var. ciliatum has a pinkish hue in contrast to the white coloration observed in Satyrium var. Nepalese [19].

The calyx is composed of lateral sepals that are oblong to sub-ovate, elliptic, and slightly oblique. Apex is obtuse at 4-6 x 1.5-2 mm, and dorsal sepals are narrowly 4-6 x 1-1.8 mm. The corolla is narrowly oblong to elliptic at 3.5-5 x 1-1.2 mm. The outer surface is carinate, and the margins are finely ciliate, incised, lip-hooded, and sub-globose at 5-6 x 4-6 mm. They sometimes curve downward at 3-13 mm [20].

The flowering and fruiting seasons are October-December. Its flowers are very significant in terms of pollination because of their peculiar form and characteristics, such as a twin-purred labellum. It has significant variability in both its vegetative features, particularly in the arrangement and form of its leaves, and in its floral characteristics, including bloom color and size. Measurements of sepal and petal lengths across the various flora treatments showed substantial variation. However, comparing these measurements is challenging because of the ambiguity over whether the authors refer to the total length, including the section that is fused to the lip at the base, or solely to the distal free part [19, 20].

8. Traditional and Ethnobotany Uses

Tubers of *S. nepalense* D. Don. are used in Nepal as tonics for the treatment of malaria, diarrhea, and dysentery. The plant's dried tubers are used as a preventive measure against dysentery, while its juice is used to treat fever, cuts, and wounds. These uses have been documented in several studies [21, 22].

Today's community in Nilgiri (India) uses the desiccated, pulverized tubers of this terrestrial orchid as an invigorating elixir. The Mopa tribe consumes the whole plant, including its roots, as a remedy for malaria and diarrhea. Moreover, the Mopa tribe in Arunachal Pradesh, located in Northeastern India, as well as Tibet in China, uses tubers for their aphrodisiac properties. The plant stem is used for blood nourishment, renal support, liver reinforcement, and mind relaxation. The indigenous communities located in the Western Himalayas in Uttarakhand and the tribal population in the Kudremukh National Park in Karnataka, situated in southwestern India, use the tubers of *S. nepalense* D. Don [23-25].

Satyrium species serve as a source of food and are crucial for human survival in the Nagaland region. *S. nepalense* is used in Pakistan for the treatment of fever, stomach aches, diarrhea, and sexual abnormalities in cattle, and is sometimes administered with *Asparagus curilius*. In China, *S. nepalense* is used for the treatment of erectile dysfunction, weak kidneys, chronic nephritis, and lower back pain. The tubers are used to make salep flour. It contains a lot of starchy polysaccharides, which are used as ingredients in ice cream, traditional Turkish drinks, and various medications. Young shoots of *S. nepalense* are used as green vegetables by the Tamang people in Nepal's rural districts [26-29].

9. Phytochemistry

Satyrium sp. has been used in ethnomedicinal studies for centuries. Over the last decade, successful identification of phytochemicals has shown them to be helpful for medical applications. Many researchers suggest that further investigation and collection of germplasm containing abundant therapeutic compounds should be conducted to enhance the potential of medicinal orchids for future artificial manufacturing. The discovery and analysis of compounds could uncover new treatment options for experimental illnesses, since a comprehensive examination of plant phytochemicals has not yet been conducted [30].

Owing to its significant chemical makeup, which consists of triterpenes, alkaloids, flavonoids, and unsaturated sterols, this orchid may be classified as a medicinal plant. Quercetin, a crucial bioflavonoid with anti-inflammatory, antioxidant, antihistamine, anti-edematous, anticancer, and direct radical-scavenging capabilities, was discovered in the tubers of *S. nepalense* D. Don, as reported by Mishra *et al*. [31].

Furthermore, they developed an HPTLC method to accurately detect and quantify quercetin in the methanol extract of the tubers of this medicinal orchid. Bhatnagar *et al*. [30] first documented the leishmanicidal and anti-mycobacterial activities of S. nepalense. Researchers investigated the ability of promastigotes and amastigotes of Leishmania donovani to kill leishmaniasis, the effectiveness of Mycobacterium TB (H37Rv and MDR strains) against mycobacterial infections, and the anti-bacterial properties of three gram-negative and two gram-positive clinical isolates.

Their analysis led them to conclude that *S. nepalense* had the greatest potential as a plant due to its substantial presence across all three functions. The methanol extract exhibited the highest levels of secondary metabolites and the most potent antioxidant and antibacterial

activities among the extracts. This may be attributed to the presence of phenolic acids and flavonoids, specifically gallic acid and quercetin, as determined by qualitative phytochemical screening and biological activity evaluation. Mishra *et al*. [32] validated this via research using LC-MS/MS. To ascertain the existence of phenolic acids, GA, CA, HBA, and SA, a comparative biochemical examination of the leaves and tubers from in-vitro and in-vivo plants was also carried out, as shown in Figure 1 [33].

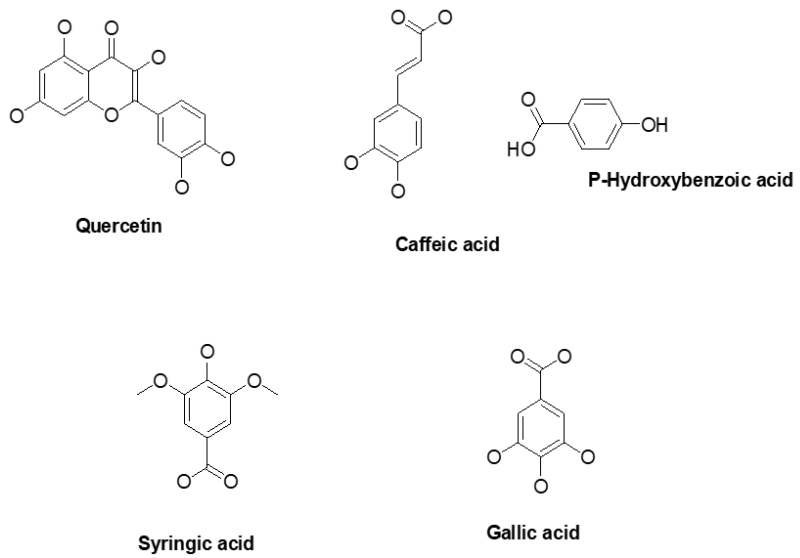

Figure 1. Structures of quercetin, caffeic acid, p-hydroxybenzoic acid, syringic acid, and gallic acid.

9.1. Acetamide derivative.

In their study, Kawra *et al*. [34] successfully isolated and characterized a new compound, an Acetamide derivative, from S. nepalense using LC-MS/MS. The studies identified the isolated Acetamide derivative as a highly effective antioxidant agent, as determined using various conventional procedures, including total antioxidant activity, DPPH free radical scavenging activity, percentage inhibition of superoxide anion radicals, and percentage inhibition of hydrogen peroxide free radicals.

10. Pharmacological Activities of *Satyrium nepalense*

10.1. Antibacterial activity.

Satyrium nepalense, often referred to as Salang mishri, is a member of the Orchidaceae family. This plant is a terrestrial herb that typically reaches a height of 25-60 cm. It is often found in regions with elevations ranging from 2400 to 3000 m. It is used as a nourishment, restorative, and in cases of malaria, diarrhoea, and dysentery. Researchers reported that the methanolic extract of *S. nepalense* exhibits remarkable antibacterial efficacy against ten different types of food-borne pathogens, namely *Escherichia coli*, *Bacillus cereus*, *Klebsiella pneumoniae*, *Enterobacter gergoviae*, *Shigella flexneri*, *Salmonella entericatyphim*, *Staphylococcus epidermidis*, *Staphylococcus aureus*, and *Streptococcus pyogenes* [30].

Bhatnagar *et al*. (2017) [30] evaluated the most accurate indicator of antibacterial effectiveness against three gram-negative and two gram-positive MDR clinical isolates. A ZOI with values greater than 10 mm was seen as indicative of activity. Remarkably, the n-hexane fraction from all three sections of Sn exhibited significant antibacterial efficacy against *S. aureus*.

10.2. Antioxidant activity.

In a study by Kawra et al. [34], it was shown that, among the five solvent extracts and the standard evaluated for antioxidant activity using the DPPH technique, the crude methanol extract of S. nepalense exhibited the highest antioxidant activity, with an IC_{50} value of 0.04 mg/ml. In comparison, the IC_{50} value for ascorbic acid was 0.02 mg/ml. The findings demonstrated that S. nepalense tubers exhibited superior antioxidant activity. Mishra *et al*. [32] also reported that the methanol extract of S. nepalense exhibited noteworthy antioxidant and antibacterial properties. Therefore, it merits consideration for potential use in medicinal plants and dietary supplements.

10.3. Anti-mycobacterial activity.

Bhatnagar *et al*. [30] assessed the anti-mycobacterial efficacy of *S. nepalense* using a colorimetric redox indicator test, reporting results as MIC values. The analysis of the data revealed that the n-hexane fraction of the flower of *S. nepalense* (referred to as n-Hex SnF) exhibited the highest anti-mycobacterial activity against H37Rv and MDR strains, with MICs of 15.7 and 42.5 µg/mL, respectively. Scientific evidence shows that a MIC of less than 100 µg/mL is considered very effective, whereas concentrations between 100 and 625 µg/mL indicate moderate anti-mycobacterial activity [35].

Furthermore, the non-polar fractions exhibited superior performance, possibly due to their association with lipophilic components. These constituents disrupt the plasma membrane, reducing permeability and preventing the leakage of intracellular materials [36]. Although in vitro biological activities may not directly translate into clinical trials, conducting in vitro research helps clarify a sample's safety profile and determine whether a drug candidate has scientific merit for further investigation.

11. Discussion and Future Perspective

In recent years, populations of several orchid species have declined significantly, reaching critically low levels. Orchids face significant challenges, stemming from both natural and human-induced factors [37]. Research has shown that certain well-known herbal medicine companies often replace therapeutic orchids with alternatives because the orchids are not readily available. A specific example is that of *E. dabia*. Currently, *S. nepalense* has replaced it because of its rarity. This is a result of the decline in the number of medicinal orchids in the state. The economic viability of these medicinal orchids may be due to their significant market demand [38].

The primary danger to this therapeutic orchid in the current scenario is the indiscriminate collection of the entire plant, along with other grasses. Due to a lack of awareness of the plant's therapeutic properties, people often disregard it as a mere grass and make no effort to protect it. Due to the overall warming trend in the alpine environment of the Nepalese Himalayas, the phenology of plant blooming, including alpine plants, may vary over time, potentially leading to reproductive failure [39]. Hence, the ongoing phenomenon of global warming is expected to pose a risk to this plant. Nonetheless, thorough research encompassing reproductive biology, phenology, and ecology is necessary to comprehend the possible dangers posed by climate change fully.

This review provides significant insights into the current conditions and potential risks to the biological genetic resources of a highly valued plant species found in alpine meadows.

Providing education to the local population about the therapeutic properties of this plant species might help prevent the decline of S. nepalense var. ciliatum in its natural habitats. Based on the results of an extensive study, it is necessary to implement efficient conservation methods and ensure the commitment of all parties involved in protecting and sustainably using resources.

12. Conclusions

In summary, *S. nepalense* D. Don, an endangered medicinal orchid, has been used in ethnomedical research since ancient times to treat malaria, diarrhea, and dysentery. This orchid is acknowledged for its medicinal properties due to its diverse chemical composition, which includes triterpenes, alkaloids, flavonoids, and unsaturated sterols. An important conservation initiative will include the widespread multiplication of *S. nepalense* D. Don using micropropagation techniques and traditional methods, and its reintroduction into natural habitats and certain ecological niches. To avoid their extinction and excessive use, promoting their cultivation on a broad scale will enhance both basic and secondary healthcare and contribute to the advancement of sustainable rural life.

List of Abbreviations

HPTLC: high-performance thin-layer chromatography; GA: gallic acid, CA: caffeic acid, HBA: p-hydroxybenzoic acid, SA: syringic acid, HPLC: high-performance liquid chromatography; MDR: multidrug-resistant; ZOI: zone of inhibition; MIC: minimum inhibitory concentration; DPPH: 2,2-diphenyl-1-picrylhydrazyl.

Author Contributions

Conceptualization, KS.; writing-original draft preparation, DJ.; validation, SK.; data curation, SB, HM, SVB.; writing-review and editing, SR. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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