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RESEARCH ARTICLE

PHARMACOLOGICAL PROPERTIES OF PODOPHYLLUM HEXANDRUM ROYLE: A COMPREHENSIVE REVIEW

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Abstract

Podophyllum hexandrum Royle is an endemic and endangered valuable medicinal plant species characterized as a herbaceous and rhizomatous perennial. The geographical presence of Podophyllum hexandrum Royle spans over the Himalayas at an altitude ranging from 2000 to 4000 m above Mean Sea Level. With a long history of usage in traditional medicine, it has been exercised as an intestinal purgative, an inhibitor of tumour growth and a salve for necrotic and infected wounds. Many secondary metabolites, such as Podophyllotoxin, have been reported to be extracted from the plant, which possesses anti-tumour properties to treat testicular and lung cancer. The extensive exploitation of Podophyllum hexandrum Royle in regions of the Himalayas has led to a decline in the frequency of the species in the past few years. This comprehensive review article aims to facilitate an updated overview of the pharmacological properties of Podophyllum hexandrum Royle including its anti-cancer, anti-inflammatory, anti-microbial, anti-viral, anti-oxidant, and radio-protective effects. This article reviews the medicinal, phytochemical, pharmacological, ethnobotanical and cultivation-related aspects of the plant.

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Introduction:

Podophyllum hexandrum Royle is derived from the ancient Greek word Podophyllum meaning foot-leaf. It is also known as Mayapple, as its fruits ripen in spring. The homeland of Podophyllum hexandrum Royle is in the Himalayan and Atlantic North American region.

The P. Hexandrum is commonly distributed in the Himalayan regions of the Asian continent popularly called Himalayan Mayapple. Similarly, the latter species P. Peltatum is called American Mayapple. Another species of Podophyllum hexandrum Royle is P. Sikkimensis[1].

Although Podophyllum was mentioned in the Pharmacopoeia, dating from 1820, as a cathartic and cholagogue but later it was removed from the 12th edition of this Pharmacopoeia, because of its severe toxicity. Podophyllum has achieved pronounced significance in various traditional systems of medicine including Ayurveda, Unani, and Siddha for the remedies of several disorders[2]. Intensive collection and inadequate cultivation of Podophyllum have led to a limited supply of Podophyllotoxin, resulting in a massive increase in its demand in the global market.

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Mayapple can be vegetatively propagated through rhizome cuttings or micropropagation, where the terminal bud is used to induce adventitious buds in the explant, resulting in a 70-90% success rate during soil acclimatisation[3]. Mayapple flourishes in shaded and moist environments, with early spring being the season of its initial sprouting. Plantings exposed to the sun have been reported to yield more podophyllotoxin than those grown in a shaded environment[4].

Since organic synthesis is not economically feasible, podophyllotoxin, which is an essential compound for the production of crucial anticancer drugs such as etoposide, etopophos, and teniposide[5], is isolated from the rhizomes of *P. Peltatum* and *P. Hexandrum* plants. Due to both intensive collection and lack of cultivation, the supply of *P. Hexandrum* rhizomes, which contain up to 5% podophyllotoxin on a dry weight basis, is limited [6,7]. *Anthriscus sylvestris* (Apiaceae; wild chervil) is a common weed in Northwest Europe, used to procure the lignans deoxypodophyllotoxin, yatein and anhydropodorhizol. Its rhizomes consist of significant amounts of yatein, the precursor of deoxypodophyllotoxin in *Podophyllum hexandrum*[8]. It is also worth noting that undifferentiated cultures of plant cells or fungi are also able to convert deoxypodophyllotoxin into podophyllotoxin after feeding[9].

Podophyllum hexandrum Royle is an important medicinal plant known for its valuable drug podophyllotoxin which is effective against various diseases: purgative, laxative, cholagogue, polyps, alterative, emetic and also useful against warts and tumours growth of skin, anticancer[10,11]. Podophyllotoxin, along with α -peltatin, and β -peltatin, are aryltetralin lignans known to have biological activity such as anticancer, antifungal, antiviral, antimitotic, and immunostimulatory properties[12]. Podophylloresin contains several lignans including podophyllotoxin from which two modern chemotherapeutic drugs etoposide and teniposide have been synthesised. These are now being used in the treatment of mild lung cancer and other tumours[13]. *Podophyllum peltatum* contains lower amounts of podophyllotoxin compared to *P. Hexandrum*[6].

Materials And Methods:

This paper includes an evidence-based overview of pharmacological and phytochemical properties and ethnobotanical uses of the *Podophyllum hexandrum* Royle, which may be helpful to establish a standard natural drug for further research. The present article provides a comprehensive review of *Podophyllum hexandrum* Royle. Collecting information on the various pharmacological studies conducted till date.

Geographical Distribution:

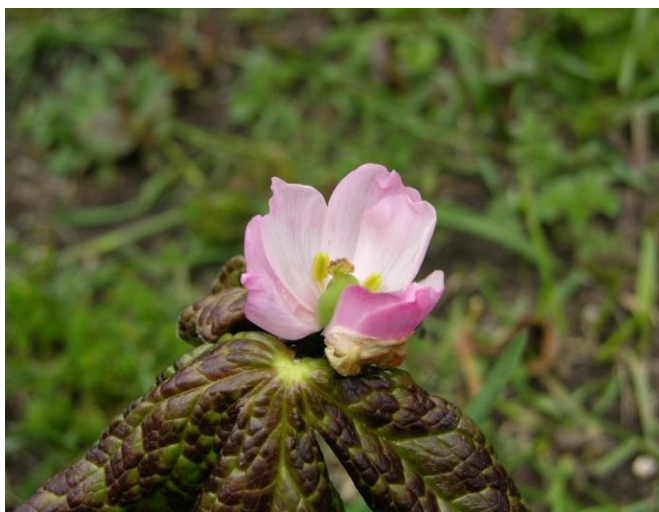
Podophyllum hexandrum Royle, a perennial herb, is known as the Himalayan Mayapple or Indian Mayapple. It was considered a divine drug in ancient times and is called Bantrapushior Giriparpat in Hindi and Ayurveda. The plant is native to the lower elevations of the Himalayan regions, including Afghanistan, Pakistan, India, Nepal, Bhutan, and S.W.China[14,15,16,17]. In India, it is primarily found in the Alpine Himalayas (at an altitude of 3000-4000 msl) in Jammu and Kashmir, Himachal Pradesh, Sikkim, Uttarakhand, and Arunachal Pradesh[18,19,20].

Habitat:

This species thrives as undergrowth in fir forests at altitudes ranging from 2500 to 4200 m. It prefers shady areas with rich humus and can be found in association with *Rhododendron*, *Salix*, *Juniperus*, and *Viburnum* spp. It can also be found in open alpine meadows. However, this species is endangered due to being collected for its medicinal value. To address this issue, it is cultivated at the High Altitude Plant Physiology Research Centre in N. Sikkim and at Kyongnosla Nursery of the State Medicinal Plant Board of Sikkim in the East District.

Cultivation And Collection:

To cultivate the plant, seeds should be sown with the pulp in June or July, and remain dormant for 9-10 months before germinating the following spring after the snow melts. The rhizome and roots are only obtained from wild plants, with propagation by rhizome cutting also reported[21]. The plant thrives in moist and shaded areas, blooms in spring, bears fruit in summer, and enters senescence in October or November. Rhizomes that produce 3-5 aerial shoots are suitable for collection, which is typically done in spring or autumn. The rhizomes are cleaned, dried in the sun, and stored in gunny bags, sometimes cut into cylindrical pieces and carefully dried. Rhizomes collected in May have higher resin content than those collected in November, and freshly collected rhizomes contain more active compounds that degrade with prolonged storage[21].

**Plant (Fig1.1)****Flower (Fig1.2)**Source:<https://biodiversity.bt/species/show/1182>**Morphology**[22,23,24]:

Characteristics	Description
Scientific name	<i>Podophyllum hexandrum</i> Royle
Plant type	Succulent, perennial herb
Height	15-40 cm
Flowering period	May to August
Petals and stamens	6 petals, 6 stamens
Seeds	Embedded in red pulp
Rhizomes	Creeping, knotted, yellowish brown to earthy brown in colour
Roots	Numerous, easily break off, brittle, bitter acrid and starchy
Leaves	2-3 umbrella-like, 10-20 cm long, deeply cut into 3 lobes
Flowers	White or pale pink, borne at the ends of stout stem; 4 cm across, appear in the fork of the stem
Fruit	Berry, oblong or elliptic, 2.5 - 5.0 cm in diameter
Fruit colour	Green when unripe, red when ripe

(Table1.1)

Physiology And Anatomy:

It has been observed that plants typically exhibit hypocotyl dormancy and delayed emergence of functional leaves. However, treatment with GA3 led to a higher percentage of seedlings exhibiting functional leaf emergence at a favourable temperature of 25°C, and even at 10°C when hypocotyl dormancy usually occurs. Additionally, there was a significant increase in biochemical parameters related to carbon and nitrogen metabolism, respiration, and total dehydrogenase activity in all seedling parts, indicating an enhancement of metabolic processes influenced by GA3 for further growth and development[25].

In terms of anatomy, the morpho-anatomical leaf traits and photosynthetic activity of *Podophyllum hexandrum* Royle were determined by factors such as mesophyll thickness, the surface area of mesophyll cells facing intercellular spaces, the surface area of chloroplasts facing intercellular spaces, intercellular spaces of mesophyll cells, photon-saturated rate of photosynthesis per unit leaf area, and ribulose-1,5-bisphosphate carboxylase/oxygenase activity[26]. The rhizome is covered externally by about six layers of tubular, thin-walled polygonal cells, and the ground tissue consists of a stout-walled cellulosic parenchyma with simple pits containing starch grains[27].

Classification:

Taxonomic Rank	Taxon
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Ranunculales
Family	Berberidaceae
Genus	<i>Podophyllum</i>
Species	<i>Hexandrum</i> (P. <i>Hexandrum</i>)

(Table2.1)

Vernacular Names[28] :

English name: Indian *Podophyllum*.

Bengali	Papra
Gujarati	Venivel
Hindi	Bakrachimaka, Bhananbakra, Papra, Papri
Kashmiri	Banwangan
Punjabi	Papri, Vankakri
Marathi	Padmel, Patnel

(Table2.2)

Ayurvedic Pharmacodynamics[29]:

Rasa: Katu Tikta

Guna: Laghu Teesksna

Veerya: Ushna

Vipaka: Katu

Karma: Pittahara

Subspecies[30]:

Dysosma emodi (Wall. ex Royle) Hiroe

Podophyllum emodi var. *hexandrum* (Royle) Chatterjee & Mukerjee *Podophyllum emodi* Wall.

Podophyllum hexandrum var. *Bhutanese* (Chatterjee & Mukerjee) Browicz *Sinopodophyllum emodi* (Wall. ex Royle) T.S.Ying

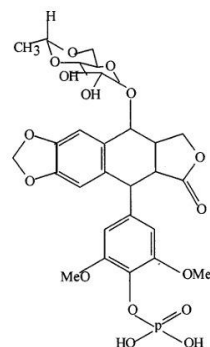
Sinopodophyllum hexandrum (Royle) Ying

Phytochemistry And Chemical Constituents:

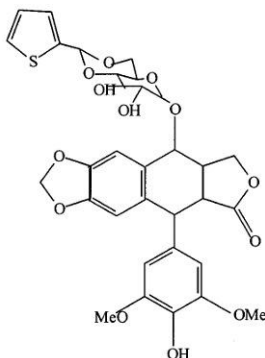
Bio-active Compounds:

Podophyllum species contain a resin called podophylloresin, which is a neurotoxin and can be processed to extract podophyllotoxin or podophyllin. The rhizomes and roots of the plant also contain anti-tumour lignans, such as podophyllotoxin, 4-dimethyl podophyllotoxin, and podophyllotoxin 4-O-glucoside[31,32]. The plant also contains

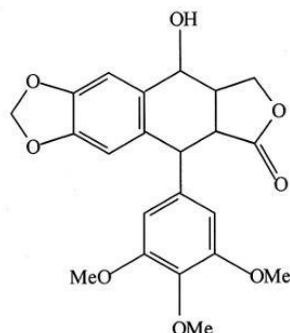
glycosides, flavonoids, saponins, D-glycoside, terpenes, and proteins, as reported by Wani et al. [33]. The plant produces the highest percentage of resin during the flowering stage, which is in May-June[34].



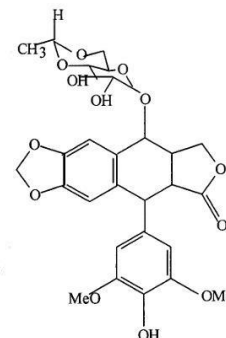
Podophyllotoxin
(Fig2.1)



Etoposide
(Fig2.2)



Etoposide Phosphate
(Fig2.3)



Teniposide
(Fig2.4)

Podophyllum species, particularly *P. hexandrum*, are known for their valuable drug podophyllotoxin (Fig2.1). This compound is used as a starting compound for the synthesis of anticancer drugs such as etoposide (Fig 2.2), etopophose (Fig 2.3), and teniposide (Fig 2.4) [35]. However, *P. peltatum* contains the active principal alpha and beta peltatins, which are absent in *P. hexandrum*.

Indian podophyllum has more than double the amount of podophyllotoxin[36].

The rhizomes of *P. hexandrum* contain hexanedioic acid, oleic acid, and octadecanoic acid[24], while tannin was found in the root of the plant[27]. It was reported that the *P. hexandrum* rhizome is rich in polyphenols and lignans[37]. The lignin compounds of podophyllin from *P. hexandrum* include podophyllotoxin, podophyllotoxinglucoside, picropodophyllin, 1-O-glucopyranosyl-picropodophyllin, 4'-glucoside, dihydropodophyllotoxin, 4'-demethylpodophyllotoxin glucoside, dihydropodophyllotoxin, podophyllol, podophyllic acid, and 4'-dimethyldeoxypodophyllotoxin glucoside[21].

In addition to these compounds, podophyllic acid, podophylloquercin, starch, picropodophyllin, calciumoxalate, kaempferol, astragalin, wax, mineral salts, and essential oil are also present, which are responsible for its odour[21,38].

Pharmacological Activities:

Gamma Radiation[39,40]:

The study on administered gamma radiation treatment to a plant and the extract's radio-protective effects on mice at the biochemical and cytogenetic level, measured various anti-oxidant parameters, including thiol content, GPx, GR, GST enzyme activity, LPO, and total protein levels. The results indicated that RP-1 provided radioprotection by protecting anti-oxidant enzymes, reducing LPO, and increasing thiol content.

Anti-tumor Activity[41,42]:

1. Podophyllin resin and its active constituent podophyllin have been found to have significant anti-tumour activity.
2. Scientific evidence for the antitumor activity of podophyllotoxin was reported in 1942 by Kaplan.
3. Aqueous extracts of podophyllotoxin have shown significant anti-tumour effects at sub-toxic, well-tolerated, sequential doses.

Anti-oxidant Activity[43]:

1. Various extracts of *Podophyllum hexandrum* Royle, including the rhizome, petiole, and leaves, have been examined for anti-oxidant activity in vitro and in vivo.
2. The ethyl acetate extract of the rhizome has been shown to be effective in both in vitro and in vivo studies.

3. The extract was tested using a DPPH scavenging assay, hydroxyl assay, H₂O₂ assay, superoxide assay, and reducing power under in vitro conditions.
4. Albino rats were used in the in vivo study to measure anti-oxidant enzyme activities and glutathione levels in liver tissue homogenate.
5. The ethyl acetate extract was found to be more effective than known anti-oxidants BHT and α -tocopherol.

Antimicrobial Activity[44,45]:

1. Methanolic and aqueous extracts of *Podophyllum hexandrum* Royle have been reported to have anti-microbial effects against bacteria and fungi in vitro.
2. Both extracts inhibited *Bacillus megaterium* MTCC 1684 and *Pseudomonas aeruginosa* MTCC 3541.
3. The extracts also inhibited the fungi *Aspergillus flavus* and *Fusarium solani*.
4. In another study, *Podophyllum hexandrum* was found to have antibacterial effects against *Staphylococcus aureus*, *Salmonella typhi*, *Klebsiella pneumonia*, and *Enterococcus faecalis*.

Antivirus Activity[46]:

Podophyllotoxin and related lignans have been found to be active against viruses in vitro and in vivo.

Anti-inflammatory Effects[47]:

The anti-inflammatory potential of the aqueous extract of *Podophyllum hexandrum* rhizome has been evaluated on lipopolysaccharide (LPS) induced inflammation in Balb/c mice.

Radio-protective Effect[48]:

1. *Podophyllum hexandrum* Royle has been identified as a promising candidate plant for the development of radio-protective drugs.
2. A study by Raj Kumar et al. (2008) found that the extract of *P. hexandrum* administered prior to irradiation provided approximately 80% whole-body radioprotection in mice.

Antifungal Activity[49]:

Two aryltetralin lignans isolated from leaves of *Podophyllum hexandrum* showed strong anti-fungal activity against *Allescheria boydii*, *Curvularia lunata*, *Epidermophyton floccosum*, *Microsporum canis*, *Nigrospora oryzae*, and *Pleurotus ostreatus*.

Cytotoxic Activity:

1. Phenylpropanoid is a derived lignan of podophyllotoxin, which is used as a starting compound for the chemical synthesis of anti-tumour agents like etoposide and teniposide[50].
2. In vitro cytotoxic activities of 4-demethyl-picropodophyllotoxin 7'-O-D-glucopyranoside (4DPG) have been reported[51].
3. 4DPG inhibits the proliferation of cancer cells and blocks the cell cycle in the mitotic phase, thus inducing apoptosis. These properties make 4DPG a potential antitumor drug.

Insecticidal Activity[52]:

The dichloromethane extract of this plant has insecticidal activity against larvae of *Drosophila melanogaster*. Isolated podophyllotoxin from the extract, which has an LC₅₀ value of 0.24 μ mol/mL against larvae of *D. melanogaster* and an LD₅₀ value of 22 μ g/adult against adults. The compound acetylpodophyllotoxin (1A) exhibited slight insecticidal activity in both assays, indicating the importance of the 4-hydroxyl group for enhanced activity.

Ethnomedicinal Uses:

The historical importance of *P. hexandrum* Royle rhizomes is undeniable, as they have been used for medicinal purposes for a long time. Native North American tribes utilised the rhizome powder as a purgative, laxative, and anthelmintic. Moreover, this plant has been used to treat various forms of warts responsible for causing certain types of skin tumours, including some forms of skin cancer. The Kashmiri people have also used this plant in traditional medicine for ages, locally referring to it as "Banwangun" due to its red-coloured fruit. Indian *podophyllum* has a rich historical significance due to its usage by the natives of the Himalayas. The aqueous extract of its roots has been used to treat catharsis and ophthalmia[23].

Furthermore, *P. hexandrum* Royle is used traditionally to treat several ailments, including colds, constipation, septic wounds, burning sensation, erysipelas, mental disorders, plague, allergic and inflammatory skin conditions, brain, bladder, lung cancer, venereal warts, monocytoid leukaemia, Hodgkin's disease, and non-Hodgkin's lymphoma[56].

In Muzaffarabad, Kashmir, the root paste of this plant is applied topically to ulcers, cuts, and wounds and is also used to treat vaginal warts. In the Battagram district of Pakistan, the rhizome is believed to have a hepatic stimulating effect and is used as a purgative, emetic, and to cure fever and body pain[53].

Cell Culture:

There are various aspects related to *Podophyllum hexandrum* Royle, a medicinal plant species known for its production of podophyllotoxin, a compound with anticancer properties.

The authors report the successful production of podophyllotoxin using cell culture of *P. hexandrum* Royle under in vitro conditions and its inhibitory effect on human breast cancer cells [54]. The genetic diversity of different accessions of *P. hexandrum* Royle was classified using morphological, phytochemical, and molecular markers, revealing high diversity among the accessions. It was also observed that the cell suspension cultures obtained from the rhizome of *P. hexandrum* (Berberidaceae) can lead to the accumulation of podophyllotoxin[55]. The scientists attempted to produce podophyllotoxin using bioreactors from plant cell cultures, but the amount produced was not enough to cope with the demand[56].

Ethnobotanical Uses Of *Podophyllum hexandrum* Royle:

Podophyllum hexandrum's ethnomedicinal uses in Kashmir Himalaya include:

1. Applying crushed leaves and roots for skin diseases[57].
2. Eating raw fruit for laxatives, chest congestion, gastric problems, and taking ripe fruit juice for stomach ulcers and dyspepsia[57,58,59].
3. Administering dried root powder orally with water to counter tumours, and using root powder mixed with oil as a remedy for skin diseases such as rashes and eczema[58].
4. Using resin in veterinary medicine as a cathartic for dogs[59].
5. Using pericarp of mature red fruit to treat eye wounds of cattle[60].

In other regions of Himalaya, the rhizomes and resin of *Podophyllum hexandrum* Royle are used for their alternative, laxative, purgative, and antineoplastic properties. They are applied externally for the removal of condyloma, anogenital warts, venereal warts, verrucae, and similar conditions [61]. They are also useful against various diseases like Wilm's tumours, genital tumours, "molluscum contagiosum", psoriasis vulgaris, non-Hodgkin lymphoma and other lymphomas, cancer of the brain, lung, bladder, leukemia [62, 63]. In the Ladakh and Tibetan Systems of Medicine, the rhizome is used against various gynaecological problems[64].

Medicinal Attributes:

Podophyllum species have a long history of medicinal use in various traditional systems of medicine. The ripened fruits are known to be edible and are used to treat fever in the traditional Indian system of medicine. The rhizome of *Podophyllum* is used to treat various gynaecological disorders in the Tibetan system of medicine[65].

Native North American tribes used *Podophyllum* rhizome powder as a laxative and anthelmintic. The powder was also used in poultices to treat skin warts and tumours[65].

The fruits of *Podophyllum* should only be eaten when fully ripe as they are juicy but insipid. While one report suggests that the leaves are edible, caution is advised due to the plant's toxicity[65].

High Altitude *Podophyllum hexandrum* Royle (HAPH) has been found to have a radioprotective effect in both in vitro and in vivo models[65]. In addition to its use in treating gynaecological disorders, ripened fruits of *Podophyllum* species are also used to treat fever[66,67,68]. The crushed leaves and roots are applied to treat skin diseases, while the fruit is used to alleviate gastric problems [69]. Powder made from *Podophyllum hexandrum* is also used as an antiseptic to promote the healing of wounds and treat small tumours[70].

Dosages[71]:

Medicine Form	Dose
Roots	5-10 grains
Podophyllin	1/4 th – 1 grain
Tincture	15 minum – 1 fluid dram
Conversion	minum = 0.0616 mL; grain = 64.8 mg; fluid dram = 60 drops

(Table3.1)

Adverse Effects:

It causes spasmodic pain, sloughing, and excoriation in the stomach when taken above the therapeutic dose[72].

Correctives[72]:

SubstancesUsed	Purpose
Curd mixed with water, honey	Counter excessive purgation due to side effects of P. hexandrum
'Lu'ab behdana' (mucilage of Cydoniaoblonga Mill. seeds)	Counter excessive purgation due to side effects of P. hexandrum
'Aspghol' (Plantago ovata Forsk.)	Counter excessive purgation due to side effects of P. hexandrum
'Ashjau' (barley water)	Counter excessive purgation due to side effects of P. hexandrum
'Ajwain Kurasani' (Hyoscyamus niger L.)	Manage spasmodic action caused by P. hexandrum
'Qinnab' (Cannabis sativa L.)	Manage spasmodic action caused by P. hexandrum

(Table3.2)

Side Effects:

While this plant is renowned for its various beneficial uses, it is important to note that there are associated side effects that must be taken into consideration. These side effects range from severe stomach pain, bloody diarrhoea, muscle paralysis, and hallucinations to kidney and breathing failure, neuropathy, and encephalopathy. Additionally, weaker side effects such as confusion, headache, local irritation, low blood pressure, nausea, and vomiting have also been reported[73,74]. Given that this plant can be potentially harmful, it should only be used under the guidance of a trained practitioner who can weigh its benefits and risks. Moreover, due to its poisonous nature, the use of this plant is contraindicated during pregnancy[75].

Future Scope:

Podophyllotoxin is a valuable extract from the roots of P. hexandrum Royle and is mainly used in the treatment of specific types of cancer. Podophyllin, a mixture of Podophyllum resin and podophyllotoxin, was first used for cancer growth inhibition in the USA in 1942 when it was applied topically. Later, podophyllotoxin was obtained from the rhizomes of this plant and used against cancerous growth. M/S Sandoz introduced the product into the market, which performed well in business. P. hexandrum Royle was widely used by British medical doctors in the Indian subcontinent, leading to over-exploitation and depletion of the plant. Today, P. hexandrum Royle is included among the endangered species in India, with its populations in the Western Himalayas decreasing rapidly due to anthropogenic activities and overexploitation.

The limited availability of Podophyllum resin is due to the plant's long juvenile phase, poor fruit-setting ability, and non-optimal yield after extraction. Podophyllotoxin is a rare and endangered species, making it difficult to cultivate. However, scientists are working on in vitro cultivation techniques to break the dormancy of seeds by artificial means. The spontaneous genetic mutations that occur during secondary metabolite accumulation in suspension culture can result in a heterogeneous population of cells. To produce a wide range of podophyllotoxin, genetically stable lines should be used. The biotechnology of plant cell cultures offers a new method for producing secondary metabolites, but commercial production has only been achieved for a few substances. To produce podophyllotoxin commercially, technological advancements in phytochemistry, regulation of secondary pathways, and transgenics are needed.

There are also semisynthetic compounds derived from podophyllotoxin that are less toxic and used in cancer treatment. However, the isolation of compounds from biomass is problematic, and the supply of P. hexandrum Royle is limited due to natural disasters and other factors. Therefore, reliable mass cultivation methods for P. hexandrum Royle are needed. The wild populations of this plant are genetically diverse and may affect the drug profile. Hence, suitable groups must be selected for continuous and reliable production of this plant and its associated substances.

Conclusion:

Podophyllum, an endangered but high-value medicinal plant found in temperate and cold climates, has a wide scope for organised scientific study. Although cultivation practices have been standardised in several locations, the quality and quantity of its bioactive compounds from wild and cultivable lands under different zones have not been reported. Standardisation of quality and quantity of podophyllotoxin contents from cultured plantlets is another area that requires organised study due to its endangered status.

The extensive therapeutic potential of *Podophyllum hexandrum* Royle has made it an important plant in various traditional systems of medicine. The plant's value in medicine has been reported by various researchers, making sustainable utilisation crucial. Documentation of the medicinal importance of such plants is necessary for discovering new drugs. Additionally, lesser-known plant species may also prove useful in phyto-pharmacological research for the treatment of challenging diseases.

Screening of its chemotypes and diversity for morphological, biochemical, and genetic levels will enable researchers to understand the existing population of *Podophyllum hexandrum* Royle and, therefore, contribute to its conservation and sustainable utilisation.

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