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Editorial

Plant Science is Essential to Maintaining the World around Us

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Plants play important roles in maintaining the environment, human life, and also provide recreational and practical benefits to the human beings. Plants purify the air, filter water, check erosion and behave a buffer against climate change. Plants offer shelter as well as medicine, food, timber and fuel to animals on the earth. By promoting the practices of afforestation, phytoremediation, nanotechnology and biofuel, we can develop sustainable environment to the human beings. Plant scientists have been making better the quality of life for people around the world for coming generations. Plant Biotechnology comprises a wide range of areas including agricultural biotechnology, industrial biotechnology, natural products from plant sources, studies on plant-microbe interactions, biochemical and molecular researches on manipulations in gene expressions, gene targeting, recombinant DNA studies on plant models, CRISPR and RNAi technologies in plants, biotechnology of endangered plant species, forestry, phytoremediation technologies, gene delivery approaches, plant tissue culture and biological and biochemical techniques and methods/protocols involved in different focal area of plant science[1].

The biotic stress is forced on plants as a result of the invasion of fungal and bacterial organisms, pests and pathogens. To enhance the tolerance of plants against such stress, disease-resistant genes are incorporated. These genes provide better yield and quality of products to the plants. Similarly, abiotic stress includes soil texture, humidity, water availability, and temperature cause great injury to the plants. Hence, plants are integrated with stress-tolerant genes for better production of yield and quality. Biofortification is another important technique used to enhance the nutritional value of a crop. The large amount of our food is produced by various species of crop plants. Beside food items, plants fulfil the basic needs of our fuel and fiber requirements, they are very important to us from every point of view. The agricultural plants fix 175 billion tons of carbon dioxide annually through photosynthesis to increase the dry matter contents. The process of photosynthesis is useful in enhancement of agricultural productivity. Low temperature, drought, photo-inhibition, the accumulations of weedicides and pesticides, or fertilizers compromise the efficiency of production in crop plants. The recombinant human proteins have been developed using plants and microorganism systems. Edible vaccines and antibiotics have been acquired from the transgenic plants[2].

Plants produce secondary metabolites to strengthen their defense system against biotic and abiotic stresses. The chemical behavior and make up of secondary metabolites vary among species of plants. The importance of secondary metabolites in traditional as well as in modern medicine have been recognized by the various researchers. The crude extracts of various plants species have shown promising antimicrobial, anticancer, anti-inflammatory, wound healing properties in different models. Over the last few decades, various researchers are focusing their attention in plant secondary metabolite research due to the availability of hi-tech research infrastructure[3].

The interaction of plants and nitrogen fixers (e.g. *Rhizobium*) play crucial roles in increasing the growth and development of plants. In several crop plants, various researchers are working on the importance of nitrogen fixation for increasing the productivity of food products. Rhizobium colonies produce nodules on the roots of leguminous plants and the research is going on the transfer of nitrogen fixing genes in other plants species. This interaction is very important in the supply of nitrogen on earth that is available for biological life and reactions. Plants assimilate ammonia to form atmospheric nitrogen and nitrogenous biomolecules. The cyanobacteria, *Azotobacter*, *Azospirillum*, *Rhizobium* and *Bradyrhizobium* develop symbiotic relationships with leguminous and non-leguminous plants [4, 5].

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Research Article

Distribution, Taxonomy and Medicinal Importance of *Solanum torvum* Sw.

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Abstract

Solanum torvum Sw., commonly known as Wild Eggplant or Turkey Berry, is a plant species belonging to the family Solanaceae. This paper provides an overview of the distribution, taxonomy, and medicinal significance of *S. torvum*. The species is native to tropical regions of the Americas but has spread to various parts of the world, including Africa, Asia, and the Pacific Islands, where it often thrives in disturbed habitats. Taxonomically, *S. torvum* exhibits considerable morphological diversity with variations in leaf shape, flower colour, and fruit characteristics, which leads to the recognition of several intraspecific taxa. Wild eggplant has long been utilized in traditional medicine systems across its range for its diverse pharmacological properties. Various parts of the plant, including leaves, fruits, and roots, are used to treat a wide array of ailments, such as inflammation, infections, diabetes, hypertension, gastrointestinal disorders, etc. Phytochemical studies have revealed the presence of bioactive compounds such as alkaloids, flavonoids, phenolics, and sterols, which contribute to its medicinal properties. Additionally, *S. torvum* exhibits antioxidant, antimicrobial, antidiabetic, and anti-inflammatory activities, making it a valuable resource in the pharmaceutical and nutraceutical industries. However, despite its medicinal importance, there are concerns regarding the potential toxicity of certain compounds present in *S. torvum* necessitating further research to ensure its safe usage. Furthermore, habitat destruction and overexploitation pose threats to the wild populations of this species, highlighting the need for and importance of conservation efforts. Overall, understanding the distribution, taxonomy, and medicinal properties of *S. torvum* is crucial for harnessing its therapeutic potential while ensuring its sustainable utilization and conservation.

Keywords: *Solanum torvum*, Nutraceutical, Medicinal properties, Taxonomy, Distribution, Conservation.

1. Introduction

Throughout history, plants have been essential in the development of modern medications used to address various diseases worldwide[1]. Traditional societies, such as those in Africa, have traditionally relied on herbal remedies for healing purposes[2]. The accessibility and affordability of traditional plant-based medicine in rural regions, as opposed to modern medicine, has proven to be a considerable benefit[3]. These beneficial attributes can be ascribed to a plethora of active phytochemicals, such as flavonoids, terpenoids, carotenoids, resveratrol, curcumin, and others.

Fig. 1(a) Plant morphology

Fig.1(b) Stem with spines

Fig. 1(c) Whole plant with inflorescence

Fig.1 (d) Fruits

Vernacular Names

The name of *S. torvum* varies from place to place[36]. In India, the common name of *S. torvum* are given in Table 1.

Sr No.	State	Vernacular names
1.	Uttar Pradesh	Banbaigan
2.	Assam	Bhi-tita, bhit tita hati, bhekuri
3.	Bengal	Tita bagoon
4.	Tamil	Soondai
5.	Telugu	Kottuvastu
6.	Malyalam	anachunda, cheriyamodumutticka, chunda, parachunda
7.	Bodo	khingathai-phang, khunthai goukha
8.	Kannada	Sundekkayi
9.	Marathi	Marang
10.	Sanskrit	Brihati
11.	English	Devil's fig pea, eggplant, prickly nightshade, turkey-berry, turkey berry wild egg plant
12.	Hindi	Bhankatiya bhurat

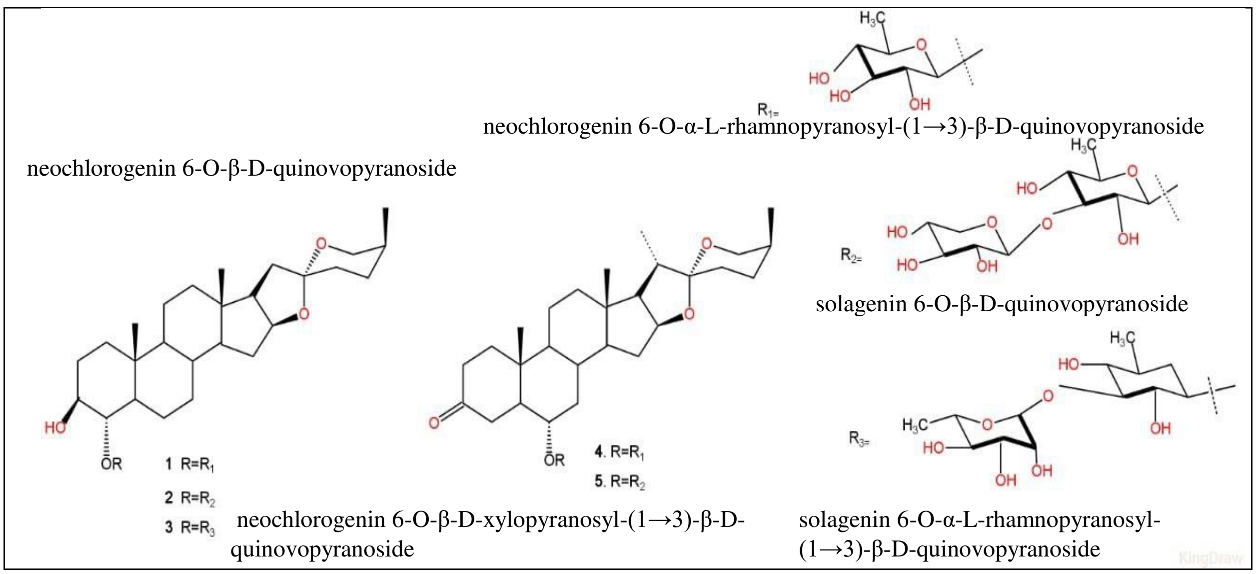

Fig. 2. Compounds identified from *S. torvum*

Plants have unequivocally established themselves as a vital source of anti-infective agents, with quinine, emetine, berberine, terpenoids, tannins, alkaloids, and flavonoids proving to be remarkably effective in combating microbial infections[4]. Originating from the Indian subcontinent, Bangladesh, Sri Lanka, and Malaysia, the turkey berry (*Solanum torvum*) is a shrub that has expanded its presence to Africa and the Caribbean. Its traditional use in medicine has been deeply rooted in different regions, highlighting its historical importance. For instance, in the Caribbean, the plant's fruits are utilized to alleviate fever, cough, and stomach ailments. In West Africa, the leaves are employed to reduce blood pressure. In the Indian Ayurvedic tradition, the turkey berry is employed for treating skin conditions. However, the lack of scientific evidence supporting these medicinal uses emphasizes the necessity for further research on this plant species[5].

Taxonomy

The Solanaceae family, which includes the Solanum genus, consists of around 100 Genera and approximately 3000 species[6]. The *Solanum* genus, derived from the Latin word "Solamen" meaning solace or quieting, is composed of about 1200 species. Well-known species within this genus include S. tuberosum (Potato), *S. lycopersicum* (tomato), and *S. torvum* (a common weed) etc. *S. torvum* exhibits characteristics of both an annual and perennial plant, with its growth cycle being dependent on environmental conditions[7]. It thrives in full sunlight and can tolerates shade. This spiny shrub typically reaches a height of 2–5 m and a basal diameter of 2–8 cm[8]. *S. torvum* is a shrub that grows in an erect manner. Its twigs and branches are covered by stellate hairs and often bear prickles. The leaves of this plant are arranged alternately and have lobes, with occasional prickles along the main veins. The fruits are spherical berries that start off green and gradually turn pale greyish green as they ripen. These berries have a thin flesh and contain numerous flat, disc-shaped, brown seeds (Fig. 1).

Distribution

This particular plant is distributed across various regions including Australia, Asia, Central America, Africa, South America, the Caribbean, the Indian Subcontinent, Mexico, Madagascar, and the Pacific region[9]. It is considered to be one of the most widely spread wild plants, with a presence that covers almost the entire globe. *S. torvum* is a wild food plant native to India that has not been cultivated [10,11]. It is frequently observed growing as a weed in agricultural fields, on the sides of roads, in unused lands, and occasionally in urban areas. This plant is generally found throughout all over India. Reports indicate that it is extensively distributed in North-eastern India, Southern India, and Himalayan region [12,13].

Nutritional Potential

India is regularly facing significant challenges in terms of protein malnutrition and nutrient deficiencies. The *S. torvum* fruits stand out as a valuable source of protein, fiber, calcium, magnesium, iron, and essential vitamins. Each 100g portion of the young fruit contains notable levels of water, protein, fat, carbohydrates, fiber, and essential vitamins and minerals. The energy content per 100g of fruit is 47 kilocalories, and the leaves and fruits are found to have an estimated 0.84% solasodine[14]. Additionally, it contains 11.9 ± 0.36 % carbohydrate, 59.51 ± 0.47 % moisture, 1.46 ± 0.23 % protein, 9.52 0.48 % total sugar, and 37.4 ± 3.64 (mg/100 g) ascorbic acid. In terms of essential minerals, every hundred grams of fruit contains 5.22 mg iron, 1.37 mg copper, 745.01 mg potassium, 3.41 mg zinc, 146.57 mg calcium, 31.98 mg sodium and 7.51 mg manganese. In terms of nutritional value, *S. torvum* is equivalent to popular fruits like papaya and strawberry, exhibiting higher quantities of vitamin C and iron when compared to apple, pomegranate, banana, and mango. Moreover, the mineral content of this plant exceeds that of other commonly consumed fruits in the market [10].

Chemical Constituents from *S. torvum*

The plant is a source of minerals, proteins, vitamins, dietary fibers, and secondary bioactive biomolecules. The phytoconstituent investigation of *S. torvum* fruits revealed presence of antiviral isoflavonoid sulfate and steroidal glycosides. In an independent investigation focusing on the methanolic extracts derived from the fruit, several noteworthy compounds were discovered. Among them, torvanol A, a novel isoflavonoid sulfate, torvoside H, a fresh steroidal glycoside, torvoside A, a previously recognized glycoside, and a tocopherol were successfully identified [15,16]. In the same manner, the upper portion of plant contained abundant saponins and steroids. Two novel compounds, solanolactosides A and B (1, 2), and two new spirostanol glycosides, torvosides M and N (3, 4), were extracted from *Solanum torvum*. Their structures were identified as solanolide 6-O-[α-l-rhamnopyranosyl-(1 → 3)-O-β-d-quinovopyranoside] (1), solanolide 6-O-[β-d-xylopyranosyl-(1 → 3)-O-β-d-quinovopyranoside] (2), yamogenin 3-O-[β-d-glucopyranosyl-(1 → 6)-O-β-d-glucopyranoside] (3), and neochlorogenin 3-O-[β-d-glucopyranosyl-(1 → 6)-O-β-d-glucopyranoside] (4), confirmed by spectroscopic analysis. Compounds 3 and 4 exhibited notable cytotoxic effects against human cancer cell lines *in vitro*[17]. Similarly, chemical constituents of *S. torvum* were investigated using silica gel, Sephadex LH-20, and Rp-C18 column chromatography. Structures were determined via ESI-MS and NMR spectroscopy, revealing nine known compounds: neochlorogenin 6-O-β-D-quinovopyranoside (1), neochlorogenin 6-O-β-D-xylopyranosyl-(1→3)-β-D-quinovopyranoside (2), neochlorogenin 6-O-α-L-rhamnopyranosyl-(1→3)-β-D-quinovopyranoside (3), solagenin 6-O-β-D-quinovopyranoside (4), solagenin 6-O-α-L-rhamnopyranosyl-(1→3)-β-D-quinovopyranoside (5), (given in fig. 2; Compound 1-5) isoquercetin (6), rutin (7), kaempferol (8), and quercetin (9). This study marks the first isolation of these compounds from *S. torvum*[18]. The roots of *S. torvum* yield steroidal glycosides like astorvosides A-G. Structurally characterized examples include (25S)-26-O-β-D-glucopyranosyl-5α-furostan-3β,6α,22β,26-tetraol 6-O-[α-L-rhamnopyranosyl-(1→3)-β-D-quinovopyranoside], (25S)-26-O-(β-D-glucopyranosyl)-22α-methoxy-5α-furostan-3β,6α,26-triol 6-O-[β-D-xylopyranosyl-(1→3)-β-D-quinovopyranoside], and others. These compounds exhibit diverse structural arrangements and pharmacological potential[19].

Pharmacological Properties

Numerous studies have verified the plant's various pharmacological benefits, including antioxidant, analgesic, anti-inflammatory, anti-microbial, anti-ulcerogenic, and antihypertensive properties etc. [20].

Antioxidant Activity

The Solanaceae group of plants, including *S. torvum*, has a significant impact on human health due to their secondary metabolites. These metabolites not only provide nutritional value but also offer medicinal benefits. *S. torvum* fruit, integral to Indian traditional medicine and culinary practices, underwent antioxidant evaluation via water (WE), methanol (ME), and ethanol (EE) extracts. Comparisons with standard antioxidants revealed significant antioxidant potential, with highest phenolic and flavonoid content in WE and EE extracts, respectively. ME exhibited superior electron quenching ability, while WE showed notable inhibition of membrane damage. HPTLC analysis revealed high gallic acid content in WE and ME, and high ferulic acid content in EE. These findings underscore *S. torvum* fruit's potential as a natural antioxidant source with therapeutic implications. Chemical investigation addressed the flavonoids, tannins, glycosides, saponins, volatile oils, and alkaloids presence[21].

Anticancer Activity

Through *in vitro* cytotoxicity testing against EAC cell lines, the ethanol extract derived from *S. torvum* berries has demonstrated its efficacy as an anticancer agent. Various concentrations of the extract, ranging from 50µg/ml to 1000µg/ml, were evaluated for their cytotoxicity. Results exhibited varying degrees of cytotoxicity, ranging from 7.09% to 85.79%, in a manner dependent on the dosage applied. Moreover, the cytotoxic attributes of methyl caffeate, derived from the ethyl acetate extract of *S. torvum* fruit via column chromatography, were investigated against A549, MCF-7, HepG-2, COLO320, and Vero cells. The study findings demonstrated that methyl caffeate possessed potent cytotoxic effects, particularly against MCF-7 cells, when compared to A549, COLO320, and HepG-2 cells[22]. In contrast, the water extract of unripe fruit showed no toxic effect on Vero cell line, while the viability of MCF-7 cells line was significantly decreased at a concentration of 1000µg/ml [23].

Antimicrobial Activity

The methanolic extract of *S. torvum* fruit exhibited broad-spectrum antimicrobial efficacy against a variety of clinical isolates from both human and animal origins. Its potency extended across diverse microbial strains, highlighting its potential as a versatile antimicrobial agent. This suggests the fruit extract's applicability in combating infections in both human and veterinary medicine. The observed antimicrobial activity underscores the pharmacological significance of *S. torvum* as a natural source of therapeutic compounds[24]. Different parts of *S. torvum* were extracted with chloroform and methanol, showing antibacterial and antifungal effects against human pathogenic bacteria and fungi. Methanolic root extracts demonstrated the most potent effects compared to leaves, stems, and inflorescence, with higher toxicity observed in roots. The minimum inhibitory concentration (MIC) values of methanolic root extracts ranged between 64-128 µg mL^{-1}, indicating potential as antimicrobial agents and environmentally friendly solutions[25]. The methanolic extract derived from the root displayed potent antibacterial activity, as indicated by the results of the minimum inhibitory concentration (MIC) tests even when administered at low concentrations (64-128 µg mL^{-1}). Furthermore, methanolic extracts of *S. torvum* exhibited remarkable growth-inhibiting property against a variety of microorganisms frequently associated with pyogenic infections in both humans and animals, as shown in various studies[26,27,28].

Anti-inflammatory Activity

S. torvum berries, traditionally used by the Tiwa tribe in Assam for inflammation, demonstrated potent anti-inflammatory properties in both *in vitro* and *in vivo* experiments, corroborated by phytochemical analysis confirming the presence of active compounds[29]. Additionally, *S. torvum* methanolic fruit extract was tested for its anti-inflammatory property in both *in vitro* and *in vivo* models. The study demonstrated that the fruit extract significantly reduced inflammation in both types of models when compared to a conventional medication. Additionally, a preliminary investigation of phytochemicals was carried out to validate the existence of compounds with strong anti-inflammatory effects[30].

Cardioprotective Activity

People who maintain a diet that is rich in fruits and vegetables, and as a result rich in phytochemicals, exhibit a lower incidence of various disorders including cardiovascular diseases. The extracts derived from *S. torvum* fruits exhibit remarkable antioxidant properties, which are closely linked to their ability to protect the cardiovascular system and prevent heart-related ailments such as hypertension, strokes, and coronary issues[31]. Another study assesses cardiovascular effects of aqueous (AES) and methanol (MES) extracts from *S. torvum* fruits, revealing significant reductions in arterial blood pressure upon intravenous administration. AES did not affect heart rate, whereas MES reduced it. AES's hypotensive effect remained unaffected by atropine but was inhibited by yohimbine, indicating a role of adrenergic receptors. AES also exhibited dose-dependent inhibition of platelet aggregation induced by thrombin and adenosine diphosphate, suggesting potential cardioprotective sources[32]. Additionally, the antihypertensive properties of extracts of *S. torvum* may be attributed to their bradycardic effects[33]. *S. torvum* fruits have been traditionally utilized in folk medicine as a remedy for hypertension [34].

Antiulcer Activity

Antiulcer activity refers to the ability of certain substances to prevent or alleviate ulcer formation in the gastrointestinal tract. Compounds with antiulcer activity often work by reducing gastric acid secretion, enhancing mucosal defence mechanisms, or inhibiting factors that contribute to ulcer formation. The anti-ulcer potential of *S. torvum* leaves was examined in rat models induced with ethanol, indomethacin, pylorus ligation, and cold-restraint stress to induce gastric ulcers[35].

Hepatoprotective Activity

S. torvum leaf extract demonstrated hepatoprotective effects in acetaminophen-primed liver injury models. Phenolic fraction from aqueous leaf extract revealed presence of 38 compounds related to flavonoids, chlorogenic acid isomers and hydroxycinnamic acid derivatives. It was demonstrated that 300 mg/kg bw phenolic fraction oral dose ameliorated liver injury markers in C57BL/6 mice[37]. The ethanolic extract from fruits was found to reduce increased levels of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) in streptozotocin challenged diabetic rats in a dose-dependent way. High levels of ALT and AST denotes liver injury[38]. Similarly, fruit derived phenolic compounds present in methanolic extract restored liver histology after administration at a concentration of 200 and 400 mg/kg/day methanolic extract for 30 days in streptozotocin primed diabetic rat models. Treatment reduced levels of biochemical markers ALT, AST and ALP[39].

Antidiabetic Activity

S. torvum fruit ethanolic extract (200 mg/kg) produced hypoglycemic and hypolipidemic effect in streptozotocin challenged male Sprague-Dawley diabetic rat models. The antidiabetic effect was produced by regenerating pancreatic β-cells and by lowering gene expression of slc2a2 (glucose transporter 2) and PCK1 (phosphoenolpyruvate carboxykinase) in extract treated rats38. Phenolic compounds present in fruit methanolic extract, *viz*., rutin, caffeic acid, gallic acid, catechin helped in reduction of blood glucose by 17.04%, and 42.10% when streptozotocin treated diabetic rats were fed with 200 and 400 mg/kg/day methanolic extract orally for 30 days. The extract increased levels of insulin, hemoglobin, and protein and decreased glycated hemoglobin after treatment[39]. Methyl caffeate isolated from fruits reduced blood glucose level in diabetic rat at a concentration of 40 mg/kg. It upregulated GLUT4 expression and induced pancreatic β-cell regeneration[40]. Ethanolic extract from the leaves (300 mg/kg bw) relieved oxidative stress in streptozotocin induced diabetic rats and also inhibited α-amylase enzyme (IC_{50} 138.46 ± 3.97 µg/ml) in vitro in a dose dependent way. The biochemical profiling of extract revealed presence of gallic acid, catechin, p-coumaric acid, fisetin, myricetin, DL-proline 5-oxo-methyl ester, salicylic acid and butylated hydroxytoluene as major components. Molecular docking studies revealed strong interaction between myricetin and α-amylase[41].

Renal Protective Activity

S. torvum ethanolic extract from dried fruits has the potential to prevent renal injury. Pretreatment with extract demonstrated protection against renal injury in doxorubicin-challenged wistar albino rats. Administration with 100 mg/kg and 300 mg/kg alcoholic extract for 4 weeks prevented elevation in kidney damage markers and relieved oxidative stress. Improved levels of superoxide dismutase and catalase was found in pretreated groups while creatinine and blood urea levels were reduced in doxorubicin-induced extract pretreated groups[42]. Methanolic and hydro-methanolic extract from dry seeds ameliorated monosodium glutamate challenged nephrotoxicity in wistar rats. The extracts were rich source of phenolic compounds as denoted by phytochemical investigation. In monosodium glutamate treated animals, levels of lipid peroxidation increased and superoxide dismutase was decreased which indicated oxidative stress. This effect of nephrotoxicity was reversed by 100 and 300 mg/kg extract treatment for 14 days. It was revealed that methanolic seed extract was more effective than hydro-methanolic extract[43].

Neuroprotective Activity

Inhibitors of acetylcholinesterase and butyrylcholinesterase are much prized in the treatment of Alzheimer's disease. Butanolic extract from *S. torvum* fruits and isolated compound methyl caffeate was tested for their efficacy against acetylcholinesterase and butyrylcholinesterase enzymes. Both these enzymes were competitively inhibited by butanolic extract and methyl caffeate in a dose dependent manner[44]. It was found that methanolic and hydro-methanolic extract from *S. torvum* seeds reversed neurotoxic effect of monosodium glutamate in Swiss albino mice after 14 days of treatment at 100 and 300 mg/kg dose. Monosodium glutamate induced reduction in relative brain weight, decline in antioxidant enzymes, deformation in brain tissue and rise in lipid peroxidation. All these effects were ameliorated by the application of phenolic compounds rich extract[45].

Conclusion

Solanum torvum Sw. (Wild eggplant) represents a fascinating botanical species with significant distribution, diverse taxonomy, and promising medicinal importance. Through its widespread presence across tropical and subtropical regions, it underscores its adaptability to varied environmental conditions. Taxonomically, its classification has evolved over time, reflecting the complexity of its genetic makeup and morphological variations. Despite taxonomic challenges, advancements in molecular techniques have provided valuable insights into its phylogenetic relationships and genetic diversity. Moreover, the medicinal properties of *S. torvum* have garnered increasing attention from researchers and traditional healers alike. Its diverse array of phytochemicals hold promise for various therapeutic applications. Studies have demonstrated its potential in managing various ailments such as diabetes, hypertension, inflammation, and microbial infections. Additionally, its rich nutritional profile adds to its value as a functional food source.

Looking ahead, further exploration and research are warranted to unlock the full potential of *S. torvum* in both medicinal and nutritional domains. Collaborative efforts involving botanists, pharmacologists, Phytochemists, and biotechnologists can contribute to a deeper understanding of its biological properties and mechanisms of action. In terms of taxonomy, integrating molecular techniques with traditional morphological studies can refine its classification and shed light on its evolutionary history. This interdisciplinary approach can enhance our comprehension of species diversity within the *Solanum* genus and inform conservation efforts. From a medicinal standpoint, conducting clinical trials and pharmacological studies will be instrumental in validating the efficacy and safety of *S. torvum* based treatments. This includes investigating potential synergistic effects with existing pharmaceuticals and exploring novel delivery systems to enhance bioavailability. Furthermore, efforts should be made to promote sustainable cultivation practices and preserve wild populations to ensure the availability of this valuable botanical resource for future generations. Engaging local communities and indigenous knowledge holders in conservation initiatives can foster a holistic approach to biodiversity preservation.

In conclusion, *S. torvum* stands as a botanical treasure with immense potential for medicinal, nutritional, and conservation purposes. Continued research endeavors and collaborative partnerships are essential to fully harness its benefits and pave the way for its integration into mainstream healthcare and dietary practices.

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Research Article

Microbiological Quality Assessment of Locally Produced Ice Balls

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Abstract

Ice balls are a famous ice product with sweetened syrup. From making ice in an ice factory to making ice balls, this ice gets exposed to many direct or indirect contact with microorganisms and contaminants. Multiple studies have proved that ice balls mainly serve as a potential source of several diseases. Contaminants got into the ice during manufacturing, storage, packaging, and dispensing of the ice. The most likely cause of ice contamination is poor handling and storage practices. Water that is used in the manufacturing of ice is mainly found to be contaminated with coliforms and sweetened syrup, which is not properly stored and thus contaminated through the fields. Pathogens like *Escherichia coli*, *Salmonella* spp., and *Klebsiella* spp., fungal strains like *Aspergillus* spp., *Candida* spp., *Fusarium* spp., *etc*., entered ice balls and caused gastrointestinal and other severe diseases, sometimes leading to death. Due to its severity, this study was conducted to assess the microbiological quality of locally produced ice balls sold in Wardha city. The sanitary conditions of the sites were also investigated.

Keywords: Contaminated, Pathogens, Disease, Ice balls, Infections.

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1. Introduction

Foodborne sickness, particularly diarrheal disease, is a major concern in underdeveloped countries[1]. Pathogenic bacteria such as *Salmonella enterica*, entero-haemorrhagic *Escherichia coli*, *Staphylococcus aureus*, *Bacillus cereus*, and *Listeria monocytogenes*, as well as viruses and fungal strains like *Aspergillus* spp., *Candida, Fusarium* etc cause this sickness. Despite several surveillance investigations, various types of foodborne bacteria have been detected from Thai raw food products[2-4] and several cases of outbreaks have been reported[5, 6].

During the summer, 'Ice Gola' is a popular street meal that is easily accessible. It is readily available in front of schools and along other roadsides, where it has caused widespread contamination and human intestinal diseases. Ice balls are made with crumpled ice, coated with colored syrup, and served in the shape of ball on a stick[7]. Ice balls, like other hawker fare, were served from pushcarts on the streets, where access to clean water and adequate food storage facilities were lacking[8]. To create a mouthwatering ice treat, you can use whatever flavor you choose or combine many flavors into a single Gola. This is a really tasty dessert dish that is made using ice and flavor-infused syrup. It is perfect for the intense summer heat.

Adulteration is the process of adding subpar ingredients or materials to a superior product, reducing its originality, nature, and taste as well as its color, smell, and nutritional value and endangering the consumers' health in the process. The last victim of these malpractices is a customer who unintentionally consumes contaminated food, which can result in major health issues like allergies and gastrointestinal disorders[9, 10]. The usage of tainted ice has been linked to many outbreaks of sickness, as per center for disease control and prevention. The selling of items like cold beverages and sweets, ice cream, and cut fruits that were contaminated with water and ice was primarily responsible for the spread of water-borne gastro-intestinal illnesses including cholera and typhoid[11]. The risk of infection was increased by manually preparing and eating ice balls[12]. Selling ice balls became less feasible as standards for food safety and hawker cleanliness evolved. Eaten in a bowl with a spoon, ice kachang gained popularity[8, 13, 14]. People may try to acquire water from anyplace during the summer months because of the heat and potential water shortage. Because of this, purification systems may be compromised, increasing the risk of water contamination from numerous bacteria that can cause water-borne sicknesses such typhoid, cholera, dysentery and diarrhoea. Other variables that contribute to the development of acute diarrhoea include eating ice cream, playing ice hockey, and consuming unclean food outside[15]. This study was carried out to evaluate the microbiological quality of locally made ice balls marketed in Wardha city because of its harshness.

2. Materials and Methods

After being gathered from various locations in Wardha City, 48 ice ball samples were placed in sterile stomacher bags and shipped in a thermally insulated package. H_2S media, which are frequently used to screen drinking water for faecal contamination, were prepared[16]. This study established a link between hydrogen-reducing microbes and the prevalence of coliform in drinking water. Before testing, the samples were left at room temperature for about ten minutes to partially defrost. The microbiological analysis started four hours post-sampling. The test relied on finding H_2S-producing bacteria in the water, such as intestinal anaerobes, *Proteus*, *Salmonella*, *Citrobacter*, and *Klebsiella*. 20 ml of frozen gola sample were added to bottles with pre-sterilized H_2S media in order to conduct the test.

Total no. of collected samples	Non- contaminated samples	Contaminated samples	Contaminated samples		
			E. coli	*Salmonella* spp.	*Citrobacter* spp.
48	**00**	**48**	**19**	**12**	**17**

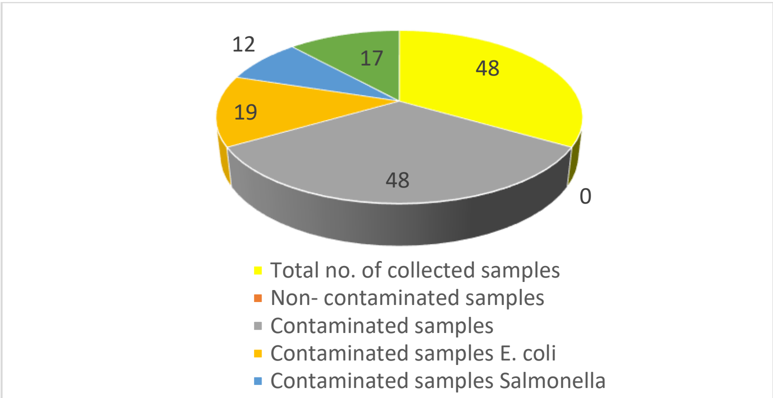

Fig 1: Microbiological analysis of Ice balls

The color shifted to black after incubation for 24 to 48 hours at 28 to 30 °C. This suggests faecal contamination in the samples, which is one of the main causes of many human disorders.

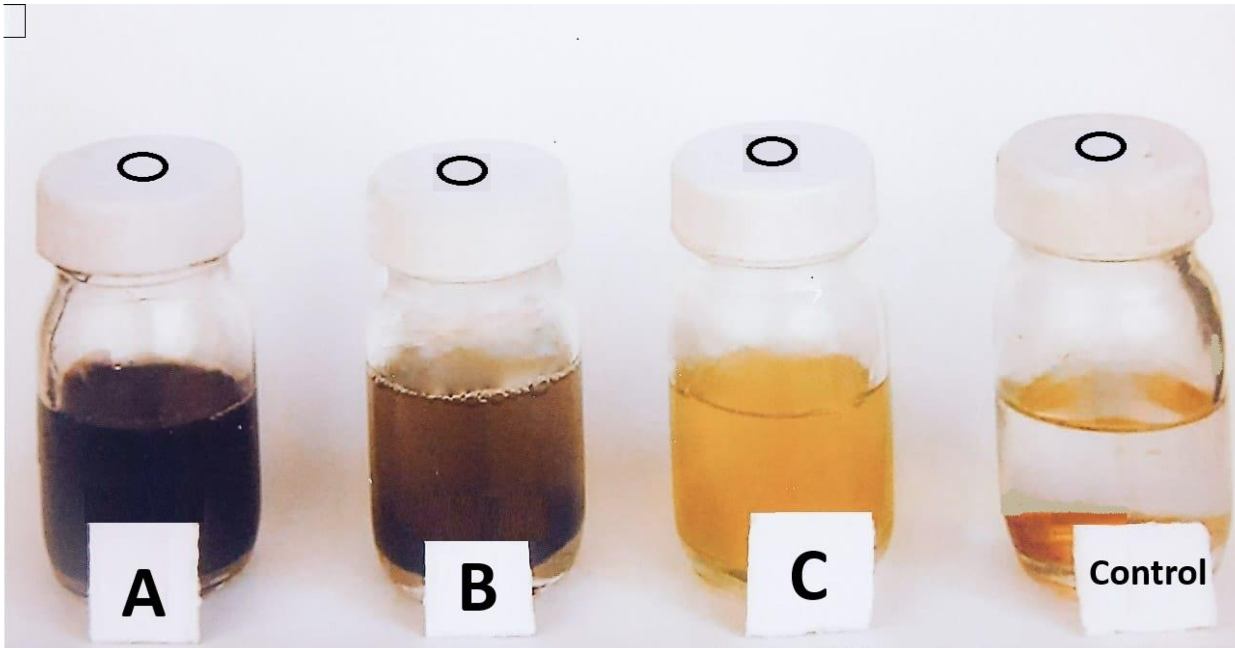

Fig 2: After Incubation results shown in test bottles (A: *Salmonella*; B: *Citrobacter*; C. *E. coli*, and Control)

3. Results and Discussion

There are numbers of reports available about Ice balls contamination. These items are mostly consumed by children results into enteric infection in human being. To verify the reports, attempts were made for microbial analysis of various samples available in Wardha city. Table 1 and Figure 2 below illustrates the analysis of 48 samples. It was discovered that, during a 24-48-hour incubation period at 28–30 °C, 19 of the 48 samples were disease-ridden with *E. coli*, 12 with *Salmonella* spp., and 17 with *Citrobacter* spp. Which indicates the unhygienic procedure of ice making and handling which made it contaminated with pathogenic organisms a chief source of human infection.

4. Conclusions

The microbiological quality of the ice that is prepared and served continues to be a cause for worry, according to the findings. Hygiene standards must be followed. Enhancing knowledge and alertness regarding the possibility of ice becoming contaminated with food-borne pathogens and providing guidance on doable steps to reduce the risk of contamination are two ways to achieve this. As a result, to prevent serious infections, take all appropriate hygiene measures before consuming the ice balls.

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Conflict of interest

Author declares that there are no conflicts of interest.

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Research Article

Exploring Novel Habitat for Critically Endangered *Aquilaria malaccensis* Lam. in Terai Region of Uttar Pradesh

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Abstract

Agarwood (*Aquilaria malaccensis* Lam.) is a highly prized fragrant resin-producing tree within the Thymelaeaceae family, renowned for its aromatic wood known as agar or oudh. With a market value of up to $100,000 per kilogram, its natural habitat in Southeast Asia has faced significant depletion due to extensive extraction driven by demand. Although naturally occurring in South East Asian countries, its cultivation has extended to the home gardens of North Eastern states of India. Given its critical endangerment in the wild and confinement to specific regions, identifying suitable habitats for *ex-situ* conservation is imperative. The introduction of agarwood to the Terai region of Lakhimpur Kheri, Uttar Pradesh, India, characterized by a humid climate and high-water table, aims to address its economic importance and habitat loss concerns. This region, situated between 27.6° and 28.6° N longitude and 80.34° and 81.3° east latitude, with an elevation of 148 meters above sea level, experiences an average rainfall of 1275mm, concentrated mainly from June to September. Such efforts are crucial for the long-term survival of agarwood species under varying climate change scenarios, necessitating collaborative conservation measures by the scientific community and agroforestry managers.

Keywords: *Aquilaria malaccensis*, conservation, agroforestry, Terai, Uttar Pradesh.

1. Introduction

Agarwood (*Aquilaria malaccensis* Lam.) is one of 13 recognized fragrant resin producing trees of the Thymelaeaceae family. It is one of the most significant and prized tree species for its fragrant wood, which is also known as agar, oudh, etc[1]. Depending on grade, agarwood may cost up to $100,000 per kilogram[2]. *Aquilaria malaccensis* possesses natural population in South East Asian countries. Large-scale extraction of *A. malaccensis* due to the high market price and demand for the resin has resulted in rapid decline in its native habitat[3]. The species is grown extensively in the home gardens of North Eastern states of India. As the species is naturally confined to the north eastern states and listed as critically endangered in wild therefore identification of suitable habitat for species is crucial for *ex-situ* conservation[4]. It will be helpful for scientific community and agroforestry managers to design suitable conservation measures along with adequate management activities for the long-term survival of the species of agar wood under different climate change scenarios.

Figure 1. *Aquilaria malaccensis* flowering branch

Figure 2. *Aquilaria malaccensis* fruiting branch

Figure 3. Single seeded fruits of *Aquilaria malaccensis*

Figure 4. Agar plant at Lakhimpur

Therefore, owing to its economic importance, swift disappearance of natural habitat, and increased demand, the species has been introduced in the Terai region of Lakhimpur kheri Uttar Pradesh, India which is located in the foothills of the Himalayas and is distinguished by a high-water table and humid climate (Figs. 1-4). Geographically, it lies between 27.6° and 28.6° N longitude and 80.34° and 81.3° east latitude in the middle plains, with an elevation of 148 m above mean sea level. The average rainfall of the region is 1275mm with erratic pattern of distribution, mostly concentrated in the month of June to September[5].

Plantation trial of *Aquilaria malaccensis* was established of about 24-month-old seedlings (average height 0.78 m and average collar diameter 1.2 cm) procured from Rain Forest Research Institute, Assam. The soil composition of site was silty clay loam, having 7.51pH along with organic carbon 0.23%. Available NPK content was found to be 163.56, 25, and 240 kg/ha. Pits of uniform dimension were dug with a spacing of 3 x3 m and filled with 1 kg of vermicompost along with treatment of termite. Plantation was done in the month of March 2022. During the summer drip irrigation facility was provided twice a week along with surface irrigation twice a month whereas during monsoon and winters irrigation was done as per the requirement. After a period of six months the survival percentage was 98% which was unchanged till date. After the establishment of plantation, growth parameters, *viz*., height (m), collar diameter (mm), number of primary branches and leaves were recorded at an interval of six months.

The average growth of height (m), collar diameter (mm), number of primary branches and leaves (Nos.) during a time frame of 18 months have been depicted in the Table.1. The average increment of height after 18 months of plantation was 0.73m whereas the average increment of collar diameter was 12.42 mm.

Table-1 Average growth of different parameters during 18 months

Age	Average height of plants (m.)	Average diameter of plants (mm.)	Average number of branches	Average number of leaves
At the time of plantation	0.78	12.31	3	132
After 6 months	1.20	15.17	5.54	165.18
After 12 months	1.32	20.35	9.26	321.79
After 18 months	1.51	24.73	12.64	385.2

2. Discussion

As per studies *Aquilaria malaccensis* is a fast-growing species during the early phase. At the age of 6 the mean annual increment of diameter and height is reported as 0.58 cm and 0.86 m, respectively. It is also reported that species can be cultivated under wide range of conditions having well drained soil[6]. Researchers have reported that Agar start flowering at the age of 3-4 years and flowering and fruiting occurs during the months of March-May and June-July respectively[7]. The same pattern of reproductive cycle was observed at the present trial. At the age of 3.5 years the flowering incidence was recorded in the month of March 2023. About 46% of plants were recorded under flowering. Further in the month of June the fruiting was recorded in about 50% of the flowered plants.

A. malaccensis produces one and two-seeded fruits[8]. However, it was observed that fruits at the trial site were only single seeded. The average length, width and thickness of fruits were 26.92 mm, 16.28 mm and 12.82 mm, respectively. Reported average fruit length, width and thickness from Assam are 29.16 mm, 16.03 mm and 11.18 mm, respectively[9].

3. Conclusion

Since *A. malaccensis* was initially brought to Uttar Pradesh, both academics and the general public have very little understanding of this species. It is anticipated that it will have the capacity to considerably increase farmers' and planters' incomes. A picture of the *A. malaccensis* plantation's early phase growth performance in the UP has been provided by the study. Additionally, it has opened up new research avenues for *A. malaccensis* in the Terai region of Uttar Pradesh.

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Research Article

The Impact Heat and Radiation on the Germination Process of Radish Seeds

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Abstract

Scientists are investigating the impact of technology on the natural environment through experiments as humanity becomes more and more reliant on technology. To find out if microwave radiation exposure affects the germination of the radish seed, the following research was carried out. The findings indicate that microwave energy has an impact on radish seed germination. In comparison to a control set or another set of the radish seed that were microwaved for one or a half minute, seeds subjected to the microwave for four minutes exhibited over 150% more seeds germinating over a period of six days. These findings provide one instance of how the natural world responds to the radiant energy generated by artificial items. The impact of radiation and heat on germination will be covered in this essay.

Keywords: Radiation, Heat, Germination, Radish Seeds, Microwave.

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1. Introduction

Radiation levels can impact radish seed germination, resulting in changes to the plant's typical activity. Microwaves and ovens are common sources of radiation for science hobbyists. Radish seeds have also been subjected to various forms of irradiation in scientific investigations, either to prevent illness in radish plants or to increase their general output[1].

1.1. Improved Disease Resistance

Researchers from Japan's National Food Research Institute found that exposing radish seeds to radiation drastically diminished the amount of E. coli bacterium present in the seeds. To different degrees of efficacy, the therapy also helped the alfalfa, mung bean, and broccoli plants. For the greatest outcomes, researchers first exposed the seedlings to dry heat for 17 hours before exposing them to radiation. The rate of seed germination, however, was unaffected by this radiation dose. The same researchers discovered in independent studies that adding dry heat to an elevated radiation dose with 2.5 KGY fully killed *E. coli*. This 2.5 KGY irradiation procedure did, however, have an impact on germination, shortening this radish sprouts. Neither seeds of mung bean sprouts nor alfalfa were negatively impacted[2].

1.2. Improved Growth Rate:

A study that was published in this Korean Journal of Horticultural Science and Technology found that low doses of gamma radiation had an impact on the germination, early growth, or antioxidant content during radish seeds.

Gamma radiation-exposed seeds grew 8 to 14 % larger than ordinary seed after germination. Radiate seed that were then placed in storage for up to a year showed no signs of alteration. Even yet, the stored and radioactive seeds grew a little more slowly than conventional seeds. However, whether incubated at ambient temperature or at 10o C, seed that were allowed to germination after radiation showed faster germinated. Radiation doses with 4 Gy, 8 Gy, 16 Gy, or 32 Gy were employed in the experiments. A 36.6 % longer time had passed for those exposed to 4 GY than for the control group. The antioxidant activity was 8% higher in those exposed to 8 GY. Overall, radiation levels of 16 or 32 GY were the best since they showed early growth, increased size, and antioxidant activity[3].

Figure 1: Radish Plants

Raphanus sativus L., a member of this Brassicaceae family that is utilized in cooking and as an addition to the diet, is more commonly known as "white radish" throughout the world. *R. sativus* is mostly consumed by people all over the world in this form with salads, vegetables, pickles, or juice. This utilized of *R. sativus*' various sections in resolving jaundice is supported by traditional medical practice, it also contains a variety of vitamins, carbs, sugars, fibers, minerals, along with secondary metabolites, all of which have promising biochemical effects on promoting human health. *R. sativus* is currently sought after by scientific communities as a component in the creation of nutritious food. The growing number of people worldwide is pushing up consumption of food to new highs while also contribute to environmental degradation. One of the objectives of the Sustainable Development Goals is to eradicate world hunger, since sustaining the increasing global population is a major socioeconomic issue on a worldwide scale. Global development, building of the infrastructures, thus industrialization is damaging the land, lowering earnings, and eventually jeopardizing the availability of food. Maintaining and increasing crop and food production through a variety of methods is crucial to addressing the issues associated with food security Modern farming practices that are socially acceptable, economically possible, and sustainable[4].

Reduction of initial seed germination development and growth is being accelerated by land degradation, genetic variety loss, seed damage, overuse of pesticides, nutrient loss, or hasty watering practices in modern agriculture. There are a number of physical, chemical, and biological solutions used to deal with the issue of seeds losing their ability to germinate and seedlings growing too quickly. Although those techniques can increase germination rates and speed up seed germination, they are labor- and time-intensive and leave behind residues that could harm the environment.

One of the most delicate and important steps in a plant's physiological development is seed germination. Over the past few decades, extensive plasma science research and its applications have produced a variety of data demonstrating how LTP seedling stimulation can dramatically enhance initial growth of seeds during development. One technology that has been shown to increase the potential of plant cultivation is low-temperature plasma (LTP). 5 Pre-sowing LTP pretreatment can promote sprouting, development, enzyme production, or plants yields, as well as speeding increase the germination of seeds and improve reproduction frequency.

The water adsorption, resulting in the concealed phase of the embryo to be broken down, has an impact on seed germination rates, which are a gauge of how efficiently the crop could be generated ultimately. The primary process underlying these beneficial effects of plasma therapy in the seed is mainly due to plasma's capacity to produce a physically rich, healthy atmosphere, as well as its capacity to allow the transportation of energy reactive molecules on the outside of biological cells, which is extremely beneficial. Furthermore, the LTP therapy reduces surface pollution and inhibits the spread of harmful pathogenic microbes in seedling.

In order to improve seed germination or seeds growth of regularly utilized food without having a detrimental environmental impact, plasma application is one of the finest methods. Studies on radishes' seeds have been conducted because they are grown and eaten all over the world. Plasma from cold temperatures has been shown to improve seed disinfecting and sprouting while also improving growth of crops, generation of biomass, branched out, seeds maturing, or resistant to disease. Investigations exposing seedling with Ar-O2 admixture discharging gas revealed that LF microwave hybrid plasma generated fewer reactive oxygen compounds than a conventional LF plasma jet. SEM examination demonstrated that the etched impacts on the seed's coating caused by the argon plasma procedures altered the wettability within the radish seeds. Plasma treatment had an impact on the kinetics of seed germination, while seed color and storage duration after harvest had an impact on the maximum germination rate [6].

Notable previous work:

Global warming and fluctuations in ozone layer thickness are expected to bring more dangerous radiation from the sun into the troposphere's lower layers. Several factors, particularly industrial processes as an instance, the utilization of chlorofluorocarbons (CFCs), which have a negative impact on this formation of ozone, are contributing towards the ozone layer's variability. The level of coverage of this ozone layer influences the quantity of radiation that penetrates the earth's surface, particularly ultraviolet (UV) radiation[7]. Radiation has a substantial impact on several biological and physiological functions in animals as well as plants. It has been demonstrated that exposure to more radiation causes skin damage, generalized DNA damage, human vision loss, cress seedling suppression, and restrictions on anthocyanin production in corn[8].

There is a wide spectrum of impacts that radiation exposure has been discovered to have on seeds. In a study on the effects of radiation on seeds conducted by Marcu et al.[9] it was discovered that radiation affects both the germinate potential along with actual qualities of these seeds that have emerged (such as root or shoot lengths). Germinate potential refers to this proportion of seeds that have successfully germinated overall as well as this timing of germination relative to the time the seeds were planted. Furthermore, it was discovered that seeds with radiotherapy had less photosynthetic pigment than seeds without radiotherapy. It is evident that radiation affects both the quantity and quality of seeds[9].

Temperature has three key effects on sprouting: moisture, hormone production, and the activity of enzymes. Seeds need water for germination, consequently that they have to consume it. This cannot occur unless there is sufficient moisture. Warmer temperatures may cause greater transpiration and less humidity, which is harmful to fertilization. Furthermore, some environmental simulations predict greater variability in the process of precipitation that could have an immediate influence on the hydrologic cycle in a variety of places (IPCC 2007)[10].

These investigations have gathered valuable information, however because the trials were carried out indoors under artificial settings, they may have overestimated the impact of radiation on plant functions. In order to determine what impact radiation affects the development of plants, field studies are required where seedlings are subjected to radiation in the environment, and their bodily reactions are investigated. In this work, we employ high altitude weather balloons to expose three different types of seeds to stratospheric radiation: garden bean (*Phaseolus vulgaris* L.), corn (*Zea mays* L.), or radish (*Raphanus sativus* L.), or we employ germinating efficiency with growth of stems as indices to investigate the effect of radiation on seeds[11].

Objectives

To optimize radish seed germination and growth, at least three small plates corresponding to different seed treatments were prepared. Radishes were particularly sensitive to temperature variations, with seed failing to sprout in soil temperature surpassing 35ºC, while their optimal growth occurred within the range of 7 to 29ºC. Germination, the pivotal process of seed development into new plants, generally transpired when a seeding emerged from either an angiosperm or gymnosperm seed, with the most favorable temperature ranging between 25ºC to 35ºC.

Methodology

This study's overall structure was exploratory. Each seedling was measured by the researchers from the bottom of the base of this root through the top of cotyledon. A seeds final measurement still contained any root tips or cotyledons that separated during handling. Radish seeds that did not sprout were given a millimeter count of 0.

We calculated and reported average seeds germinate rates with the 20 seeds in a 1.5 microwave, 4-minute microwave, as well as controlled groups. A second lot of 60 radish seed comprising these initial seeds package was utilized in every step of the study on an additional day. To ensure consistency with this previous study, a second group of radish seeds were placed in this same Petri dishes as the first batch. Over a six-day span, the room's temperature stayed at 21–22°C[12].

Result and Discussion

An approved test was conducted using 20 radish seeds in every group of experiments plus the control group to evaluate the influence of radiant radiation upon the development of radish seed. In the present study, radish seeds were heated using microwave oven radiation. Both independent groups of subjects were exposed to differing quantities in microwave radiation: one set for radish seeds spent 1.5 minutes within the microwave, whereas the other endured 4 minutes inside the microwave.

The authority group of radish seeds received no microwave treatment. After six days, we utilized a metric ruler to measure each seedling's germinating length, which is the millimeter separation between the base between its root tip with the apex of the cotyledon. On an alternate day, we conducted second research. The average radish seed development length was estimated from the information gathered by summing the radish seed germinated durations for every category and multiplying by 40 (the total number of seeds). This study's findings indicate that seed being exposed to microwave technology for more than 1.5 minutes may have an effect on radish seed development[13].

The seeds which were microwaved for 4 minutes developed an average of at 114.8 mm, which was approximately 1.5 times longer that either the control along with the 1.5-minute microwave group (Figure 2). Conversely, the seeds in the microwave for both the control or 1.5-minute microwave groups developed at 67.8 mm (control) with 78.6 mm (1.5-minute microwave) (Figure 2). 14

An ANOVA statistical analysis comparing the three groups participating in the experiment yielded F values of 12.12 and 3.07, respectively. Therefore, were able to reject the null assumption because the F value surpassed the critical value of F, and we concluded that there was indeed an important distinction between the three radishes seedling groupings depending on how long they were subjected to the microwave. A t-test was also used to compare both the control and the experimental groups. The rate of germination of radish seeds in the control along with 1.5-minute microwave groups was not significantly different ($p = 0.231$). The 1.5-minute exposure period doesn't seem to have altered radish seed development; hence the no effect hypothesis cannot be rejected. However, the test for significance indicated an important statistical distinction between this control group and 4-minute microwave radish seed groups ($p = 0.000042$).

This suggests that being exposed to sunlight within a microwave for 1.5 to 4 minutes affects the ability of radish seeds to develop into plants. It was concluded that the seeds of radish exposed to microwave radiation for up to 4 minutes produce seedling that survive more than 1.5 times longer after a 6-day germinating period. 15

The procedure was repeated on a second day to investigate statistical variability, as multiple variables can influence the procedure for germination. Despite performing the experiments across multiple days, we noticed that the identical experimental groups had comparable germination times (Tables 1 and 2). Between tests 1 or 2, the untreated radish seed sprouted on the average 62 mm rather than 73 mm; the 1.5-minute heated in the microwave seeds propagated on average 80 mm rather than 77 mm; and the 4-minute heated in the microwave seeds developed on the average 112 mm rather than 117 mm. We conclude that the consistency of the experimental result among radish seed group indicates a well-monitored experiment with a high level of accuracy for detecting the effects of radiant radiation on seed germination.

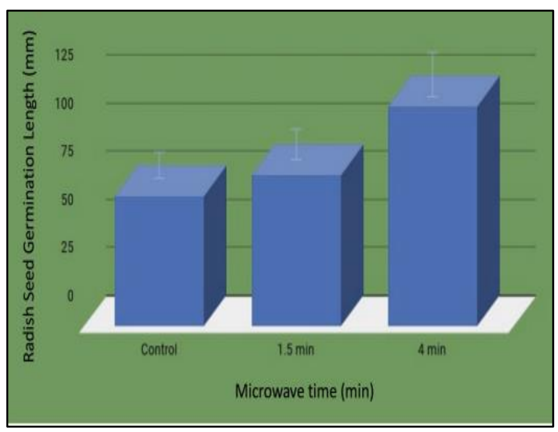

Figure 2. The average time for seeds to germinate after six days

Table 1. The average of the germination data from Experiments 1 and 2				
Groups	**Count**	**Sum**	**Average**	**Variance**
Control Group	40	2711	67.8	1934.2
11/2 Minute Microwave	40	3144	78.6	1286.9
4 Minute Microwave	40	4590	114.8	2742.1

Table 2. The average length of radish seed germination by experiment after six days [17]		
Experimental Groups	**Experiment #1 (n=60)**	**Experiment #2 (n=60)**
Control	62.4 mm	73.15 mm
1.5 Minute Microwave	79.75 mm	77.45 mm
4 Minute Microwave	112.3 mm	117.2 mm

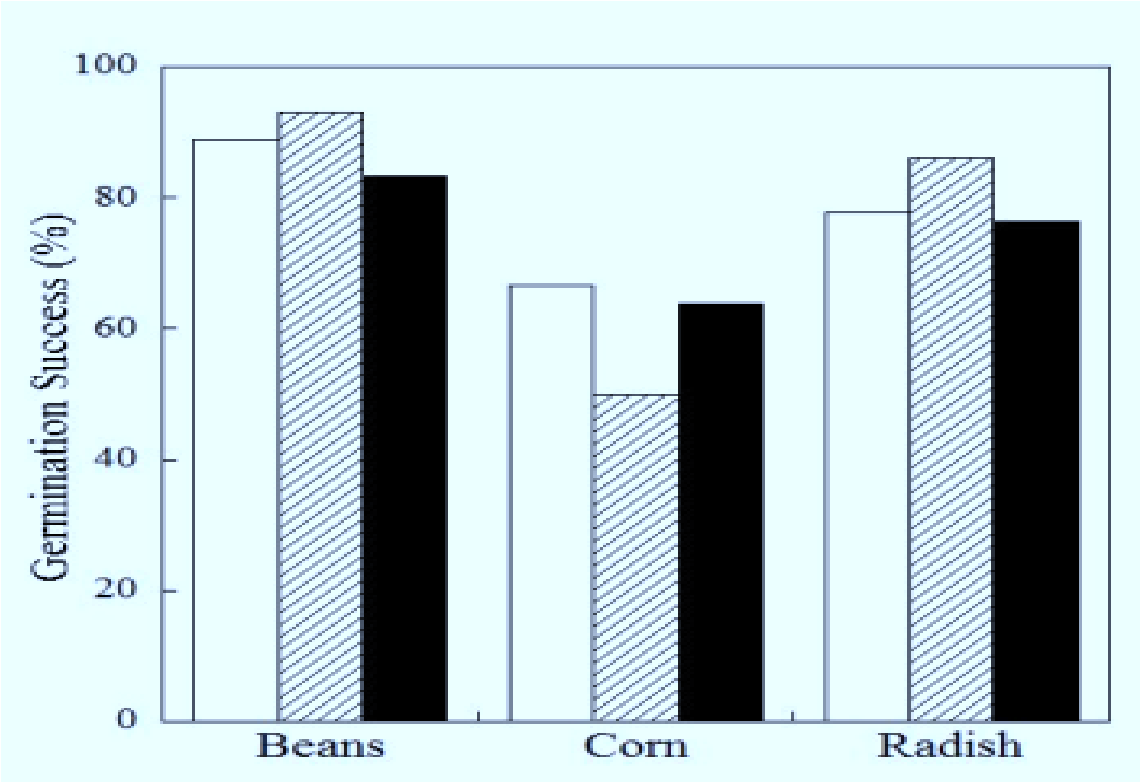

Figure 3. The percentage of seeds that germinated compared to those planted of a specific type and exposure, representing germination success with 5% error. The seeds were divided into three groups: outside (dark), inside (diagonal), and control (clear). 21

The proportion of seeds the fact that developed was investigated after studying how radiation impacted seeds. Figure 3 shows the success percentage of germination of seeds for each type of seed. The rate at which germinates of bean seeds produced in the lab (as a control) is approximately 88.9%. The germination success percentage for protected seedlings (inside the payload box) was 93.1%

The initial germination success percentage for seeds that were placed outside the box and subjected to high radiation was 83.3%. In the lab, control maize plants germinated at an 83.3% rate. The average success rate of seeds made from corn inside the box (inside) was 63.8%, which was significantly lower than the achievement rate for the control seeds, although the effectiveness rate of radiation-exposed seeds outside (outside) was 86.1%, which was slightly higher than the control[19].

The ingestion of radiation was also discovered to improve the likelihood of radish germination. The germination success rate of the radish seedlings within the payload box was 86.1%, compared to 77.8% for the control seeds and 76.4% for the seeds inside the payload box. Figure 3 illustrates a comparison of germination rates. Statistics revealed that the overall height of control bean plants differed significantly from outside and inside bean plants (p=5.296E-5 and p=1.768E-3, respectively)[20].

Conclusion

Radiation not only affects a seed's likelihood of germinating, but it also has long-term consequences for the seedlings' eventual survival rate. Given how crucial plants are to the maintenance of healthy ecosystems, this is incredibly pertinent. It is crucial to take into account how radiation may affect the quantity and quality of new plants that are produced as an ecosystem is rebuilt. Plants are frequently the key to an ecosystem's ability to recover after a disaster. In addition, a lot of study has been done on using radiation in agriculture to control the growth of microorganisms.

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Review Article

Genetic Strategies for Heat-Tolerant Pigeon pea: A Comprehensive Review on GWAS, QTLs, and beyond

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Abstract

Pigeon pea [*Cajanus cajan* (L.) Huth], a vital global protein source, faces substantial yield losses due to severe heat stress during reproduction. Genetic diversity exploration, employing GWAS and QTL mapping, reveals markers linked to heat resistance and identifies crucial candidate genes. Heat stress disrupts germination, pod development, and photosynthesis, resulting in smaller grains. Pigeon pea's physiological responses, including a sophisticated osmotic mechanism, showcase its ability to adapt to elevated temperatures. Certain genotypes exhibit notable heat tolerance, informing the breeding of resilient cultivars. Functional genomics, using techniques like RNA-seq, uncovers key heat stress-tolerant genes, offering avenues for potential genetic modifications. The review guides transformative interventions for sustainable cultivation, emphasizing the importance of incorporating identified markers into breeding and crop management practices for effective heat mitigation. Challenges persist, including exploring gene regulation and epigenetic aspects associated with the heat stress response. This comprehensive overview contributes to the development of sustainable cultivation practices, vital for ensuring food security amid climate change.

Keywords: Pigeon pea, heat stress, genetic diversity, GWAS, QTL mapping, candidate genes, heat tolerance, climate change.

1. Introduction

As a crucial source of protein and nutrition for millions worldwide, the Pigeon pea [*Cajanus cajan* (L.) Huth], faces a formidable foe: heat stress. Once classified solely as a cool-season crop, this legume now encounters scorching temperatures during its reproductive stages, particularly in warmer regions and with late sowing. These elevated temperatures wreak havoc on Pigeon pea, causing flower and pod detachment, stunted seed size, and ultimately, devastating yield losses exceeding 100%[1]. The damage doesn't stop there. Heat stress not only cripples pollen viability and fertility, hindering pod development[2,3], but also disrupts sucrose synthesis, further compromising pod formation[1]. This cascade of disruptions leads to stunted grain growth, premature senescence, and reduced grain weight, posing a significant threat to overall yield and global food security[4].

However, amidst this challenge lies a beacon of hope. *Unlocking the secrets of genetic diversity* holds the key to identifying Pigeon pea varieties with inherent heat tolerance[5, 6, 7]. Powerful tools like *genome-wide association studies (GWAS)* and *quantitative trait loci (QTL) mapping* are paving the way for pinpointing genomic markers associated with heat resistance[8]. By delving deeper into these regions, researchers are identifying *candidate gene***s** that play a vital role in the Pigeon pea's heat stress response[9, 10]. This journey into the molecular mechanisms of heat tolerance provides us with valuable insights not only for protecting Pigeon pea, but also for developing *resilient food systems* capable of withstanding the ever-increasing heat stress brought on by climate change. In this paper, we will delve deeper into the intricate dance between Pigeon pea and heat stress, exploring the latest research advancements and potential solutions for safeguarding this vital crop for generations to come.

Heat Stress Vulnerability throughout the Pigeon pea Lifecycle

From Seed to Pod: A Fragile Journey under Rising Temperatures

While resilient, the Pigeon pea faces a formidable foe throughout its lifecycle: heat stress. This unrelenting pressure disrupts various aspects of growth, influencing phenology, development, biomass, flowering time, pod number, maturity, seed weight, and ultimately, the crucial yield[11, 12, 13]. Understanding the specific vulnerabilities at each stage is key to unlocking resilience and safeguarding this vital crop.

Premature Bloom: How Heat Endangers Germination and Seedling Establishment

The very foundation of the Pigeon pea's life cycle, germination, is threatened by scorching temperatures. Inappropriate heat diminishes enzyme activity and oxygen availability, hindering the delicate process[14, 15]. Different varieties demonstrate varying levels of tolerance, with some struggling above 45 °C and experiencing hampered growth or even mortality. Studies like Rhythm et al.[16] paint a stark picture, with temperatures reaching 40 °C proving lethal to seedling length.

Reproductive Meltdown: The Devastating Effects of Heat on Pod Set and Grain Yield

The stakes skyrocket during the reproductive phase, which emerges as particularly sensitive to heat stress compared to vegetative stages[17]. This critical period witnesses significant grain yield losses attributable to the scorching sun. Genetic variations influence aspects like phenology, growth, and yield components. Rising temperatures translate to fewer flowers, delayed pod initiation, and reduced pod set[17, 18]. Heat-sensitive genotypes suffer further setbacks, with compromised pollen viability, reduced germination, and weakened stigma receptivity hindering pod development.

Physiological Mayhem: A Cascade of Disruptions under Heat Stress

Heat stress throws a wrench into the Pigeon pea's delicate physiological processes. Heat-sensitive genotypes experience a marked reduction in stomatal conductance, leaf water content, chlorophyll, membrane integrity, and photochemical efficiency[19]. These disruptions essentially compromise the plant's ability to breathe, photosynthesize, and maintain its structural integrity, hindering its ability to thrive under harsh conditions.

Reproductive Organ Mishaps

From Anther Abnormalities to Male Sterility:

Beyond physiological disruptions, heat stress wreaks havoc on the reproductive organs themselves. Rising temperatures induce aberrations in the development of anthers, impacting the number of locules and thickening the anther wall[20]. This directly translates to male sterility, further jeopardizing pod set and ultimately, grain yield.

Pollen's Plight

More Vulnerable Than Its Counterpart:

The Pigeon pea's pollen emerges as even more susceptible to heat stress compared to the female gametophyte[21]. Soaring temperatures post-anthesis lead to a devastating chain reaction: reduced pollen germination, stunted pollen tube growth, hampered fertilization, and a decline in stigmatic receptivity. This effectively cuts off the pathway for successful reproduction, significantly impacting yield potential.

Oxidative Stress and Nutrient Deprivation

A Double Whammy for Pod Development:

Elevated temperatures trigger oxidative stress within the Pigeon pea, further impeding pod development. This stress disrupts photosynthesis in leaves, leading to reduced levels of soluble carbohydrates and ATP in the pistil, the female reproductive organ[20]. This translates to a lack of essential nutrients for developing pollen tubes, further hindering their growth and ultimately impacting ovary development.

Economic Impact

Beyond Biological Consequences:

The biological consequences of heat stress on the Pigeon pea translate to significant economic losses for farmers and broader food security concerns. Studies estimate yield losses exceeding 50% under severe heat stress conditions[22]. This translates to reduced income for farmers, impacting their livelihoods and contributing to wider food price fluctuations. Understanding these vulnerabilities at each stage of the Pigeon pea lifecycle is crucial for developing targeted strategies to combat heat stress. From breeding heat-tolerant varieties to employing precision agriculture techniques, ongoing research offers hope for safeguarding this vital crop for generations to come.

Physiological and Biochemical Responses to Heat Stress

Silenced Sunbeams: Heat's Disruption of Pigeon pea Photosynthesis:

Heat stress doesn't just impact Pigeon pea growth and development; it throws a wrench into the very heart of its energy production: photosynthesis. This vital process, akin to the sunbeams powering the plant, is severely disrupted by rising temperatures.

Impaired Photosystems:

Several studies paint a concerning picture. While initial heat increases (up to 35°C) might not impact Photosystem II (PSII) activity, sustained high temperatures, like 46°C experienced during pod filling, wreak havoc. Research by Hasanuzzaman et al.[23] suggests this triggers "irreversible damage" to the photosynthetic system, essentially silencing the sunbeams within the plant. Additionally, Srinivasan et al.[24] found severe damage to PSII at even higher temperatures (50 °C) within 48 hours.

Reduced Grain Size and Disrupted Metabolism

The consequences of this photosynthetic disruption are dire. Temperatures exceeding 35 °C during the reproductive phase lead to smaller grains due to suppressed photosynthesis, disrupted electron flow within the plant, and altered metabolic pathways[25]. Compared to other legumes, Pigeon pea exhibits even higher sensitivity to this disruption, particularly in membrane stability and PSII function[26].

Chlorophyll Breakdown and Leaf Aging

Heat stress doesn't stop at PSII. Long-term exposure (16-35 °C for 10 days) induces leaf aging, damaging chloroplasts and reducing chlorophyll content[27, 28]. This translates to a decline in the green pigment responsible for capturing sunlight, further hindering photosynthesis.

Heat-Sensitive Varieties Face the Brunt

Unfortunately, not all Pigeon pea varieties are created equal. Studies like Kaushal et al.[25] reveal that heat-sensitive genotypes suffer more significant leaf damage compared to heat-tolerant ones under high temperatures. This vulnerability stems from a greater reduction in leaf water content, potentially decreased stomatal conductance, and limitations in the root's ability to deliver water (hydraulic conductivity).

Reduced Transpiration Efficiency

Adding another layer to the challenge, research by Singh[29] and Singh et al.[30] indicates an inverse relationship between temperature and transpiration efficiency in Pigeon pea. Simply put, hotter temperatures make it harder for the plant to efficiently manage water loss, further exacerbating stress. Understanding these intricate disruptions at the physiological and biochemical levels is crucial for developing strategies to combat heat stress and safeguard Pigeon pea's photosynthetic potential. By exploring mitigation strategies like breeding heat-tolerant varieties and implementing precision agriculture techniques, we can work towards ensuring this vital crop continues to thrive under a changing climate.

Physiological Adaptations to Heat Stress

In response to abiotic stress, particularly heat stress, Pigeon pea orchestrates a sophisticated osmotic adaptive mechanism aimed at preserving turgor pressure and ensuring the plasticity of cell walls. This intricate process involves the accumulation of vital biochemical compounds, including proline, glutathione, trehalose, molecular chaperones, and a diverse array of antioxidant enzymes. Notably, enzymes crucial for fundamental processes like carbon fixation (RUBISCO), sucrose synthesis (sucrose phosphate synthase), and sucrose hydrolysis (invertase) experience robust inhibition under elevated temperatures, particularly at 45/40 °C[31, 32, 33]. The introduction of exogenous proline has proven effective in mitigating the adverse effects associated with heightened temperatures in Pigeon pea. Additionally, optimal zinc nutrition has been identified as a key factor in fostering Pigeon pea growth, particularly in the face of high temperatures and arid climatic conditions [34, 35, 36, 37]. These physiological adaptations underscore the plant's intricate strategies to combat the challenges posed by heat stress, highlighting the complex interplay of various biochemical processes in maintaining cellular integrity and functionality.

Unravelling the Genomic Landscape with GWAS and QTLs

In the pursuit of deciphering the intricate molecular mechanisms governing heat tolerance in Pigeon pea, a multifaceted approach integrating genome-wide association studies (GWAS) and Quantitative Trait Loci

(QTLs) mapping has been pivotal. Leveraging cutting-edge genotyping technologies like genotyping by sequencing (GBS) and SSR markers, significant QTLs linked to heat stress have been pinpointed [8, 34, 38]. Concurrently, the exploration of candidate genes nestled within these identified QTLs, such as LRG 30, ICPL 85063, and ICPL 332, elucidates potential contributors to heat stress tolerance as revealed by Choudhary et al.[39]. Moreover, the discernment of gene expression alterations, notably the overexpression of CcHyPRP and CcCYP, unveiled through studies[40, 41, 42] have underscored their roles in fortifying heat resilience. Complementary homology studies by Tamirisa et al.[43] regarding CcCDR and the qRT-PCR analysis of DLP (dehydrin-like protein) by Singh et al.[44] (2021) further deepen our understanding of the molecular intricacies underlying heat stress response. This integrative approach not only enhances our comprehension of the genomic landscape but also provides a strategic framework for developing more robust and climate-resilient Pigeon pea cultivars.

Unveiling Functional Insights through Genomic Approaches

***Functional Genomics at the Helm*:**

In the pursuit of understanding the intricate responses to heat stress, functional genomics emerges as a pivotal tool, unravelling the roles of candidate genes in-depth. Employing advanced techniques like RNA-seq, specific genes have been pinpointed as key contributors to heat stress tolerance. Noteworthy among these are Ca_25811, Ca_23016, Ca_09743, and Ca_17680, identified through RNA-seq analyses, which play vital roles in orchestrating the plant's defense against heat-induced challenges[45].

Candidate Genes Steering Heat Resilience

The exploration of identified Quantitative Trait Loci (QTLs) has unearthed a plethora of candidate genes integral to heat stress response. Among these are genes encoding heat shock proteins, pivotal in cellular protection during stress, heat shock transcription factors crucial for regulatory responses, and genes intricately involved in the regulation of flowering time and pollen-specific functions. This detailed analysis, exemplified by studies from Zhu et al. (2021) and Paul et al.[47] (2018), provides a molecular roadmap for understanding and enhancing heat stress tolerance.

Transcriptional Dynamics

Transcriptional analyses have spotlighted specific genes, such as CaGolS1, exhibiting a preferential induction over CaGolS2 in response to heat and oxidative stress in Pigeon pea[48]. These genes play pivotal roles.

Comprehensive Review and Future Prospects

Unravelling Genomic Signatures:

Genome-wide association studies (GWAS) and the identification of Quantitative Trait Loci (QTLs) have emerged as powerful tools in decoding the genomic underpinnings of heat stress resilience. Recent studies utilizing advanced genotyping approaches such as genotyping by sequencing (GBS) and SSR markers have yielded a treasure trove of QTLs associated with crucial traits under heat stress conditions[46, 48, 49, 50]. These genomic signatures provide valuable markers for breeding programs, offering a precision-guided approach to developing Pigeon pea varieties tailored for heat-prone environments.

Translating Knowledge into Action

While this review comprehensively captures the current state of understanding, the translation of this knowledge into actionable strategies is a critical next step. Harnessing the identified QTLs and candidate genes, breeding programs can expedite the development of heat-tolerant Pigeon pea cultivars. Additionally, the integration of these findings into agronomic practices and crop management strategies can provide holistic solutions for mitigating heat stress impacts on Pigeon pea yield.

Challenges and Future Directions

As we advance in deciphering the molecular nuances of heat stress response, several challenges and unexplored territories await. Exploring the temporal and spatial regulation of candidate genes, understanding gene interactions, and unravelling the epigenetic aspects of heat stress response are potential avenues for future research. Moreover, the integration of multi-omics approaches, including proteomics and metabolomics, can offer a holistic view of the intricate networks governing heat stress resilience in Pigeon pea. This review serves as a roadmap, navigating the molecular landscape of heat stress response in Pigeon pea. The amalgamation of genetic insights, genomic markers, and functional genomics sets the stage for transformative interventions, fostering the development of Pigeon pea varieties equipped to thrive in the face of escalating temperature challenges. The journey, however, continues, with the promise of unravelling deeper layers of complexity and paving the way for sustainable and resilient Pigeon pea cultivation in the era of climate change.

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Authors' contribution

PG, HJH, KKS: Writing original Draft and data curation. DS: Review, editing, supervision and conceptualization.

Conflict of Interest

The authors have no conflicts of interest to declare.

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Research Article

Challenges and Opportunities in Conserving Grassland Ecosystems of Western Himalayan region

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Abstract

Grasslands are delineated as terrestrial ecosystems principally distinguished by predominantly herbaceous flora devoid of shrubbery, and their persistence hinges upon mechanisms such as combustion, herbivore browsing, harvesting, arid conditions, and exposure to sub-zero temperatures. The primary plant families encountered in grassland ecosystems include family Poaceae, Cyperaceae, Fabaceae, and Asteraceae. In India, there are different types of grasslands observed, but in the Western Himalayan region, Cool temperate grassy slopes grasslands, Sub-alpine meadows grasslands, Alpine meadows and Steppe formations of trans-Himalaya grasslands predominantly prevail. Furthermore, the grasslands are primarily inhabited by small herbs, which directly or indirectly hold immense importance in the lives of local communities. The Western Himalayan stands as one of the most recent and dynamically evolving mountain ranges globally, marked by both activity and vulnerability. They confront human-induced challenges in the pursuit of development. Grassland communities are encountering numerous threats due to significant human activities, including land degradation, intense grazing, habitat fragmentation, invasive species, and, to some extent, the impact of climate change. These factors are contributing to the decline of grasslands and a decrease in species diversity. Preserving grasslands necessitates a comprehensive approach encompassing a variety of tactics. Diverse conservation strategies are needed for the management of various grassland types. The mid-elevation grasslands, especially the meadows used for hay production, are preserved through the control of livestock grazing and controlled burning during the winter season. While several government departments are active in different grassland regions, focusing on habitat restoration and eco-development, their collective efforts are directed towards preserving these distinctive habitats.

Keywords: Alpine meadows, Biodiversity, Conservation, Cyperaceae, Poaceae, Uttarakhand, Threats.

1. Introduction

Grasslands are ecosystems characterized by the dominance of graminoids, which include grasses and grass-like plants. The primary plant families commonly encountered in these ecosystems are Poaceae, Cyperaceae, Fabaceae, and Asteraceae[1]. While Western Himalayan grasslands can be viewed as intermediary ecosystems that, with increased moisture, could evolve into forests, or with reduced moisture, could transform into deserts-like condition[2]. Grasslands worldwide are categorized into Tropical Savannas, Temperate Grasslands, and Steppes. The five general forms of grass cover are found in India, according to Dhadabgao and Sankarnarayan's book "The Grass Cover of India" from 1973[3].

When considering the Western Himalayan region, it primarily consists of two types, they are: A) *Themeda-Arundinella* grasslands extend across the foothills and lower hills, including the Shiwalik hills, in the states of Uttarakhand, Himachal Pradesh, and Jammu and Kashmir, within an elevation range of 350 to 2000 meters above sea level; B) Temperate Alpine grasslands are distributed throughout the Himalayan states, encompassing Uttarakhand, Himachal Pradesh, and Jammu and Kashmir, at elevations exceeding 2000 meters above sea level. Moreover, the temperate alpine grassland can be classified into two subcategories: 1. Moist Alpine Meadows: These are grasslands that thrive in regions with relatively higher moisture levels. They are typically found at higher elevations in the Himalayas, above 2000 meters, and 2. Cold Arid Meadows: In contrast, cold arid meadows exist in areas with lower moisture levels and are often located at even higher elevations in the Himalayas. These regions experience harsher climatic conditions, with colder temperatures and less precipitation (Fig. 2).

The Western Himalayan region's unique geographical and have 1123 plant species specifically used for medicinal purposes, based on a recent study on the floral biodiversity of the area[4]. Due to its over-exploitation mainly as a source of incense material at an alarming rate, the species population is decreasing in its natural habitat at a faster rate, consequently fulfilling the criteria of being listed as endangered for the Himalayan region, arousing serious distress among the scientists and environmentalists[5].

However, these ecosystems face various challenges, including habitat fragmentation, climate change, and human activities such as deforestation and unsustainable grazing practices. Conservation efforts in the Western Himalayas must take into account the preservation of both mountain forests and alpine meadows to ensure the ecological balance and sustainability of this region.

Grasslands in Western Himalayan region are among the most imperiled ecosystems, yet they have received insufficient attention in India's conservation and restoration policies. Protected areas cover less than 5% of India's grasslands[6], and the on-going government-sponsored restoration initiatives tend to prioritize the transformation of natural grasslands into planted forests. In India, the grassland area decreased from 18 million hectares to 12.3 million hectares, marking a decline of 31% between 2005 and 2015[7]. One factor that has played a role in the reduction of grasslands is the longstanding inclination towards forest ecosystems embedded within the policies of the Indian government[8]. This inventory offers an all-encompassing roster of plants within the grassland ecosystem (Fig. 3), with a particular emphasis on identifying the challenges this distinct ecosystem faces and outlining strategies for its conservation.

2. Material and Method:

2.1 Study area: The study encompasses the entirety of three Western Himalayan states, namely Jammu & Kashmir (JK), Himachal Pradesh (HP), and Uttarakhand (UK), spanning geographical coordinates from approximately 28º52'N to 35º03'N latitude and 79º59'E to 73º33'E longitude. This vast study area covers a total expanse of 530,000 square kilometres (Fig: 1).

2.2 Data collection and literature survey: By combining field observations with secondary data sources like herbarium records, research articles, short notes, and checklists, the inventory aims to provide a comprehensive and accurate account of the plant species present in the grassland ecosystem. This approach helps ensure the reliability and completeness of the inventory's findings. We also compiled more than 140 years literature starting from 1879 A.D. to present and conducting such a thorough literature review over an extensive timeframe, the inventory seeks to offer a comprehensive and well-documented account of the plant species that have been recorded in the Western Himalayan grasslands, serving as a valuable resource for research, conservation, and management efforts. The field survey was conducted during the transition from the post-monsoon period in 2022 to the pre-monsoon phase in 2023, with the aim of comprehending the prevalence of species, the presence of various species, and the phonological aspects of these species

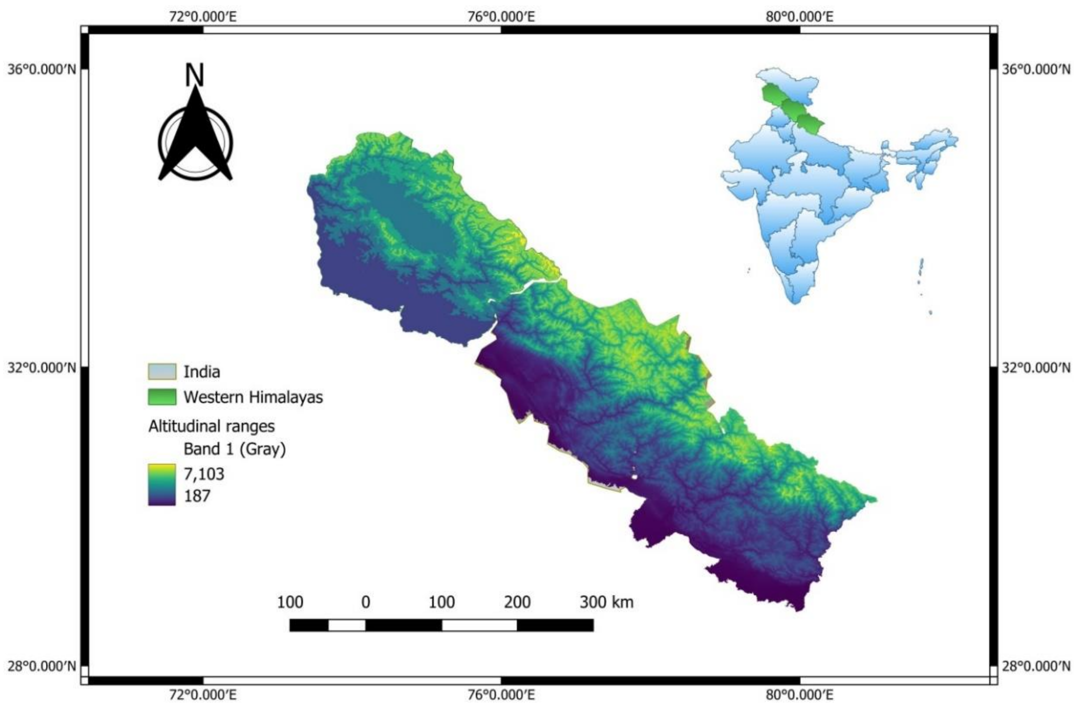

FIGURE 1: The Western Himalayan range encompasses various altitudes.

3. Result and discussion:

3.1. Result:

A meticulous and all-encompassing aggregation of grassland biodiversity was undertaken, and the enumeration has been structured in accordance with alphabetical sequencing in Table 1.

3.2. Discussion:

In many grassland ecosystems, especially those found in mountainous regions like the Western Himalayas, there is a noticeable pattern of species distribution in relation to changes in altitude or elevation. The prevalent and primary form of alpine grassland occurs within an elevation range of 2500 m to 4200 m, where *Danthonia cachemyriana* Jaub. et Spach is the predominant grass species. The foliage is reputed to be highly nourishing for domesticated animals. Nevertheless, grasslands situated at altitudes below 2500 m are characterized by the prevalence of grass species, although certain areas also exhibit dominant sedge-dominated grasslands.

Table 1: Biodiversity of grasslands of Uttarakhand.

Family	Plant Name	Family	Plant Name	Family	Plant Name
Apiaceae	*Trachydium roylei* Lindl.	**Cyperaceae**	*Erioscirpus comosus* (Wall.) Palla.	**Orchidaceae**	*Neottia pinetorum* (Lindl.) Szlach.
	Bupleurum longicaule Wall. ex DC.		*Carex nubigena* D. Don.		*Dactylorhiza hatagirea* (D.Don) Soó.
Asteraceae	*Taraxacum* sect. *Taraxacum* F. H. Wigg.		*Carex setigera* D. Don		*Pleione hookeriana* (Lindl.) Rollisson
Balanophoraceae	*Balanophora involucrata* Hook.f. & Thomson	**Euphorbiaceae**	*Euphorbia stracheyi* Boiss	**Onagraceae**	*Epilobium angustifolium* (L.) Scop. subsp. *angustifolium*
Balsaminaceae	*Impatiens scabrida* DC.	**Fabaceae**	*Trifolium repens* L.	**Papaveraceae**	*Corydalis cashmeriana* Royle
Boraginaceae	*Arnebia benthamii* (Wall. ex G. Don) I. M. Johnst	**Gentianaceae**	*Gentiana stipitata* Edgew.	**Plantaginaceae**	*Kashmiria himalaica* (Hook.f.) D.Y.Hong
	Eritrichium canum (Benth.) Kitam.		*Gentiana argentea* (Royle ex D.Don) Royle ex D.Don		*Picrorhiza kurroa* Royle ex Benth
Campanulaceae	*Cyananthus lobatus* Wall. ex Benth	**Lamiaceae**	*Prunella vulgaris* L.	**Poaceae**	*Agropyron dentatum* Hook.f
Caprifoliaceae	*Valeriana hardwickei* Wall		*Origanum vulgare* L.		*Agropyron himalaicum* (Nevski) Melderis
Celastraceae	*Parnassia nubicola* Wall. ex Royle.	**Orchidaceae**	*Cypripedium cordigerum* D. Don		*Agropyron macrolepis* Drob
Circaeasteraceae	*Circaeaster agrestis* Maxim.		*Cypripedium himalaicum* Rolfe		*Agropyron repens* (L.) P. Beauv

Table 1 Contd.

Family	Plant Name	Plant Name	Plant Name
Poaceae	*Agropyron shrenkianum* (Fisch et Mey) Drob	*Chrysopogon echinulatus* (Nees.) W.Wats	*Hierochloe flexuosa* Hook.f
	Agropyron thoroldianum Oliver	*Chrysopogon gryllus* (L.) Trin	*Hierochloe laxa* R.Br
	Agrostis gigantean Roth	*Colpodium himalaicum* (Hook.f.) Bor	*Hordeum distichon* L.
	Agrostis munroana Aitch. Et Hemsl	*Colpodium nutans* Griseb	*Hordeum vulgare* L.
	Agrostis pilosula Trin	*Colpodium tibeticum* Bor	*Koeleria macrantha* (Ledeb.) Schult
	Agrostis semiverticillata (Forssk.) Christ	*Colpodium wallichii* (Hook.f.) Bor	*Leymus secalinus* (Georgi) Tzvelev
	Agrostis tenuis Sibth	*Cymbopogon stracheyi* (Hook.f.) Raizada et Jain	*Melica persica* Kunth
	Andropogon tristis Nees	*Cynodon dactylon* (L.) Pers	*Oryzopsis aequiglumis* Duthie
	Apluda mutica L	*Dactylis glomerata* L.	*Oryzopsis gracilis* (Mez) Pilger
	Arundinaria falcate Nees	*Danthonia cachemyriana* Jaub. et Spach	*Oryzopsis humilis* Bor
	Avena ludoviciana Dur	*Deschampsia flexuosa* (L.) Trin	*Oryzopsis lateralis* (Regel) Stapf
	Brachypodium distachyon (L.) Beauv	*Digitaria setigera* Roth	*Oryzopsis munroi* Stapf
	Brachypodium sylvaticum (Huds.) P.Beauv	*Duthiea nepalensis* Bor	*Oryzopsis wendelboi* Bor
	Bromus japonicus var. *falconeri* (Stapf) Stewart	*Elymus dahuricus* Turcz	*Panicum miliaceum* L.
	Bromus himalaicus Stapf	*Elymus dahuricus* Turcz	*Pennisetum flaccidum* Griseb
	Bromus tectorum L.	*Elymus nutans* Griseb	*Pennisetum lanatum* Klotzsch
	Calamagrostis decora Hook.f	*Eragrostis nigra* Nees	*Pennisetum orientale* L.C..Rich
	Calamagrostis emodensis Griseb	*Erianthus rufipilus* (Steud.) Griseb	*Phacelurus speciosus* (Steud.) C.E..Hubbard
	Calamagrostis epigejos (L.) Roth	*Festuca lucida* Stapf.	*Phleum alpinum* L.
	Calamagrostis gigantea Roshev	*Festuca polycolea* Stapf.	*Phleum pratense* L.
	Calamagrostis holciformis Jaub. et Spach	*Festuca rubra* L.	*Phragmites australis* (Cav.) Trin
	Calamagrostis pseudophragmites (Hall.f.) Koeler	*Festuca valesiaca* Schleich	*Poa alpina* L.
	Catabrosa aquatica (L.) P.Beauv	*Helictrotrichon virescens* (Nees) Henr	*Poa angustifolia* L.

Table 1 Contd.

Family	Plant Name	Family	Plant Name	Family	Plant Name
Poaceae	*Poa annua* L.	**Poaceae**	*Poa stapfiana* Bor		*Koenigia polystachya* (Wall. ex Meisn.)
	Poa aratarica Trautv		*Poa tibetica* Munro		*Bistorta vivipara* (L.) Delarbre
	Poa burmanica Bor		*Poa trivialis* L.		*Rumex nepalensis* Spreng
	Poa eleonorae Bor		*Polypogon fugax* Nees	**Primulaceae**	*Primula denticulata* Sm
	Poa falconeri Hook.f		*Stipa orientalis* Trin	**Rhanunculaceae**	*Oxygraphis endlicheri* (Walp.) Bennet & Sum.Chandra
	Poa koelzii Bor		*Stipa purpurea* Griseb		*Anemonastrum polyanthes* (D.Don) Holub
	Poa lahulensis Bor		*Themeda anathera* (Nees) Hack		
			Themeda arundinacea (Roxb.) Ridley		*Ranunculus hyperboreus* Rottb
	Poa ludens R.R..Stewart			**Rosaceae**	*Cotoneaster integrifolius* (Roxb.) G.Klotz
	Poa nemoralis L.		*Themeda tremula* (Nees) Hack		*Geum elatum* Wall. ex G.Don
	Poa nephelophila Bor		*Trikeraia hookeri* (Stapf) Bor		*Potentilla argyrophylla* Wall. ex Lehm.
	Poa pagophila Bor		*Trisetum aeneum* (Hook.f.) R.R.Stewart		*Potentilla atrosanguinea* Raf
	Poa pratensis L.		*Trisetum clarkei* (Hook.f.) R.R.Stewart		*Potentilla fulgens* Wall. ex Sims
	Poa pseudamoena Bor		*Trisetum spicatum* (L.) Richt		*Fragaria nubicola* (Lindl. ex Hook.f.) Lacaita
	Poa rhadiana Bor		*Triticum turgidum* L.	**Salicaceae**	*Salix lindleyana* Wall. ex Andersson
	Poa setulosa Bor	**Polygonaceae**	*Koenigia tortuosa* (D. Don) T.M.Schust. & Reveal	**Violacae**	*Viola biflora* L.

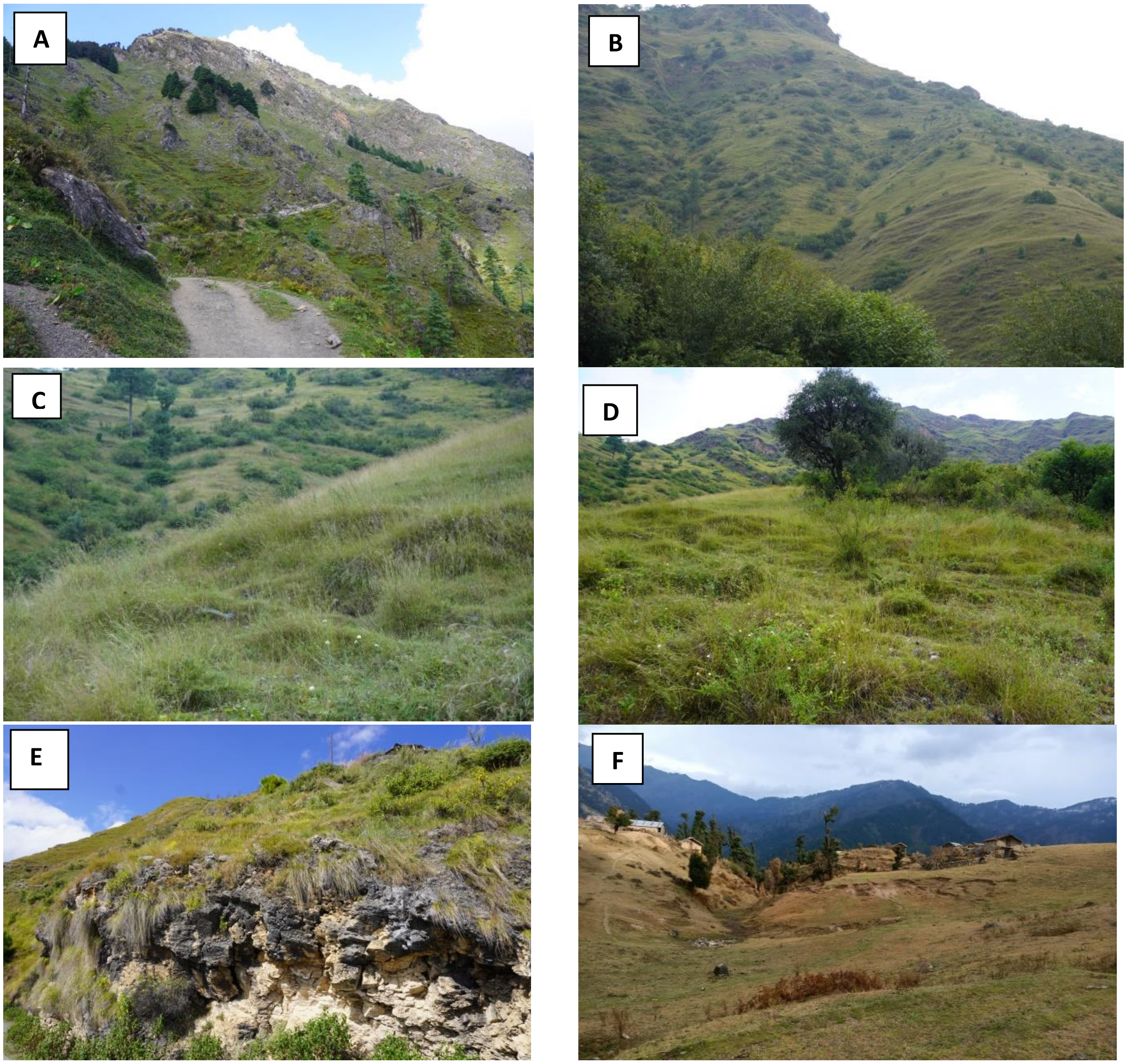

FIGURE 2: Different types of grasslands habitat. A) Dry grassland habitat, B) Grassland (< 2500 m) scattered with small patches of short height of shrubs, C) Grassland (< 2500 m) with no shrub species, D) Grassland interspersed with occasional clusters of *Pinus* sp, E) Grassland with dominant sedges species (*Erioscirpus comosus* (Wall.) Palla.), F) Alpines meadows (> 3000m).

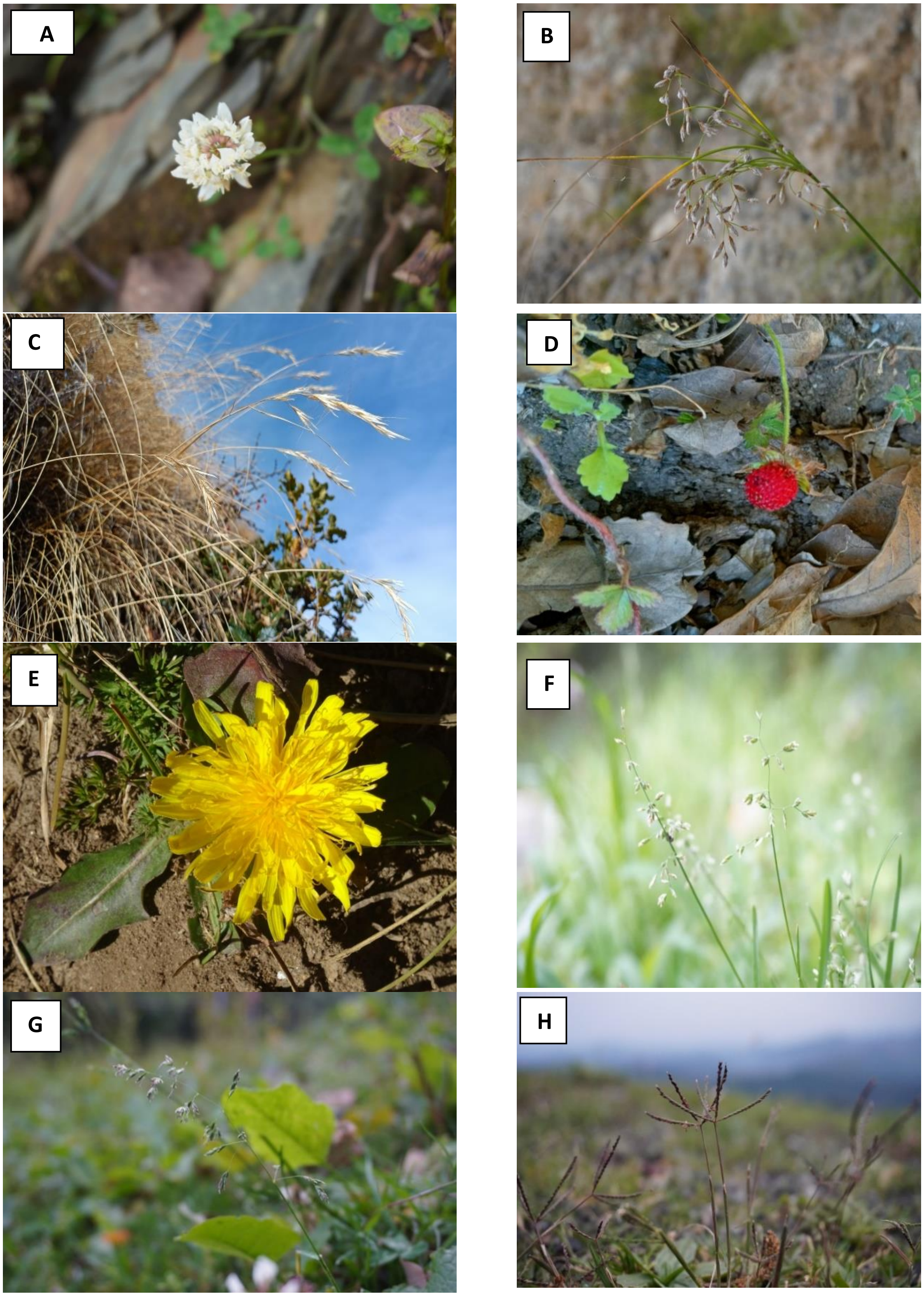

FIGURE 3: Floristic diversity of grassland. A) *Trifolium repens* L., B) *Erioscirpus comosus* (Wall.) Palla., C) *Danthonia cachemyriana* Jaub. & Spach., D) *Fragaria nubicola* (Lindl. ex Hook.f.) Lacaita, E) *Taraxacum* sect. *Taraxacum* F.H. Wigg., F) *Poa annua* L., G) *Poa pratensis* L., H) *Cynodon dactylon* (L.) Pers.

Erioscirpus comosus (Wall.) Palla. is the primary sedge species that dominantly occurs in various grasslands situated at elevations below 2500 m. This study reveals that various species exert dominance in the grassland environment. The Poaceae family of plants stands out as the most prevalent species, while Orchidaceae and Rosaceae species are also notably abundant within grassland ecosystems (Fig 4). The Poaceae family exhibits a significant number of species and holds a substantial dominance, accounting for approximately 69%.

3.2.1. Challenges facing grasslands:

The grasslands of the Western Himalayas encounter a multitude of natural stressors such as varying environmental conditions, water scarcity, and various natural phenomena. Additionally, there are several human-induced threats that can negatively impact their ecosystems. On the contrary, there are instances where extensively managed grasslands are predominantly human-made, in contrast to the less intensively managed rangelands, many of which have undergone modifications from their natural grassland state. The majority of human-made grasslands were established through the clearance of native forests, a phenomenon observed in both temperate Mediterranean and tropical regions[9]. While human-created grasslands exhibit ecological fragility, the botanical composition undergoes swift alterations, particularly in response to grazing or cutting management practices[10, 11].

3.2.1.1. Natural threats:

Diverse natural challenges, encompassing phenomena such as flash floods, soil erosion, climate change impacts, and even avalanches and landslides, inflict significant harm on grassland ecosystems, often leading to extensive destruction of this distinctive environment. Climate change, characterized by the decreasing annual snowfall, unregularly rainfall, and rising temperatures, is leading to significant ecological shifts in grasslands. This, in conjunction with increased temperatures, is creating conditions conducive to a substantial reversal in succession trends, potentially resulting in the complete replacement of alpine vegetation with sub-alpine or temperate species. The expansion of *Cynodon dactylon* (L.) Pers. up to an altitude of 3000 meters serves as significant evidence of this transformation. Simultaneously, the introduction of non-indigenous alien grasses, such as *Bromus catharticus* Vahl, into high-altitude grasslands[12, 13].

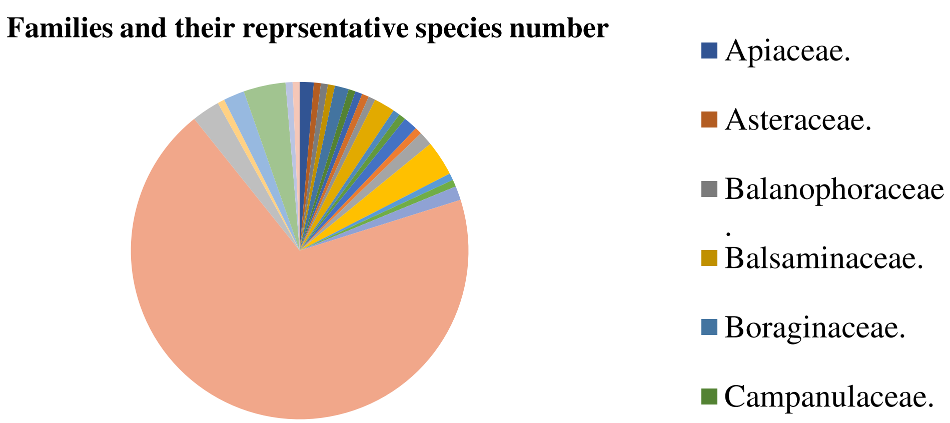

FIGURE 4: Variation in species distribution within grasslands at the family level.

3.2.1.2. Anthropogenic threats:

a. Over -Grazing: Grazing plays a vital role in the context of grassland biodiversity. Through grazing, seeds are distributed from one grassland to another. The traditional practice of raising sheep, which has been on-going for many years, is now manifesting its harmful consequences. The site of Topidunga stands as a poignant example of these effects. Areas rich in Aconite plants were safeguarded, and the grazing of livestock was prohibited in these regions due to concerns about Aconite poisoning. Many of these regions, known as “Bishanthouds,” have significantly depleted Aconite populations due to unregulated harvesting of their roots. Consequently, they have transformed into pasturelands. Additionally, areas where sheep, horses, and other animals rest at night have transitioned into extensive areas dominated by *Rumex nepalensis* Spreng., driven by the elevated nitrogen levels in these sites

b. Over-exploitation of endangered and endemic medicinally significant plant species: The unregulated harvesting of valuable medicinal herbs such as *Nardostachys jatamansi* (D. Don) DC, *Picrorhiza kurroa* Royle ex Benth., *Gymnadenia orchidis* Lindl., and *Polygonatum verticillatum* (L.) All. represents significant medicinally important components in pharmaceutical industry. The distribution of these crucial plant species is primarily confined to the alpine meadows. The excessive harvesting of these uncommon plants results in direct harm through excavation, leading to a decline in the population of rare and endangered species. Additionally, it leads to indirect damage to the habitat, including practices like camping, the cutting of shrubs for fuelwood and campfires, and hunting of wild animals for sustenance.

c. Infrastructure development projects (e.g., road construction): The growth in tourism has also given rise to concerns such as camping, littering, hunting, and the gathering of wild plants, posing threats to the ecosystem. Nevertheless, the alpine grasslands in the regions of Uttaranchal and Himachal Pradesh have encountered extensive tourism activities, resulting in the fragmentation of areas like the “Dayara Bugyal” or other alpine meadow[7] in Uttarakhand.

d. Habitat degradation: The partitioning of grassland habitats brought about by infrastructure development, agricultural activities, and urban expansion disrupts the seamless continuity of these ecosystems. Isolated clusters of grasslands can result in diminished genetic diversity and impede the movement of wildlife.

3.2.2. Conservation strategies:

While the majority of India's environmental and restoration initiatives have historically disregarded the presence of grasslands, there is now a growing acknowledgment of the significance of these landscapes as integral and deserving of protection. The 'Summary of Elaborate Project Assessments for the Revitalization of Significant Indian Rivers via Afforestation Initiatives' as presented by the Indian Council of Forestry Research and Education (ICFRE), along with the 'Bonn Commitment and Its Relevance to India' study [2], acknowledge the importance of grasslands in principle. The ICFRE categorizes grasslands as inherent natural settings within a river basin, incorporating them alongside other environmentally vulnerable habitats. The concept of 'grassland degradation' encompasses both soil erosion and sedimentation. "For instance, in the Yamuna floodplains of Madhya Pradesh, the report allocates INR 0.016 billion for various projects such as 'enhancement of grasslands in wildlife zones,' 'riverine grasslands development (Godavari, Telangana),' 'enhancement of grasslands in riverine regions (Krishna, Telangana),' and 'revival of

Shola forests and grasslands (Cauvery, Kerala, Tamil Nadu)[8]. The Western Himalayan grasslands necessitate the establishment of a national policy framework for the conservation and rejuvenation of these ecosystems. This framework should incorporate the significance of grasslands and other non-forest ecosystems, encompassing their roles in conservation and the myriad benefits they provide to communities, within the broader legal structure.

Moreover, in the protection of Western Himalayan grasslands, it becomes imperative to embrace an all-encompassing approach that addresses these obstacles, gives precedence to sustainable land administration, and fosters recognition of the ecological importance inherent in these unique ecosystems.

a. Necessitate in the regulation of grazing:

There has been a notable decline in the number of families relying on grazing. The current practice of sheep rearing is carried out less by traditional shepherds and more by hired shepherds employed by affluent livestock owners residing in the lowlands. Additionally, sizeable sheep herds are brought in from Himachal Pradesh, even though they possess their own grazing grounds. Such external sheep rearing should be prohibited, with exclusive permission granted to the local population who rely entirely on this livelihood. Furthermore, it is essential to establish appropriate periods of rest for various identified grazing lands.

b. Focus on the conservation of rare medicine plants:

A majority of medicinal plants face indiscriminate harvesting from their natural habitats. As these plants are not abundantly available, various populations have been entirely depleted in an effort to make collection economically viable. Within this trade, numerous intermediaries take advantage of collectors, reaping substantial profits. It is imperative to designate Conservation and Harvest Zones where authorized agencies exclusively carry out collection. Additionally, cultivation methods should be standardized and promoted, while simultaneously ensuring the quality of the yields.

c. Enhancement of the workforce within the forest department:

Until recently, the majority of alpine grasslands were not categorized as Reserved Forests; instead, they fell under the jurisdiction of local Panchayats. While efforts have been made to establish Van Panchayats, the effectiveness of protection measures remains inadequate, primarily due to the presence of a migratory population, albeit in smaller numbers. Many regions have been designated as National Parks, Sanctuaries, and Biosphere Reserves, but staffing is primarily concentrated at the central and sub-alpine levels. There is a pressing need for a permanent workforce in the higher elevations, working in close collaboration with the Indo-Tibetan Border Police.

d. Promotion of awareness and eco-tourism:

This is crucial to avert unintentional harm to the ecology of these grasslands caused by uninformed individuals and to cultivate a conservation ethos among both the general public and tourists. Additionally, it is necessary to limit tourist traffic to alleviate pressure on popular tourist pathways.

4. Conclusion:

The high-altitude grasslands in Western Himalayan region exhibit extensive biodiversity and possess significant economic and ecological value. While surveys of cold deserts have predominantly occurred in Jammu and Kashmir and Himachal Pradesh, those in Uttaranchal have been excluded due to their proximity to the international border, creating challenges for researchers because of security concerns. Nevertheless, it is imperative to conduct a comprehensive examination of the area's richness and formulate conservation strategies. Simultaneously, it is essential to preserve the culture and traditions of the local population and harness their indigenous knowledge for the betterment of our nation and humanity.

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Case Study

Ethnomedicinal Plants Used in Tharu Community, A Case Study of Rapti Sonari, Western Nepal

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Abstract

Tharu is a tribal community residing tropical region of Nepal, growing crops, and practicing diverse natural remedies for curing human and livestock diseases since long. They have firm belief in the use of medicinal plants to treat ailments such as cough, common cold, fever, burn, wound, fracture, stomach-ache, headache, gastritis, loss of appetite, nausea, vomiting, diarrhoea, dysentery, and so on. The present study focused to document their traditional knowledge on the use of medicinal plants. Information was collected via survey and the focus group discussion (FGD). A detailed structured questionnaire was used for interview in order to document medicinal practices. A total of 44 local people aged between 20-80 years old were participated including 23 farmers, five local health workers, nine teachers, and one community head. Plant specimen was collected from nearby forest and agroecosystem with the help of local guide. Specimen were identified in laboratory with the help of experts, digital herbarium images and published literatures. Frequency of citation (FC) and Relative Frequency of Citation (RFC) were calculated for each plant species. Altogether 30 plant species including wild and cultivated species, belonging to 24 families were documented. The Relative Frequency of Citation (RFC) was highest for *Ocimum tenuiflorum* (0.91) followed by *Citrus aurantiifolia* (0.89), and *Zingiber officinale* (0.77). The people in *Tharu* community are practicing their ethnic traditional practices for curing different ailments with the help of locally available plants. Their ethnic knowledge differed slightly than that of other ethnic community and such practices seems less familiar among youngers which may indicate the possible threat to these knowledges in near future.

Keywords: Ethnomedicine, Medicinal Plants, *Tharu* Community, Ailments, Indigenous Knowledge

Abbreviations

FC- frequency of citation; RFC- Relative frequency of citation; n-number; asl-above sea level

Introduction

Tharu is a tribal community residing along the southern foothills of Nepal Himalaya and they are the first people who settled in the Terai region and they have a different culture as well[1]. *Tharu* people have their language, norms, values, festivals, dress, traditions, and so on. They worship some holy plants such as "Tulsi" [2].

These plants are used traditionally as medicine, food, fodder, dyes, energy, construction, to perform rituals, and many more[3]. Their major occupation is agriculture since a long, and prefer to live closer to the forests[4]. They are fond of growing crops and following their own traditions and culture from food preference to the healthcare practices. They are practicing diverse natural remedies for curing human and livestock diseases. These therapeutic drugs and their practices are not a new discovery, rather it is a long-practiced medication system among the members of *Tharu* community residing adjacent to the forest and utilizing the available resources. Along with *Tharu* people, most of the other people living in the rural areas of Nepal, also depend on the traditional medicine for their basic health care needs[5, 6].

Traditional healers and elderly people of the community have learned folklore through apprenticeships to treat common health disorders based on their traditional knowledge[7,8]. Some ethnic groups have developed their own traditional healing systems and they transfer their knowledge orally through generations [7,9]. *Tharu* is one of the largest ethnic groups representing 6.56% of national population and 13.47% of the Tarai population[10]. They have a distinct language, culture, folklore, rituals, customs, lifestyles as well as traditional knowledge about medicinal plants and their uses. Their Guruwa, a local healer uses plants and its resources to treat various health issues. Now adays, with availability of modern drugs and clinical services, such valuable traditional knowledge and healing practices are at the risk in lack of written documents [11]. Whereas, plants with medicinal properties are used to cure several ailments and it is essential to produce different medicines[12].

Documentation of ethnobotanical information and traditional healing systems among *Tharu* community residing different part of Banke district awaited long. The present study aimed to document the traditional knowledge on medicinal plants from ethnic *Tharu* community in Rapti-Sonari. They have firm belief in the use of medicinal plants to treat ailments such as cough, common cold, fever, burn, wound, fracture, stomach-ache, headache, gastritis, loss of appetite, nausea, vomiting, diarrhea, dysentery, and so on. The present study focused to document their traditional knowledge on the use of medicinal plants.

Materials and Methods

Study Area

The present study enlisted the knowledge on the medicinal use of plants among the *Tharu* community residing in Rapti Sonari Rural Municipality-09. It lies at 28.002’40’’N and 81.057’19’’E at an altitude of 80 m above sea level (Fig 1). It falls under the Banke district, Lumbini Province of Nepal, with a total population of 5,584 people including 2919 females and 2665 males[10]. The area is dominated by *Tharu* ethnic community and others were Brahmin, Chhetri, Magar, Kami, Kumal, Damai, Kurmi, Gurung, and Dhobi[10]. *Tharu* is the major language (48.31%) spoken in the area, followed by Nepali (41.07), and others (10.62%)[10].

Data collection & analysis

The data collection was made between January and April 2023. Individual informant consent was taken orally for the recording and publication of their information on the use of plant resources, with assurance that their details to be confidential and unpublished. The individual interview was highly preferred, however, focus group discussions (FGD) were made in the case of health workers and teachers for their time convenience.

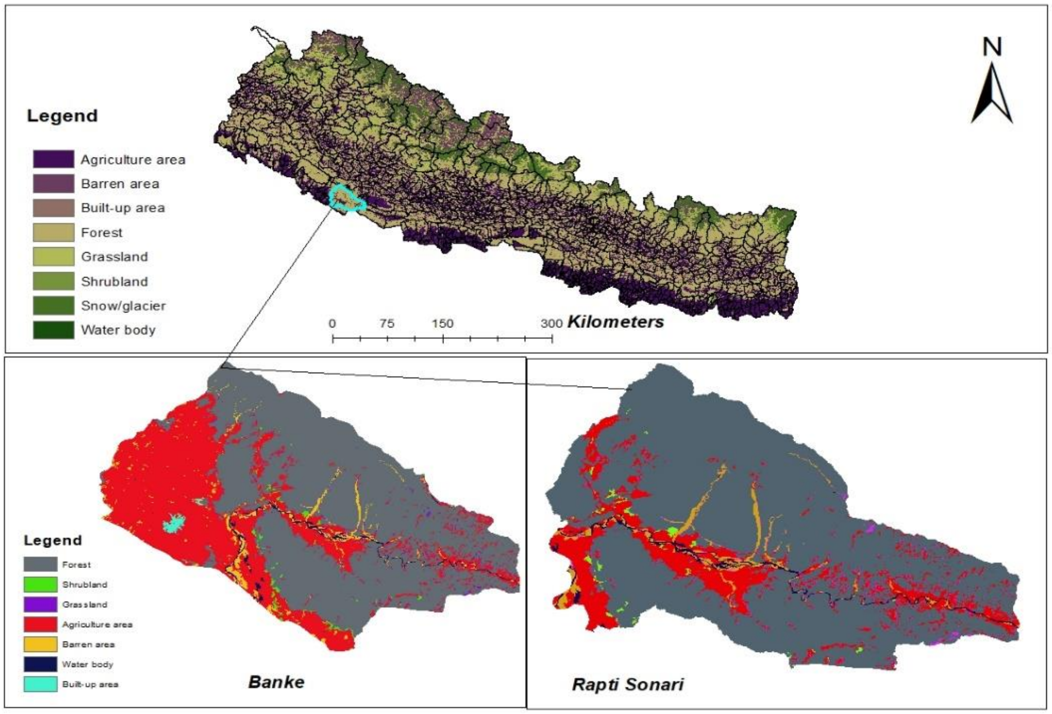


Fig 1: Map of Study Area

A total of 44 respondents (23 female & 21 male) participated in the interview belonging to different age groups (Table 1). Among the respondents, key informants were local health workers (n=5), teachers (n=9), and farmers (n=23). A structured questionnaire was used to record details on the medicinal use of plants.

Table 1: Socio-Demographic Status

Demographic Characteristics	No. of Respondents N=44	Percentage (%)
Gender		
Male	21	47.72
Female	23	52.27
Age		
20-35 Years	16	36.36
36-50 Years	7	15.90
51-65 Years	10	22.72
65- above	11	25
Occupation		
Agriculture	23	52.27
Student	2	4.54
Housewife	9	20.44
Local Healer	5	11.36
Labor	4	9.09
Teacher	1	2.27
Educational Status		
Literate	34	77.27
illiterate	10	22.72

Guided field visits were made for specimen collection and identification of plants by local names with the help of Local herder. Later, collected specimens were identified by comparison with the digital herbarium, and confirmation was made based on published literature including floras, revisions, articles, and books. Further, using interview data, the frequency of citation (FC) and relative frequency of citation (RFC) were calculated[13].

Results

In total 30 plant species (16 wild and 14 cultivated) were reported with their medicinal properties. Various combinations of these plants were known for the treatment of various ailments in the *Tharu* community within a single ward of Rapti Sonari rural municipality. The details on the parts of plants used, use methods, and major ailments treated were enlisted (Table 2). Among the 30 species belonging to 24 families, Combretaceae, Zingiberaceae, Poaceae, Rutaceae, and Solanaceae have 2/2 species and remaining families have single species (Fig 2). The most of medicinal plant species reported were herbs (n=15) followed by trees (n=8) and shrubs (n=7).

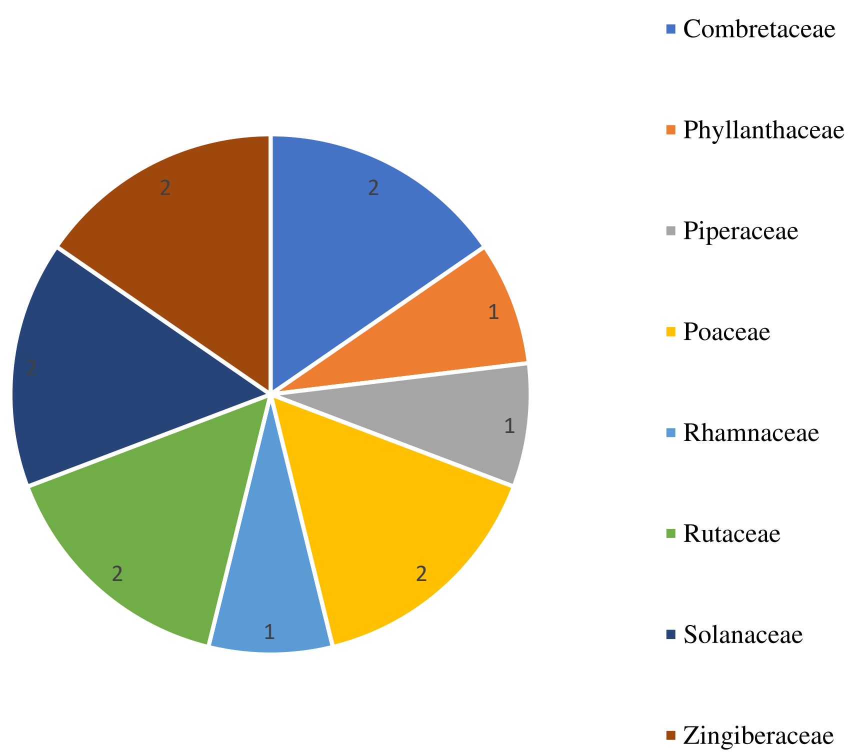


Fig 2: Number of species along families

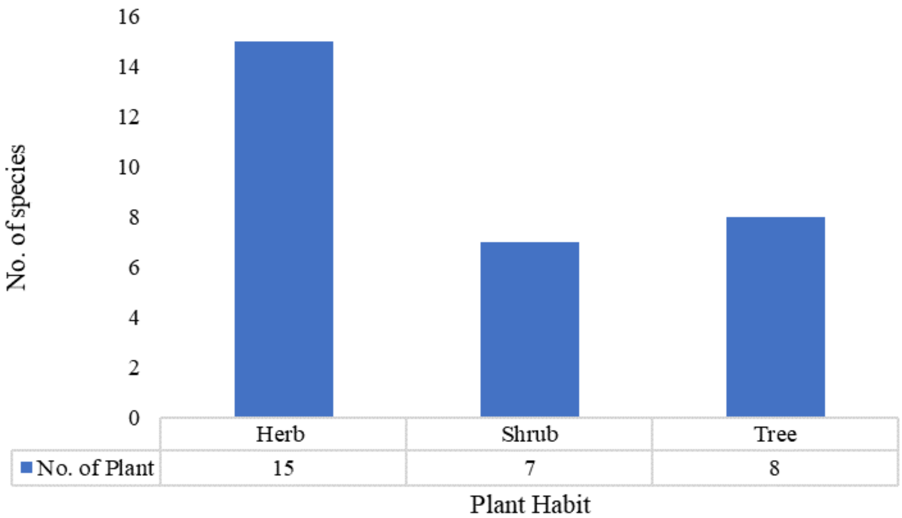
Table 2: List of medically important plants used by local inhabitants of the study area

Family	Scientific name	Common name	Local name	LF	Parts use	Aliments	Mode of use	Use method	Preparation methods
Lamiaceae	*Ocimum tenuiflorum* L.	Holy Basil	Tulsi	H	Leaves	Inflammation, Common cold, Hypoglycaemia	R, C	O	Boiling leaves with water
Asphodelaceae	*Aloe vera* (L.) Burm.f.	Aloe vera	Ghyukum ari	H	Pulp	Gastritis, Hypertension, Skin problem, Headache	R	O, T	Extract gel from leaves and apply
Combretaceae	*Terminalia chebula* Retz.	Black myrobalan	Haran/ Harro	T	Stem, Bark, Fruit	Asthma, Indigestion, Urinary tract infection	R	O, To	Use dry fruit
Combretaceae	*Terminalia bellirica* (Gaertn.) Roxb.	Beach-almond	Bahera/Ba rro	T	Stem, Bark, Fruit	Fever, Asthma, Wound, Kidney problem	R	O, To	Use dry fruit
Piperaceae	*Piper longum* L.	Long pepper	Pipala	H	Fruit	Asthma	R	O	Drying the fruit and use of it powder
Euphorbiaceae	*Euphorbia hirta* L.	Spurge	Dudhi	H	Leaves	Diarrhoea, Dysentery	R	O	Making juice from leaves
Rutaceae	*Aegle marmelos* (L.) Corrêa	Stone apple	Bael	T	Fruit, leaves, Pulses	Fever, Fatigue, Diarrhoea, Dysentery	R	O, To	Making juice from fruit
Apocynaceae	*Calotropis gigantea* (L.) W.T.Aiton	Crown flower	Aank	S	Leaf, flower, Fruit	Vomiting, Common cold, Skin problem, Swelling, Inflammation	R	O, To	Applying latex from stem
Phyllanthaceae	*Phyllanthus emblica* L.	Indian gooseberry	Amla	T	Fruit	Indigestion, Skin problem	R, C	O, To	Grinding the fresh fruit and apply on hair
Meliaceae	*Azadirachta indica* A.Juss.	Indian lilac	Neem	T	Leaves, Twigs, Bark	Inflammation, Toothache, Wound, Diabetes, Asthma, Fever	R	O, To	Boiling with water
Amaryllidaceae	*Allium sativum* L.	Garlic	Lasun	H	Bulb	Arthritis, gastritis, Headache	R, C	O, To	Eating raw
Zingiberaceae	*Zingiber officinale* Roscoe	Ginger	Aduwa	H	Rhizome	Stomach-ache, Common cold	R, C	O	Taking raw or boiling with water
Rhamnaceae	*Ziziphus nummularia (Burm.f.)* Wight & Arn	Chinese jujube	Bayer	S	Fruit	Gastritis	R	O	Taking raw or powder
Caricaceae	*Carica papaya* L.	Papaya	Mewa	T	Fruit	Gastritis, Constipation	R, C	O	Taking or in Vegetable or Fruit Salad

Asteraceae	*Artemisia myriantha* Wall. ex Besser	Mugwort	Titepati	S	Leaves	Wound, Gastritis	R	O	Boiling leaves and squeeze it on cuts
Apocynaceae	*Rauvolfia serpentina* (L.) Benth. ex Kurz	Java devil pepper	Sarpagandha	H	Roots	Hypertension	R	O	Clean the root and consume
Fabaceae	*Mimosa pudica* L.	Touch me not plant	Lajawati	H	Entire plant	Fever, Leucorrhoea	C	O	Drying roots
Poaceae	*Cymbopogon flexuosus* (Nees ex Steud.) W.Watson	Lemon grass	Kagati ghas	H	Leaves	Stomach-ache, Vomiting, Common cold	R	O	Dry leaves boil in water
Lauraceae	*Cinnamomum tamala* (Buch. -Ham.) T.Nees & Eberm.	Bay leaf	Tejpat	T	Leaves	Common cold, Tuberculosis	R, C	O	Dry leaves boil in water
Zingiberaceae	*Curcuma longa* L.	Turmeric	Besar	H	Rhizome	Wound, Inflammation, Skin problem	R, C	O, To	Grind and boil in water
Acoraceae	*Acorus calamus* L.	Sweet flag	Bojo	H	Roots	Stomach-ache	R	To	Drying leaves
Asparagaceae	*Asparagus officinalis* L.	Asparagus	Kurilo	S	Roots	Ulcer, Stomach-ache	R	O	Making juice of fresh roots
Solanaceae	*Datura metel* L.	Nightshades	Dhaturo	S	Seeds	Intestinal problem, Toothache	R	O	Grinding the seeds
Cannabaceae	*Cannabis sativa* L.	Hemp	Ganja	S	leaves, bark, seed	Body ache, Sleeping disorder, Loss of appetite	R	O	Dry leaves with smoke
Amaranthaceae	*Achyranthes aspera* L.	Pigweed	Ultekuro	H	Roots	Loss of appetite	R	O	Boiling with water
Poaceae	S*accharum officinarum* L.	Sugarcane	Ukhu	H	Stem	Constipation, Stomach-ache, Cancer, Jaundice	R	O	Direct consume and juice
Solanaceae	*Solanum lycopersicum* L.	Tomato	Tamatar	H	Fruit	Burn	R, C	O, To	Apply liquid part of tomato on burned area
Rutaceae	*Citrus aurantiifolia* (Christm.) Swingle	Lemon	Nibuwa	T	Fruit	Indigestion, Vomiting	R	O	Mixing lime juice with water or eating raw
Asteraceae	*Eclipta prostrata* (L.) L.	False daisy	Bhringraj	H	Shoot	Diarrhoea, Dysentery	R	O	Making juice of shoot and adding mustard oil
Cactaceae	*Opuntia monacantha* Haw.	Prickly pear	Siudi	S	Latex, fruit	Pneumonia	R	O	Applying latex from cactus and raw fruit

*Note: **[*Notes on Table 2: Herb-H; Shrub-S; Tree-T; Raw-R; Cooked-C; Oral-O; Topical-To]**

Medicinal plant species with medicinal property were reported in different life form as herb, shrub, and tree (Fig 3). Among them, herb species (15) were dominant than shrub (7), and tree (8) species. Interestingly among 30 species, 25 were recorded first time as medicinal plants used by *Tharu* community in that area (Table 2; represented by * after each scientific name).



Almost half of the ailments were reported with multiple species option to cure (n=17) and remaining half with single species (n=17) (Table 3). The ailments with many plant species alternatives were common cold, gastritis, stomach-ache, wound, fever, and skin problems. Similarly, the most used plant species in various ailments were *Calotropis gigantea, Azadirachta indica, Saccharum officinarum, Cannabis sativa, Aegle marmelos, Curcuma longa,* and *Aloe vera*.

Table 3: Ailments and plant species used by *Tharu* community for medicine

Ailments	Name of plant species
Arthritis	*Allium sativum*
Asthma	*Terminalia chebula,Terminalia bellirica, Piper longum, Azadirachta indica*
Body ache	*Cannabis sativa*
Burn	*Solanum lycopersicum*
Cancer	*Saccharum officinarum*
Common cold	*Ocimum tenuiflorum, Calotropis gigantea, Zingiber officinale, Cymbopogon flexuosus, Cinnamomum tamala*
Constipation	*Carica papaya, Saccharum officinarum*
Diabetes	*Azadirachta indica*
Diarrhoea	*Euphorbia hirta, Aegle marmelos, Eclipta prostrata*
Dysentery	*Euphorbia hirta, Aegle marmelos, Eclipta prostrata*
Fatigue	*Aegle marmelos (L.) Corrêa*
Fever	*Terminalia bellirica, Aegle marmelos, Azadirachta indica, Mimosa pudica*
Gastritis	*Aloe vera, Allium sativum, Ziziphus nummularia, Carica papaya, Artemisia myriantha*
Headache	*Aloe vera, Allium sativum*
Hypertension	*Aloe vera, Rauvolfia serpentina*
Hypoglycaemia	*Ocimum tenuiflorum*
Indigestion	*Terminalia chebula, Citrus aurantiifolia, Phyllanthus emblica*

Inflammation	*Ocimum tenuiflorum, Calotropis gigantea, Azadirachta indica, Curcuma longa*
Intestinal problem	*Datura metel*
Jaundice	*Saccharum officinarum*
Kidney problem	*Terminalia bellirica*
Leucorrhoea	*Mimosa pudica*
Loss of appetite	*Cannabis sativa, Achyranthes aspera*
Pneumonia	*Opuntia monacantha*
Skin problem	*Aloe vera,Calotropis gigantea, Phyllanthus emblica, Curcuma longa*
Sleeping disorder	*Cannabis sativa*
Stomach-ache	*Zingiber officinale, Cymbopogon flexuosus, Acorus calamus, Asparagus officinalis, Saccharum officinarum*
Swelling	*Calotropis gigantea*
Toothache	*Azadirachta indica, Datura metel*
Tuberculosis	*Cinnamomum tamala*
Ulcer	*Asparagus officinalis*
Urinary tract infection	*Terminalia chebula Retz.*
Vomiting	*Calotropis gigantea, Cymbopogon flexuosus, Citrus aurantiifolia*
Wound	*Azadirachta indica, Terminalia bellirica, Artemisia myriantha, Curcuma longa*

Furthermore, fruit (n=11) was reported as a most used plant part for medicinal purposes followed by leaf (n=9), bark (n=4), roots (n=4), and stem (n=3). Other parts used were bulbs, flowers, and latex obtained from few species with specific medicinal value, and some species with entire plant parts (Fig 4).

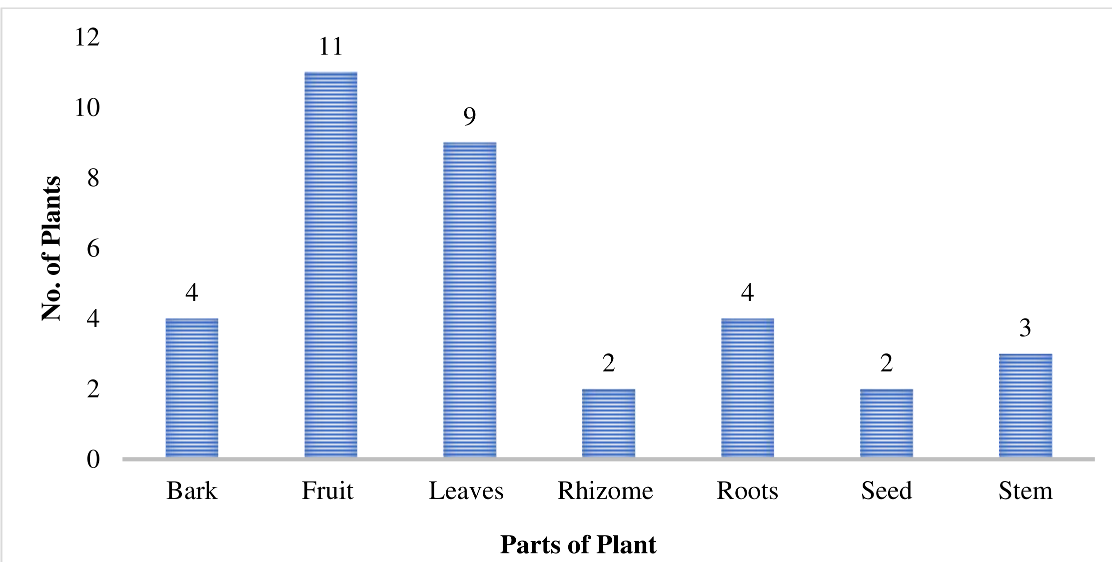


Fig 4: Parts of plants used for medicinal purpose

The frequency of citation for each species implies the recurrence in their use reported. The values of frequency of citation ranged from 13 to 42 and accordingly the value of relative frequency of citation was between 0.30 to 0.95 (Table 4). The RFC value was highest for *Azadirachta indica* (n=0.95) followed by *Ocimum tenuiflorum* (n=0.91), *Citrus aurantiifolia* (n=0.89), and lowest for *Cinnamomum tamala* (n=0.30).

Table 4: Frequency of citation and Relative frequency of citation

Plant species	FC	RFC (FC/N)	Plant species	FC	RFC (FC/N)
Ocimum tenuiflorum L.	40	0.91	*Rauvolfia serpentina* (L.) Benth. ex Kurz	23	0.52
Aloe vera (L.) Burm.f.	30	0.68	*Mimosa pudica* L.	21	0.48
Terminalia chebula Retz.	17	0.39	*Cymbopogon flexuosus*	17	0.39
Terminalia bellirica	33	0.75	*Cinnamomum tamala*	13	0.30
Piper longum L.	21	0.48	*Curcuma longa* L.	15	0.34
Euphorbia hirta L.	25	0.57	*Acorus calamus* L.	16	0.36
Aegle marmelos (L.) Corrêa	24	0.55	*Asparagus officinalis* L.	23	0.52
Calotropis gigantea	22	0.50	*Datura metel* L.	24	0.55
Phyllanthus emblica L.	32	0.73	*Cannabis sativa* L.	37	0.84
Azadirachta indica A.Juss.	42	0.95	*Achyranthes aspera* L.	33	0.75
Allium sativum L.	36	0.82	*Saccharum officinarum* L.	32	0.73
Zingiber officinale Roscoe	34	0.77	*Solanum lycopersicum* L.	18	0.41
Ziziphus nummularia	25	0.57	*Citrus aurantiifolia* (Christm.) Swingle	39	0.89
Carica papaya L.	22	0.50	*Eclipta prostrata* (L.) L.	22	0.50
Artemisia myriantha	18	0.41	*Opuntia monacantha* Haw.	29	0.66

These plant resources were recorded to be used either in raw or cooked form depending upon ailment, resource availability and species used in medicine preparation (Fig 5). Most of the species were reported to be used in raw form (76%) and remaining in cooked form (24%). And these medicinal plants were applied to the treatment of ailment by means of topical application or oral consumption (Fig 6). Regarding application of medicine, 29 plant species were reported to be orally consumes, and 1 species being used both orally and topically, while only one species being used topically alone.

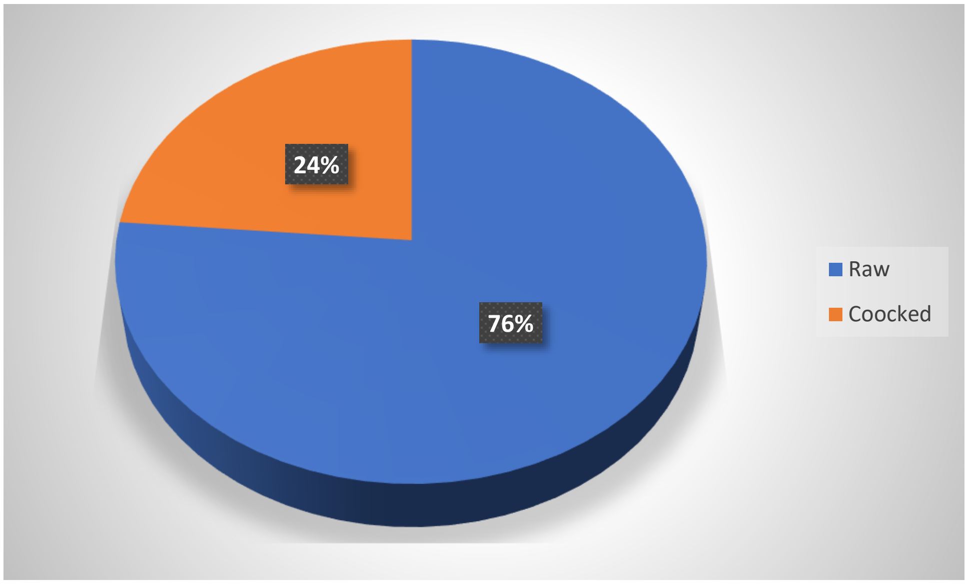


Fig 5: Use methods of plant parts

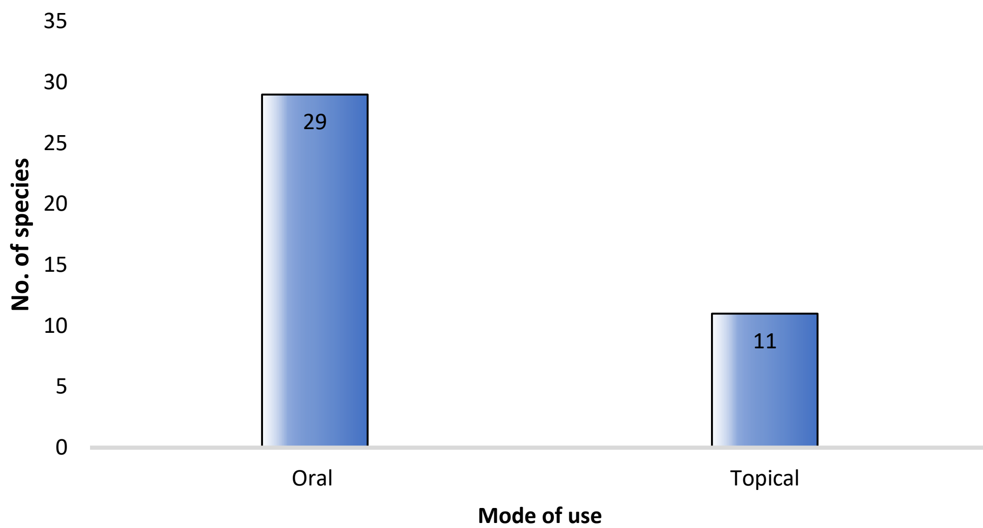


Fig 6: Mode of use of extracts of medicinal plants

Discussion

People of *Tharu* community uniquely cited the use of different plant species available locally and from market for the cure of disease and their symptoms. Such medicinal use of plants is not new rather, as older as origin of disease in the human being. *Tharu* community of Eastern and Central Nepal has also cited a good number of plant species for medicinal use[1,14,15]. Although previous study has been made more recently in the area, interestingly, this study further added 25 different species in the record of medicinal plants used by *Tharu* community from the same area[16]. Continue addition of species with exploration of larger areas shows uniqueness and importance of medicinal plants among these communities. Further, it has essential role in the livelihood of people residing rural region and support the income by employing chain of people from collection to the market[17].

Diverse plant species reported in different life form; dominated by use of herbaceous plant species might refer to the efficacy, sustainability, and wide distribution range of herbs. Shorter life cycle, easier access, plant variation, and food habit might have supported the diversity and use of herbs among *Tharu* people for treatment practices[1,14]. Study further revealed common cold, gastritis, stomach-ache, wound, fever, and skin problems with many species alternative to treat them, that might because these diseases and symptoms are quite abundant in the area and all the resources are not available throughout the year; and consequently, practice was made in such a way that a single ailment can be treated using different species depending on availability of resources in that season. Also, cultivated species might be an alternative to wild species for easy access to them in need. Formerly, headache, menstrual disorder, snake bites, cuts, wounds, respiratory problem, skin diseases, cold and cough, headache, fever, and toothache were common ailments reported among *Tharu* community treated using locally available plant species[1,14,15].

The major species used as medicinal plants were *Calotropis gigantea*, *Azadirachta indica*, *Saccharum officinarum*, *Cannabis sativa*, *Aegle marmelos*, *Curcuma longa*, and *Aloe vera*. *Ocimum tenuiflorum* noted as used for curing inflammation, common cold, and hypoglycaemia is a holy plant that has been used for long. It might be due to long practiced use of holy basil via cultural and traditional aspect. It contains some radio-protective properties[18]. Plants are identified as the main sources of novel bio-molecules[19].

Piper longum reported to be used for asthma in the recent study and similarly, effective in curing diseases like cancer, inflammation, depression, diabetes, obesity, and Cough[20]. *Aloe vera* is reported with use in gastritis, hypertension, skin problem, and headache might due to cooling and digestive property in it. Prior studies reported *Aloe vera* to care ulcers in men and burn and frostbite injuries in animals[21]. *Terminalia chebula* reported here to be used for the treatment of asthma, indigestion, and urinary tract infection that might due to its vitamin and mineral rich nutrient composition. Nutritious feature of *Terminalia chebula* for health benefits were discussed quiet earlier as well[22].

Phyllanthus emblica is highly nutritious and contains a high source of vitamin C, amino acids, and minerals which is useful in the treatment of jaundice, diarrhoea, and inflammation[23]. However present study reported its use for digestion improvement and caring skin problems and as mentioned earlier its vitamin, mineral and fibre content might have supported the health benefit over these ailments reported. *Azadirachta indica* is quite common and familiar remedy in Terai region, especially among ethnic communities as *Tharu* community in present study, due to its highly effective curing property in different ailments such as inflammation, toothache, wound, diabetes, asthma, and fever[24].

Zingiber officinale (Ginger) has been effective for the treatment of stomach-ache and common cold, effective for pregnancy-induced and postoperative nausea and vomiting, somehow it is also used to treat arthritis symptoms[25]. Gastritis and constipation were treated by using papaya, might due to its nutrient composition and known as traditional systems of medicine and valuable nutraceutical fruit plant[26]. *Curcuma longa* has healing mechanism on wound, inflammation, and skin problem that has been previously reported with cure for stomach and liver ailments[27]. *Cymbopogon flexuosus* (Lemon grass) used to treat stomach-ache, vomiting, common cold, might because it contains antioxidant property and thus used to treat cough, diarrhea, stomach-ache, hypertension, gastrointestinal problems, and fever in other places as well[28].

Artemisia myriantha used for wound healing and gastritis control. Artemisia herbs are highly fragrant and medicinal herb used worldwide and *Artemisia vulgaris* has been considered as “mother of herbs” in middle age[29]. *Saccharum officinarum, Calotropis gigantea, Aegle marmelos, Euphorbia hirta, Mimosa pudica, Cinnamomum tamala, Acorus calamus, Rauvolfia serpentina, Eclipta prostrata,* and *Ziziphus mauritiana* as recorded in present study, has highly medicinal value with both topical and oral modes of use for different cardiovascular, hepatological, pulmonary, insomnia, gastrointestinal, sexual, and hormonal ailments[30-41].

Similarly, *Solanum lycopersicum, Asparagus officinalis, Allium sativum, Citrus aurantifolia, Opuntia monacantha, Cannabis sativa,* and *Datura metel* due to presence of vital nutrients including vitamins, mineral, protein, and fibres and their antioxidant, anti-inflammatory, and antibacterial property, used for the control of dermatological, cardiovascular, renal, gynaecological and gastrointestinal problems[9,15, 22,23,26,30,39,41,44].

It suggests the need of well documentation and understanding on valuable plant species and their ethnomedicinal use in different ailments. Availability of modern medicines, has limited the use and practices of traditional medicines especially in the young generation indicating towards the threat over local practices and ethnic knowledge. There seems need of conservation of ethnobiological knowledge via proper documentation and application of such knowledge to seek new aspect utilizing locally available resources, connecting to development of industries, opportunity generation and resource sustainability in coming days.

Conclusion

Study revealed ethnomedicinal use of different plant species from Tharu community of Rapti-Sonari area of Banke district and added some valuable wild and cultivated species in the list of previous medicinal herbs in the area. The mode of use and practices for their consumption helped to understand the detail approach to use them and look forward for their biochemical and modern synthesis of drug.

Declarations

Ethics approval and consent to participate: Prior interview, oral informed consent was taken from each participant.

Consent for publications: Not applicable.

Availability of data and materials: All data are mentioned in the manuscript

Conflict of Interest: Authors have no conflict of interest.

Funding: Authors have not received any funding during this research.

Author Contribution: SDG, PN, and GTM developed the idea. SDG and PN collected data from field. AKS and GTM analysed and prepared the manuscript draft. Final manuscript is reviewed and confirmed by all the authors.

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Research Article

A Remark on the Occurrence and Nomenclature of North Indian *Tropidia maxwellii* Ormerod (Asparagales: Orchidaceae)

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Abstract

Since its discovery in 1971, the name of *Tropidia maxwellii* Ormerod, found in the Doon Valley in northern India, has been unclear. *Tropidia curculigoides* Lindl. and *Tropidia pedunculata* Blume were the names given to the species in the past. In order to make identification easier, the current article explains the terminology and provides coloured photos, and a thorough description. There's also a brief mention of the freshwater marshes in Dehradun, which serve as its habitat..

Keywords: *Tropidia*, Doon Valley, Freshwater Swamp, nomenclature, conservation.

1. Introduction

John Lindley created the genus *Tropidia* in 1833, with *T. curculigoides* serving as the type species. One species, *T. polystachya*, is found in Ecuador and is dispersed from the United States to South Eastern Asia, the South Pacific Islands, and Northern Australia[1,2,3]. The genus has thirty-three species. Six species had previously been found in India to constitute the genus Tropidia[4,5].

From North India, a species, *viz. T. curculigoides* Lindl. was reported by Deva and Arora[6]. However, during the preparation of the orchid flora of Western Himalaya, Deva and Naithani[7] placed it under *T. pedunculata* Blume. Later, Ormerod[1] while revising Asiatic *Tropidia,* stated that the material quoted by Deva and Naithani [7] under *T. pedunculata* belongs to *T. maxwellii* which was first described by Ormerod[1] from Thailand. Its distribution is in India (Uttarakhand, Jharkhand, Sikkim), Bangladesh, Myanmar, Philippines, Indonesia, and Papua New Guinea. Ormerod[1] further stated that Hooker[8] was the first to realize the mixture in Lindley's concept of *T. curculigoides*. Later, Seidenfaden[9] identified material from Thailand as *T. pedunculata*, followed by Deva and Naithani[7] and Jalal *et al.*[10]. The confusion about the identity of this species still exists as the recent publications, Singh *et al.*[5] and Rawat *et al.*[11] have placed it under *T. pedunculata*. Also, Naithani[12]mentioned the occurrence of *T. pedunculata* from India. However, the true *T. pedunculata* is distributed in Malaysia, Indonesia, the Philippines, and Papua New Guinea [1,2].

2. Materials and Methods

During a recent botanical exploration in the Doon Valley, Uttarakhand, a scattered population of *Tropidia* was located in the Golatappar (30º04’51.8” N, 78º12’21.5” E, 397 m) freshwater swamp. After a critical and comparative study of the specimens based on literature[1] and the type collection (Online), it was identified as *Tropidia maxwellii* Ormerod. The specimens are submitted to the Herbarium of Forest Research Institute, Dehradun (DD).

3. Result and Discussion

After Arora and Som Deva, the present collections made by the authors (S.K. and H.B.N.) from the same locality (i.e., Golatappar) are after a lapse of 54 years. Its collection from only one place and four collections indicates its rarity in North India. To facilitate identification, detailed descriptions, and colored photographs have been provided.

Tropidia maxwellii Ormerod, Checkl. Papuas. Orch.: 438. 2017 et in Harv. Paper. Bot. 23(1): 79. f.2. 2018. *T. curculigoides* auct. non. Lindl., Lindl., Gen. Sp. Orch. Pl. 497. 1840 p.p.; King & Pantl. in Ann. Roy. Bot. Gard. Calcutta 8: 275. 1888; Deva & Arora in Indian Forester 97: 699. 1971. *T. pedunculata* auct. non. Blume, Saidenf. &S mitinand, Orch. Thailand 1: 98. 1959; Deva & Naithani, Orch. Fl. NW Himal. 93. f.42. 1986; Misra, Orch. Orissa: 277-281, f.’s, 771 p.p., 2004; Uniyal, Sharma, Choudhery & Singh, Fl. Pl. Uttarakhand (Checklist) 234. 2007. Lucksom, Orch. Sikkim & NE Himal.: 73, f.45. 2007; Rawat, Jalal and Rawat, Orch. Uttarakhand 339. 2023. *T. formosana* auct. non. Rolfe, Gogoi, Orchidophile 116: 335, f., 2016. (Figure 1, 2).

Terrestrial herbs that can grow up to 30 cm in height. Wiry roots. Stems: upright, terete, solitary or branched; internodes 2–5 cm long; main stem 7–11 leaves, branches 4–7 leaves, dark green. Sheathing into the stem, the leaves cluster close to the inflorescence. They are dark green above, 6-18 × 1-3 cm, narrowly lanceolate to lanceolate, or broadly elliptic, with pronounced veins on the lower surface that extend to the sheath. Both terminal and axillary inflorescences are present; the terminal inflorescences are 7–31 mm long, the axillary ones are leaf opposed, simple or rarely branched, and the peduncle is 3–17 mm long. The peduncle sheaths are 1-2 and tubular, and the rachis is 4–14 mm long. The floral bracts are broadly triangular to lanceolate, acute, 3-5 veined, with the marginal veins not reaching the apex, and they are green, measuring 3.5–10 mm long. Flowers are light greenish-white in color, with a yellow anther cap, a yellow lip tip, and a white column. Pedicel plus ovary terete to clavate, 4–7 mm length, sparsely furfuraceous. Dorsal sepal: 5.5-10 × 2.5-3.0 mm, sparsely furaceous basally, ovate-elliptic to oblong-lanceolate, apex subacute, 3-5 veined, concave. Lateral sepals: ovate-elliptic to oblong-lanceolate, oblique, acute to subacute; lower inner edges adherent, sparsely furfuraceous basally, 6-11 × 2.6-3.2 mm; midvein carinate at apex; 3.5 veined. Petals are obliquely oblong-lanceolate, acute to subacute, faintly falcate, with three veins, 4.7-9.2 × 1.9-2.8 mm, with a broadly thickened lower midvein. 4.2-7.0 mm long, labellum ovoid-cymbiform; hypochile cymbiform to ovate-elliptic; epichile oblong to ovate-lanceolate; apex obtuse, deflexed, and briefly cucculate; 1.2-2.2 mm long. column 2.9–3.8 cm long, robust, and slant upright.

Note: *Tropidia pedunculata* can be easily distinguished from *T. maxwellii* by its proliferated inflorescences. Also, *T. maxwellii* can be differentiated from *T. curculigoides* in having pedunculate inflorescences (vs. sessile in *T. curculigoides*) and longer narrower floral bracts.

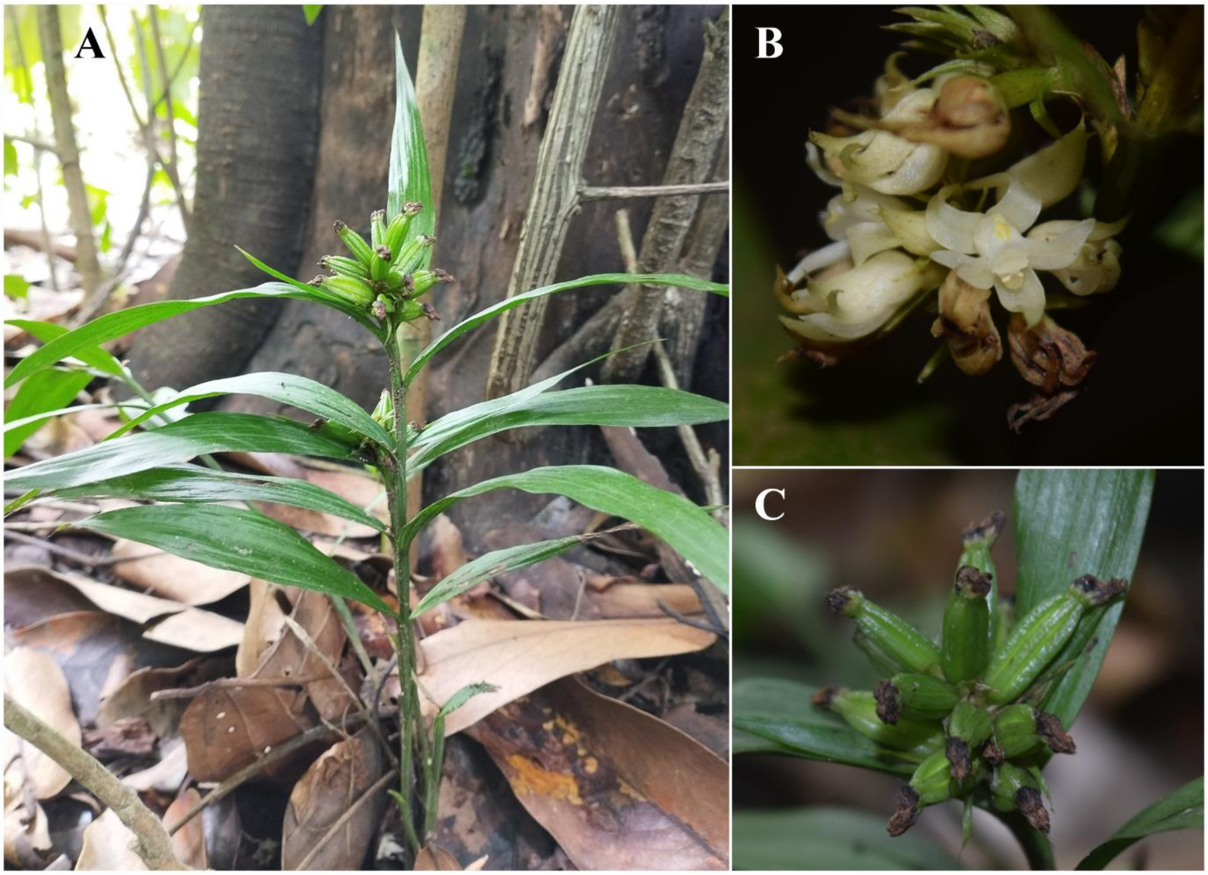

Figure 1. *Tropidia maxwellii* Ormerod: A. Habit with infructescence; B. Flower; C. Fruits.

Specimens examined: Golatappar swamp, Dehradun, 3rd August 2023, Shivam Kishwan 309, Acc. No. 174903, 174904, 174905 (DD); Golatappar swamp, Dehradun, 16th August 2023, H.B. Naithani 5893, Acc. No. 174115 (DD); Golatappar, Dehradun, 8th May1969, Som Deva4184, Acc. No. 153545, 154513(DD).Golatappar, Dehradun, July 1969, CM Arora, Acc. No. 38869 (BSD).

Habitat and Ecology: The species grows in the freshwater swamp forest of Golatappar Swamp in Doon Valley. It generally grows under shady to semi-open canopy in solitary or small clumps of 5-6 individuals connected by runners.

Associated species: Commonly associated tree species of *Tropidia maxwellii* are *Diospyros malabarica*, *Pterospermum acerifolium*, *Shorea robusta*, *Syzygium cumini* and *Acronychia pedunculata*. Other associated species include *Ficus pomifera*, *Jasminum multiflorum*, *Curculigo orchioides*, *Desmodium heterocarpon*, *Phyllanthus amarus*, *Ardisia solanacea*, *Cyperus mindorensis*, *Pogostemon benghalensis*, *Cyperus paniceus*, *Floscopa scandens*, *Rotala rotundifolia*, *Knoxia sumatrensis*, *Calamus tenuis*, *Arundo donax*, *Mimosa pudica*, *Pouzolzia pentandra*, *Rorippa nasturtium-aquaticum*, *Limnophila rugosa* and *Ophioglossum vulgatum*.

4. **Conclusion:** This article provided the all-inclusive information related occurrence and nomenclatural details of a rare plant of family Orchidaceae, *Tropidia maxwellii*. The article will be helpful for future taxonomists as an important source of reference.

Author contributions:

SK: field-work, collection, conceptualization, manuscript writing; HBN: field-work, collection, manuscript writing, review; AC & PKV: review and editing.

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Daltonia decolyi Gangulee: New record for Western Ghats, South India

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Abstract

The endemic species *Daltonia decolyi* Gangulee has only been documented from Darjeeling in the eastern Himalayas. It has been recorded for the first time during the current investigation from the Doddabetta region in the Nilgiri Hills (Western Ghats). One of the 34 hot spots for biodiversity in the world, the Western Ghats of India are situated in eight of the warmest "Hot Spots" on the planet. The corticolous, glossy plants, oblong, late leaves with a prominent border, and an erect capsule with double peristome teeth—the endostome and exostome being roughly equal—are the characteristics of this species. The base was bordered with calyptra.

Keywords: Bryophyta, Daltoniaceae, *Daltonia decolyi*, Corticolous, Western Ghats.

1. Introduction

One of the 34 global hotspots for biodiversity, the Western Ghats of India are situated amidst eight of the world's hottest "Hot Spots"[1]. The six Indian states of Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu, and Kerala are where they originate and culminate, with Kanya Kumari marking the tip of the Indian peninsula. Part of peninsular India, the Western Ghats account for the greatest proportion of indigenous flora in India (about 33%) and the biggest source of biodiversity in the country, second only to the eastern Himalaya.

The tiny family Daltoniaceae consists of two genera, *Actinodontium* and *Daltonia*, each with 14 species that are primarily found in the eastern Himalayan region[2]. There are 11 species of *Daltonia* in India[2, 3]. Ten of these species were restricted to the eastern Himalaya, but two species—*Daltonia marginata*[4] and *D. reticulata*[5] were reported from south India. Only one report of the endemic species *Daltonia decolyi* has come from Darjeeling thus far[6]. It is first recorded in the current study from the Doddabetta location in the Nilgiri Hills, which indicates a wide distribution throughout the nation, spanning from north-east India to south India.

2. Materials and Methods

The Nilgiri Hills' Ootacamund (Dodabetta) is where the plants were gathered. Under a Stereoscopic Zoom Binocular Microscope (Carl Zeiss, M140, Germany) and a Leica Binocular Compound Microscope (LEICA DM LB2), the plants (dried herbarium specimens) were examined closely. Temporary slides were made for anatomy and exterior morphology research in 70% aqueous glycerin. A Nikon Camera Lucida at the appropriate magnifications and an Olympus OIC 66116 light microscope were used to create the line drawing illustrations. An occulometer and a stage micrometer were used to collect measurements.

2.1 Taxonomic Description:

Daltonia decolyi Gangulee, Mosses E. India 6: 1473. 1977.

(Plate 1: Figs. 1-15)

Plants yellow green, pleurocarpous, epiphytic, 0.5-1.0 cm long and 1-2 mm wide with leaves; stem circular in cross-section, 0.19-0.22 mm in diameter; one row of exterior cortical cells somewhat copious walled, small, brown in color; inner cortical cells thin walled, large, 17-40 x 19-25 µm; central strand lacking; leaves compactly arranged on stem, oblong-lanceolate, 2.5-4.0x 0.5-0.9 mm, apex acute; costa single, prominent, covering about 2/3 of leaf length; leaf-cells rhomboidal, 20-45 x 7-11 µm at apex; middle cells 12-22 x 7-11 µm; 3-4 rows of marginal cells elongated, forming distinct border, 56-80 x 3-7 µm; basal cells rectangular, 20-75 x 11-19 µm. Seta upright, scabrous at tip, 6–8 mm long; capsule erect, ovate 1.7–2.1 x 0.5–0.6 mm; peristome teeth double; endostome more or less equal to exostome; calyptra fringed at base; spores 18–24 µm, finely papillose.

Habitat: Plants epiphytic, developing on the bark association with the *Macromitrium hymenostomum*, *Claopodium assuregens*, *Syntrichia fragilis* and *Bryum argenteum.*

Range: Endemic to India[6].

Distribution in India: Eastern Himalaya: West Bengal: Darjeeling[4], South India: Tamil Nadu (Nilgiri hills: Ootacamund).

Specimen examined: South India: Tamil Nadu, Nilgiri hills, Ootacamund: Dodabetta, alt. ca. 2600 m, S. C. Srivastava & Party, 7 January, 2006, 18590/06, 18602/06 (LWU).

3. Discussion

Daltonia decolyi is an endemic species that is reported so far from Darjeeling only[4]. In the present study, it is reported for the first time from the Doddabetta locality in the Nilgiri Hills. It is characterized by an oblong lanceolate leaf with a single costa reaching up to 2/3 of the leaf. Capsules are erect with fringed calyptra.

4. Conclusion

Based on the findings of the current investigation, *Daltonia decolyi* Gangulee is being registered as a new record for the Western Ghats, South India.

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The author would like to thank Prof. Geeta Asthana, the former head of Lucknow University's department of botany, for her help in providing resources and guidance regarding plant identification. The author also commends the principal of Shaheed Smarak Government College in Yusufpur, Ghazipur, for fostering a healthy environment and providing moral support.

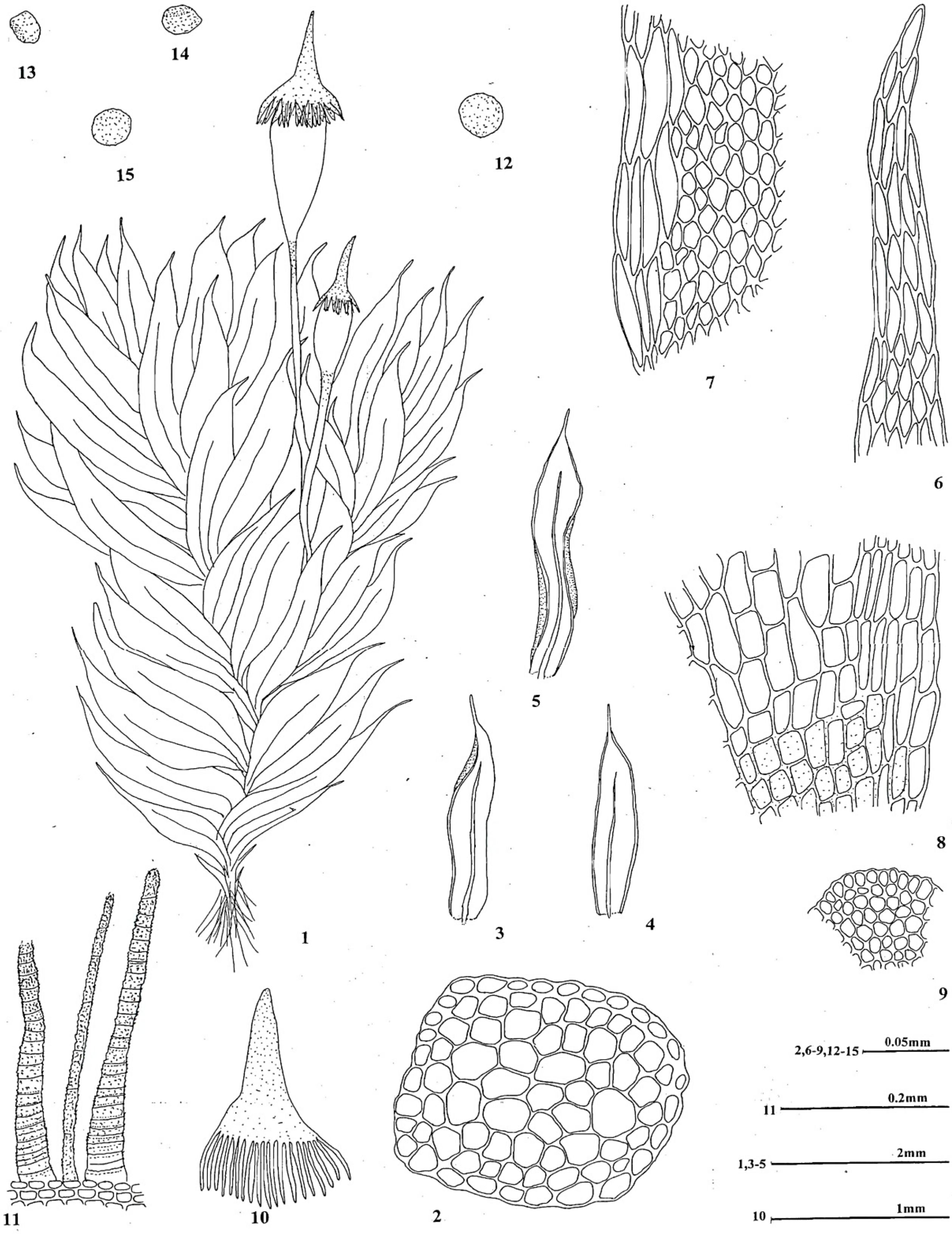

Plate 1; Figs. 1-15. *Daltonia decolyi* Gangulee: 1. Habit of plant. 2. Cross-section of stem. 3-5. Leaves. 6. Apical leaf-cells. 7. Median leaf-cells. 8. Basal leaf-cells. 9. Cross-section of seta. 10. Calyptra. 11. Peristome teeth. 12-15. Spores. All figures drawn from 18590/06 (LWU).

Conflicts of interest

Not Applicable.

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