eISSN: 2976-1190

Journal of Engineering and Sciences

Vol. 4 Issue 1 May 30, 2025

DOI:10.3126/jes2.v4i1.79919

Journal homepage: **Journal of Engineering and Sciences (nepjol.info)**

Publisher: Research Management Cell, Pashchimanchal Campus, Lamachour, Pokhara

Study of Materials Science of *Eulaliopsis binata* Fiber with an Overview on Its Sustainable Economic Prospects as a Non-timber Forest Product

Hari Sharan Adhikari[1,2*], Ganesan Krishnamoorthy[3], Rameshwar Adhikari[2,4,5*]

[1] *Department of Applied Sciences, Pashchimanchal Campus, Tribhuvan University, Pokhara, Nepal*

[2] *Nepal Polymer Institute, Kathmandu, Nepal*

[3] *Department of Chemistry, Indian Institute of Technology Guwahati, Assam, India*

[4] *Central Department of Chemistry, Tribhuvan University, Kirtipur, Kathmandu, Nepal*

[5] *Research Centre for Applied Science and Technology (RECAST), Tribhuvan University, Kirtipur, Nepal*

* *Corresponding authors: adhikaripkr687@gmail.com; nepalpolymer@yahoo.com*

(Manuscript Received: 29/04/2025; Revised: 26/05/2025; Accepted: 30/05/2025)

Abstract

The present study demonstrates that Babiyo (*Eulaliopsis binata*) leaves, a grass of *Poaceae* family, produce commercially viable fibers with multifaceted applications. It is a plant of high resilience to climatic adversities and soil infertility, and a strong root system to prevent erosion. The morphological studies *via* field emission scanning electron microscopy (FE-SEM) revealed that *E. binata* fibers with high cellulose content could essentially be used to prepare high-quality paper and fiber-based utility items, and it could lend itself as a reinforcement material to be incorporated in a polymer matrix to give high-performance composite materials customized mechanical and tribological applications. The energy dispersive X-ray spectroscopy (EDX) analyses showed the abrasion-resistant surface of the fiber due to almost consistent distribution and interactive dispersion of silicon, carbon, oxygen, nitrogen, sodium, magnesium, silicon, phosphorus, sulfur, potassium, calcium, iron atoms throughout the fiber structure. The powder X-ray diffraction (PXRD) study showed the fiber surfaces' crystalline behavior (crystallinity index 30.02%). The literature shows that *E. binata* methanolic extract contains flavonoids and phenolic compounds with anti-oxidant behavior, owing to which the extract brings about an increase in the reduced level of natural *in vivo* and *in vitro* glutathione (GSH) level. The *E. binata* extracts show the healing of wounds, antibacterial activity and anti-ailment behavior in dermatological diseases. The toxicological study of n-hexane, ethyl acetate and methanolic extracts of *E. binata* shows no detrimental effects to vital organs. At this juncture, the *E. binata* cultivation, fiber processing, and industrialization are crucial towards the sustainable economic growth of rural people, revenue generation, soil conservation initiatives, and the utilization of non-timber forest product (NTFP) resources.

***Keywords**:* Babiyo (*Eulaliopsis binata*); Morphology; Natural fibers; Non-timber forest product; Biopolymer

1. Introduction

The *Eulaliopsis binata* (Retz.) is a perennial grass of *Poaceae* family (Sahu *et al.*, 2010) distributed in Southeast China, South Asia, and south-eastern countries of Asia (Hunsigi, 1989; Chand and Rohatgi, 1992). It possesses the culms branched from a base, the new thin leaflets of 2-5 mm width, the grown stooping leaves of up to 90 cm length and the spikelets of 3.5-4.5 mm length. The awns differ from spikelets in several nerves and teeth of the lower glume. The polea are long, like glumes, and ciliated at the top with narrow stigmas (Sahu *et al.*, 2010), and the seeds are black, extremely small and light (Kumar *et al.*, 2018). *E. binata* is an environmentally sustainable grass with high tolerance to drought and poor soil fertility, a massively developed root system and quick grass coverage (Zou *et al.*, 2000) owing to which the surface water and soil are retained and erosion is minimized (Zou *et al.*, 2000; Huang *et al.*, 2002). *E. binata* (called Babiyo in Nepali) has been used in Nepal as an ethno-botanical fiber material to make paper, rope for swing and thatched roof (Rijal, 2011). The high fiber and low lignin contents in *E. binata* leaves have been found advantageous for manufacture of crafts, printing paper, artificial silk and rayon threads (Sahu *et al.*, 2010). The suitability of *E. binata* leaves in plaiting the interlaced rope items to make the utility like hitch knot for cattle ties is attributed to their flexibility and firmness (Basu *et al.*, 2006). The *E. binata* leaves have been used to treat papillary wounds and internal injuries in cattle stuff (Manandhar, 1998; Pandey *et al.*, 2007; Han *et al.*, 2008; Zou *et al.*, 2013). *E. binata*-based industries involve large-scale production of the grass, and fiber processing towards the preparation of ropes, paper (Sahu *et al.*, 2010; Basu, *et al.*, 2006) textile (Chand, and Rohatgi, 1992), utility items such as carpets, chairs, cushions and fashion articles (Hathy *et al.*, 2010). *E. binata* farming, value-added processing, and marketing for the industries and mills could provide the farmers with a sustainable approach to raising their income and raise economic standard (Acharya and Pradhan, 2019).

The utilization of value-added non-timber forest products (NTFPs) has obviously been important towards the reduction of poverty of indigenous and rural people, plant resources and soil conservation, buffer zone management, bio-prospecting, watershed management and degraded land rehabilitation (Rijal, 2011). Natural fibers (such as that from the NTFPs) have been accepted as responsible and healthy, eco-friendly and sustainable, and high-tech and fashionable choices for economic improvement and better lifestyle (Dwari and Khandual, 2018). *E. binata* grass fiber possesses desirable mechanical properties so as to lend itself as a reinforcement composite material (Acharya and Pradhan, 2019). It is a natural fiber with a very high amount of 50% cellulose, a low amount of 18% lignin and other constituents such as hemicellulose, pectin, wax, nitrogenous compounds, tannin, ash, inorganic salts and coloring materials (Dwari and Khandual, 2018). It has been mentioned in *E. binata* Babui, sabai grass PFAF plant data base that *E. binata* grows well up to an altitude of 1400 m on loam and sandy soil with a rainfall of 750-1500 mm annually. It is propagated by rootstock divisions and the seedlings raised in nurseries.

The brownish-yellow colored *E. binata* fiber has been found to have fiber curl index 0.5-10 mm, fiber kink index 0.5-5 mm, fiber width 7-45 µm, and fiber length 3.5-4.4 mm (Chand and Rohatgi, 1992). The clear water drainage system attributed to low lignin in *E. binata* fiber makes it favorable for pulp and paper manufacturing (Gierlinger *et al.*, 2008). *E. binata* fiber has been found to show minimal degradation and weight loss upon the treatment with alkali. *E. binata* pulp obtained by alkali treatment is mixed with agricultural waste material or hardwood pulp in the process of paper manufacturing. Its breaking strength and moisture retention capacity have been found comparable to that of cotton and flax (Dwari and Khandual, 2018). The porous carbon materials derived from *E. binata* fiber can be used in manufacture of electric double layer capacitors (EDLCs), as the rechargeable devices for electrochemical energy storage (Liu *et al.*, 2016).

2. Materials and methods

The Babiyo (*Eulaliopsis binata)* grass in successive growth stages is shown in Figure 1. The matured leaves of the grass were collected from a degraded and infertile slopy land in Babiyodhunga, Lamachaur, Pokhara, Nepal (830 m altitude). The grass leaves were sun-dried for a week till they appeared greenish yellow in color. The bundle of the Babiyo dry leaves (Figure 2) was stored in an arid environment for a week to retain its natural luster. The dry grass was washed with distilled water, dried well, and trimmed into short fiber fragments.

Figure 1: Photograph of Babiyo in successive growth stages

Figure 2: Dry leaves bundle

The XRD measurement of Eb was carried out on a Bruker D8 ADVANCE ECO P-XRD system and used a Cu Kα target at 40 kV-50 mA with a scattering range (2θ) of 5-60°.
The *Debye-Scherer formula:* $D = \frac{k\lambda}{\beta\cos\theta}$ was used to find the particle size (D) from PXRD curve where 'k' is shape factor (0.9), 'λ' is wavelength of X-ray (0.1541 nm), 'β' is full width at half maxima (FWHM)) (0.043 radian observed upon Gaussian peak fit after the baseline correction) and 'θ' is the Bragg angle (Dehaghi *et al.*, 2014; Kucukgulmez *et al.*, 2011). The crystallinity index was determined with the formula: $Crystallinity\ Index = \frac{I\max - Iam}{Imax}\ X\ 100$ where I_{max} (arbitrary unit) is the maximum intensity peak intensity and I_{am} (arbitrary unit) is amorphous diffraction intensity (Kumirska *et al.*, 2010; Lomadze and Schneider, 2005; Zhang *et al.*, 2005).
The size determination and morphological studies of Eb were made by scanning electron microscopy (Carl Zeiss FE-SEM). The elemental composition was determined by energy-dispersive X-ray (EDX) analysis (Gemini SEM 500-8203017168, system vacuum 1.283-06 mbar, analytic column mode, 0 V ESB grid) and mapping (kV: 20, mag.: 1000, take off: 37.6, amp. Time: 3.84 µs, resolution: 126.1). The sample for these studies was prepared on a 300-mesh copper grid coated with carbon at a concentration of 1 mg/mL in distilled water.

3. Results

3.1 Powder X-Ray Diffraction (PXRD) Analysis

The PXRD curve of *Eulaliopsis binata* fiber (Eb) (Figure 3) showed three peaks corresponding to 2θ at 21.9385, 29.8488, and 39.9946 with successive decreases in their peak intensity. The crystallinity index of the Eb fiber was found 30.02% and the remaining material of the fiber was semi-crystalline. The average size of particles in a crystallite in Eb fiber was found 15.07 nm.

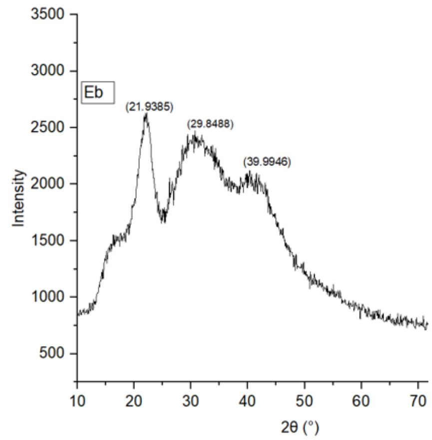

Figure 3: The PXRD curves of E. binate (Eb) fiber

3.2 Field emission scanning electron microscopy (FE-SEM) analysis

The microstructure images of Eb fibers taken from FE-SEM analysis comprised long fiber cross-section (Figure 4), the internal structure of the fiber (Figure 5) and magnified views of external surfaces (Figure 6).

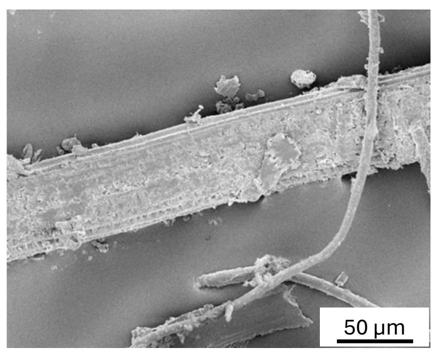

Figure 4: FE-SEM micrograph of the Eb showing the surface morphology along the fiber bundle length.

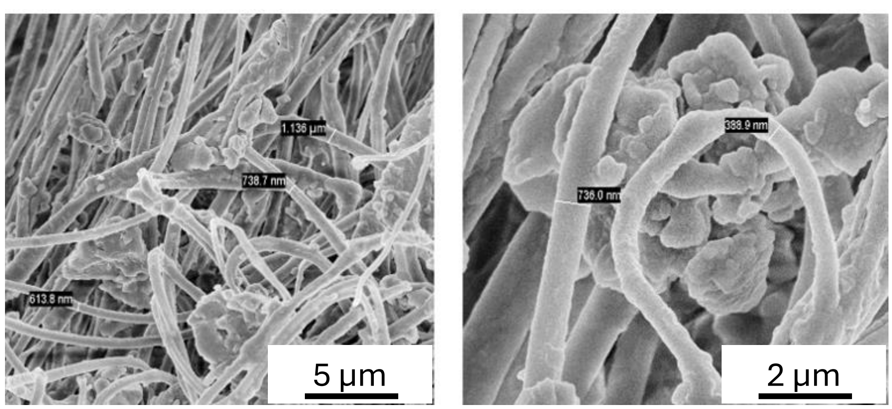

Figure 5: FE-SEM micrograph of the Eb showing the detailed surface morphology of the fibers in different magnifications.

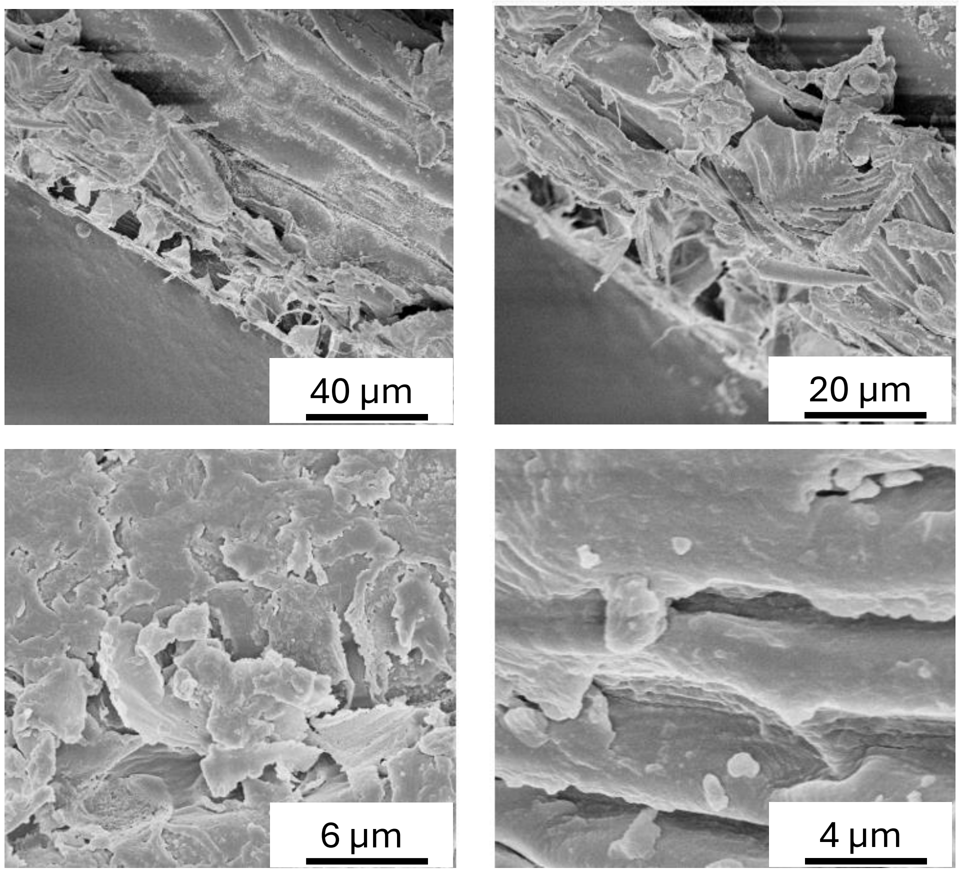

Figure 6: FE-SEM micrographs illustrating the magnified views of the outer surface structures in different magnifications.

3.3 Energy-dispersive X-ray (EDX) analysis: determination of elemental composition

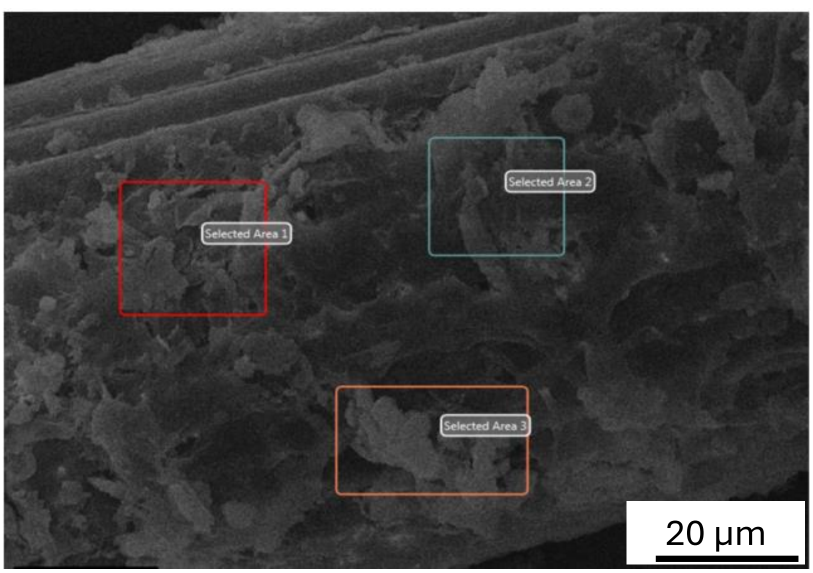

Figure 7: FE-SEM image of the Eb fiber with selected areas I, II, and III for EDX analyses as indicated.

The FE-SEM image of Eb fiber at 1 KX magnification with selected areas I, II and III for EDX analysis (Figure 7) showed the open and relaxed distribution of fibers in the material microstructure. The elemental composition (w/w%) data of different elements in the selected areas I (Figure 8), II (Figure 9) and III (Figure 10) showed that the major constituents were O, C, N, K and Na along with P, S, Ca, Fe, Si and Mg.

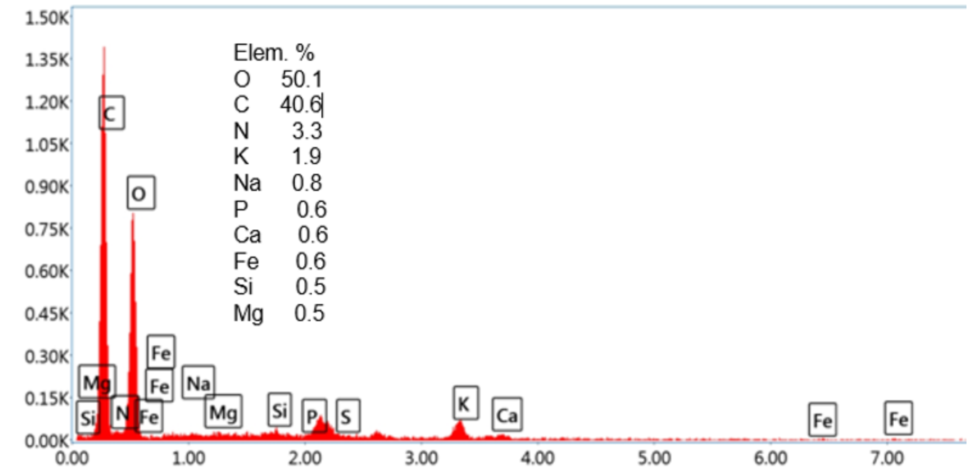

Figure 8: Elemental composition (wt.-%) of different elements in selected area I from Figure 7

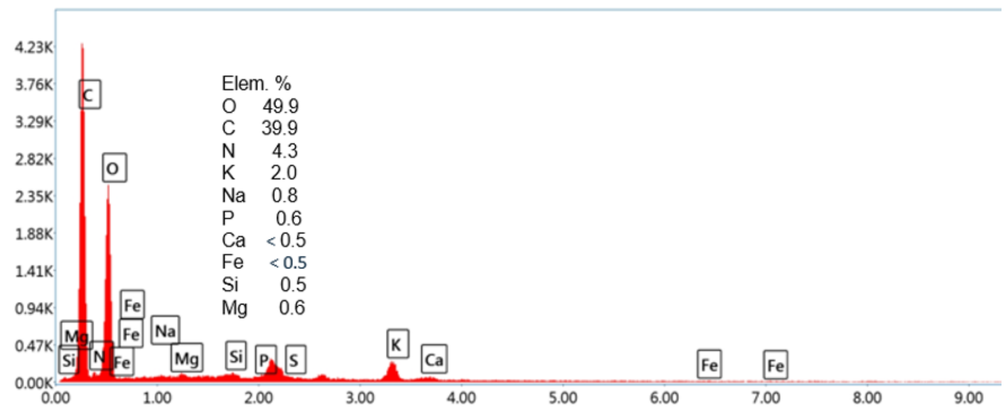

Figure 9: Elemental composition (wt.-%) of different elements in selected area II from Figure 7

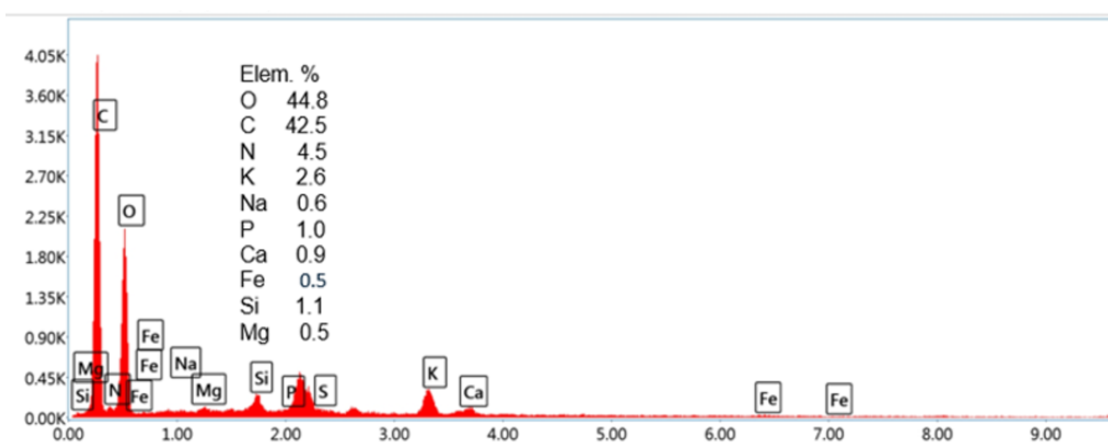

Figure 10: Relative composition (wt.-%) of different elements in selected area III from Figure 7

4. Discussion

4.1 Characterization

The PXRD analysis of Eb fiber material corresponds to an inconsistent periodic arrangement of layers with different thicknesses. The distributed crystallinity phases and crystal orientations, variations in crystal size and lattice strains, and mostly a semi-crystalline fiber pattern can be inferred from the enrichment of crystallinity index at 30.02% and average particle size of 15.07 nm. The major part of the fiber material was semi-crystalline and the removal of adhering impurities and moisture was found highly essential before the fiber processing. The FE-SEM images reveal rough and fibrous topography, wavy and uniform fiber microstructure, compact and consistent microcrack-free surfaces, and open and loose anatomy that could allow the penetration of moisture and liquor materials (Acharya and Pradhan, 2019). The FE-SEM and EDX data show that the percentages of elements have some variations in the randomly selected areas. This is indicative of selective distribution of constituent elements in different parts of the fiber microstructure, and yet there is consistent accumulation with interactive dispersion of these elements. The results indicate that the fibers have high cellulose content and resistance to abrasion and the fibers could lend themselves as a reinforcement material to be incorporated in polymer matrix to give polymer-based composites for mechanical and tribological applications. The FE-SEM and EDX data favor the high impact strength, hard surface as a result of chemical interaction of silicon content with carbon and oxygen. The *E. binata* fibers are intact with porous parts and they maintain innate roughness due to which they could be bonded to polymer matrix like epoxy resin to give fiber-epoxy polymer composite of multiple applications (Pradhan *et al.*, 2020).

4.2 Morphological characteristics of E. binata: an overview

E. binata grass collected by Acharya and Pradhan from Mayurbhanj, Odisha, India with its long fibers of uniform diameter and short fibers of 11 mm length (Acharya and Pradhan, 2019) has been reported to show the long, thin and slender stalks with somewhat the pointed ends changed into short fibers. The *E. binata* fiber consists of cellulose as the main structural component to provide stability and strength to cell walls. The degree of polymerization (DP) of cellulose varying from 7000-15000 DP units can give the fibers of divergent properties, and the high cellulose content makes *E. binata* fiber a potent textile fiber (Dwari and Khandual, 2018; Majumdar and Chanda, 2001; Satyanarayana *et al.*, 1986; Rowell *et al.*, 2000; Fuqua *et al.*, 2012). Hemicellulose with a DP from 500-3000 present in the interfaces between cellulose and lignin provides the fiber with hydrophilic interaction towards alkali (Dwari and Khandual, 2018). In an infra-red spectroscopic study by Dwari and Khanduwal (Dwari and Khandual, 2018), the *E. binata* fiber obtained after acid hydrolysis and alkali-hydrogen peroxide degumming process was found to have an intact cellulose content with the transmittance peaks of cellulose at 3402 cm^{-1} ν (OH), ν at 1431, 1166, 1059 cm^{-1} attributed to cellulose structure in fingerprint area, and non-cellulose materials lignin, hemicellulose and pectin were found to be eliminated.

The scanning electron microscopy (SEM) images of *E. binata* long fiber cross-section, a magnified view of the external surface and internal structure of the fiber taken by Acharya & Pradhan (Acharya and Pradhan, 2019) have respectively revealed a natural and rough fiber surface, uniform structure from one end to another end of the fiber, and wavy structure of the fiber circumference.

The *E. binata* short fibers up to 30% weight fraction in a composite with epoxy resin as a matrix material have been found to behave as potent reinforcement material, and this *E. binata* short fiber (30% w) – epoxy resin composite has been optimized to show the prudent modulus of elasticity, modulus of rupture, impact strength and hardness. More than 30%w of *E. binata* short fibers added in epoxy resin has been found to cause agglomeration, poor bonding at matrix-fiber interface, and the subsequent deterioration in mechanical strength of composite (Acharya and Pradhan, 2019). The SEM analyses have shown that the improper fiber-matrix ratio could cause matrix-fiber de-bonding, fiber pull out and micro-crack propagation to cause composite failures (Dalbehera and Acharya, 2018; Acharya and Pradhan, 2019). The high surface roughness of *E. binata* fibers as revealed by microstructure analyses could bring about a substantial matrix-fiber bonding, and better stability of composite. So, *E. binata* fiber possesses high impact potential towards the preparation of polymer composites. The energy dispersive X-ray spectroscopy (EDX) analyses have shown the presence of carbon, oxygen, silicon and potassium on the *E. binata* fiber surfaces. The hard fiber surface is formed as a result of chemical interaction of silicon with carbon and oxygen. The abrasion-resistant surface of the fiber is due to uniform structural distribution and dispersion of atoms on the surfaces (Pradhan *et al.*, 2020). The *E. binata*-epoxy composites have been reported to show abrasive wear behaviour with tribological applications (Pradhan *et al.*, 2020).

4.3 E. binata cultivation, harvesting and fiber processing: an overview

The method of cultivation involves ploughing or digging the fields, removing the weeds and planting the seedlings in the rainy season with a gap of 2.5 feet between the crops. One month after the plantation, the weeds are uprooted, and the periodical removal of weeds is continued. The plant yields the grass for more than ten years, after which the field is prepared for the plantation of new seedlings. The grass can be harvested once or twice annually depending upon the amount of rainfall and irrigation facility in the dry season. The grass is sun-dried for a couple of days to retain its greenish yellow color, made into bundles and stored in a dry room or shadow to protect its natural color and luster (Sahu *et al.*, 2010). The dry grass is moistened with water and plaited with hands into the interlaced ropes. The ropes can be tightened by further twisting with hands or local devices. The ropes can be sold for weaving the cots, sofa set, chair, vases, door mats, bags, etc. (Sahu *et al.*, 2010).

In the Kraft process of preparing pulp, the plant fibers are treated with caustic soda and sodium sulfide so that lignin is solubilized and cellulose fibers are separated. The cellulose fibers are bleached and beaten into paper stock. The paper stock is sent to the paper machine, where a major amount of water is removed, and the pressed and consolidated sheet is obtained. It is further dried by evaporation and the travelling sheet is converted into reels of paper (Bajpai, 2018).

The *E. binata* fibers can be processed into polymer composites, such as epoxy resin- *E. binata* fiber composite. For this, the fibers of uniform diameter are properly washed to remove the undesirable residues, dried in the sun for 3 days, cut into short fibers of 11 mm length, and left in the oven at 50 ℃ for 40 min to remove the moisture. A mixture of epoxy resin (Bisphenol A-DGEBA) and LapoxK6 hardener in the ratio of 10:1 is taken in a wooden mold glued to a perpex sheet on a smooth flat surface. The *E. binata* fibers are gradually added to the epoxy-hardener mixture, and stirred continuously until the fibers are completely wet and the bubbles cease to be formed. The void formation is prevented by adding epoxy-hardener mixture on the mold and applying a moderate load on the perpex sheet kept at the top of the mold (Pradhan *et al.*, 2020).

4.4 Economic prospects of E. binata as a non-timber forest product

Many people in rural regions of Nepal have been generating off-farm employment from collecting and selling non-timber forest products (NTFP) for their livelihood (Edwards, 1994; Olsen, 1998). But, ethno-botanical knowledge on traditional uses of plants has still to be properly documented (Chaudhary, 1998), as such knowledge of only a few medicinal plants has been recognized (Khan, 1998; Manandhar, 1989). The *E. binata* grass has been commonly used as fodder, cultural and religious material, broom, thatching, and fiber material to make ropes (Rijal, 2011). The *E. binata* fiber has also been traditionally used to make Nepali paper for writing and printing purposes. The sales and usage of *E. binata* are in need of further commercialization through the extension and capacity enhancement of relevant entrepreneurships and industries.

The *E. binata* fibers can be used as reinforcement material to get the polymer composites of tribological applications. For instance, the mechanical behavior and abrasion resistance of epoxy resin can be enhanced to optimum level by incorporation of 30 and 20%w of *E. binata* fibers respectively in epoxy resin matrix (Pradhan *et al.*, 2020). The fibrils formation and de-bonding at the matrix fiber interfaces that arise the composite failure can be checked by taking a suitable *E. binata* fiber to epoxy matrix ratio (Dalbehera and Acharya, 2018; Acharya and Pradhan, 2019). *E. binata* extract has been found to show conspicuous healing of wounds (Jyotsana *et al.*, 2013), antibacterial activity against *Escherichia coli* (Tian *et al.*, 2014) and anti-ailment behavior in dermatological diseases (Jyotsana *et al.*, 2013; Sharma *et al.*, 2014). *E. binata* extracts have been shown to have antibacterial activity against the gram positive (*Bacillus sp.*) and gram negative (*E. coli*) bacteria at 50 µg mL^{-1} concentration. The antibacterial flavonoids and phenolic compounds found in methanolic extract of *E. binata* could be important attributes to reveal the antibacterial potential of *E. binata* (Baharfar *et al.*, 2015; Xu *et al.*, 2016). Moreover, the presence of flavonoids and phenolic compounds can make the methanolic extract of *E. binata* exhibit anti-inflammatory, anti-hyperglycaemic, anti-diarrheal, and anti-cancer effects (Kumar *et al.*, 2018). The toxicological study of n-hexane, ethyl acetate, and methanolic extracts of *E. binata* leaves has revealed no *in vivo* or *in vitro* adverse effects. In addition, the methanolic extract of *E. binata* has been found to increase the reduced level of natural antioxidant glutathione (GSH), and this antioxidant behavior has indicated the possibility of therapeutic use of *E. binata* methanolic extract against the disturbed cellular signaling and fatal pathological states caused by oxidative stresses (Sharma *et al.*, 2015).

E. binata has an extended and strong root system so as to resist soil erosion (Huang *et al.*, 2002) and it is resilient to soil infertility and drought (Zou *et al.*, 2000). So, the *E. binata* cultivation in erosion-prone slopes and degraded lands brings about sustainability in conservation initiatives. It has been reported that the climate change may cause detrimental effect on the plants with confined geographic distribution (Kunwar *et al.*, 2014; Acharya *et al.*, 2022). *E. binata,* being a plant species native to a certain geographic region, may also be adversely affected by variations in morphology and phenology due to climate change. In this context, the extensive *E. binata* cultivation and gene bank establishment may also be important for future conservation strategies. Overall, the *E. binata* cultivation and the *E. binata-based agro-industrial development are pivotal towards creating a sustainable source of income for rural people, soil conservation,* and revenue generation.

5. Conclusion

Babiyo (*Eulaliopsis binata*), a grass of *Poaceae* family, mostly grown in loam sandy soil can tolerate adverse climatic condition of drought and soil infertility. It has been used to make cattle hitch tie, ropes, paper and fiber-based utility items. It shows medicinal uses against skin ailment, papillary wounds and internal injury. It has a massively developed root system and shows quick grass coverage to prevent soil erosion. The ethnobotanical knowledge and traditional applications of *E. binata* are in need of conservation and development *via* the extensive cultivation and establishment of *E. binata* fiber-based enterprises and industries. The FE-SEM and EDX analyses showed that *E. binata* fiber with high cellulose content could be used as a reinforcing material with polymer matrix material. The *E. binata* fiber possesses high impact strength, a hard surface as a result of the chemical interaction of silicon content with carbon and oxygen. The uniform structural distribution and dispersion of atoms on the surfaces make the *E. binata* fiber resistant to abrasion. The *E. binata* short and porous fibers with innate roughness have been found to get adequately bonded to an epoxy resin matrix to give a fiber-epoxy polymer composite of tribological and mechanical applications. The pharmacognostic and phytochemical screening of *E. binata* extracts has mainly shown their non-toxicity to vital organs, antioxidant activity, and antibacterial effects against gram-positive and gram-negative bacteria. The large-scale cultivation of *E. binata* and its agro-industrial commercialization as a non-timber forest product (NTFP) have been assessed to be very important for conservation initiatives, creating self-employment opportunities for rural people, and generating revenue. It is essential that the *E. binata*-based industries and paper mills be established at the local level to provide the cultivators with the opportunity to sell the fiber materials.

Acknowledgements

We are very thankful to Professor Govindarajan Krishnamoorthy and acknowledge North East Centre for Biological Sciences and Healthcare Engineering (NECBH), Indian Institute of Technology Guwahati (IITG), Assam, India, for supporting the characterization part of this study.

Conflict of interest

The authors declare no conflict of interest regarding the publication of this article.

References

[1] Sahu, S. C., Rout, N. C., & Dhal, N. K. (2010). Ethnobotany of Eulaliopsis binata (Retz.) Hubbard - Poaceae, in Odisha, Eastern India: Cultivation Practice, Economics and Prospects, Journal of Advances in Developmental Research, 1 (2), 155-160.

[2] Hunsigi, G. (1989). Agricultural fibres for paper pulp, Outlook on Agriculture, 18 (3), 96-103.

[3] Chand, N., & Rohatgi, P. K. (1992). Potential use, mechanical and thermal studies of sabai grass fibre, Journal of materials science letters, 11 (9), 578-580.

[4] Kumar, V., Sharma, A. K., Rajput, S. K., Palc, M., & Dhiman, N. (2018). Pharmacognostic and pharmacological evaluation of Eulaliopsis binata plant extracts by measuring in vitro/in vivo safety profile and anti-microbial potential, Toxicology Research, 7, 454-464.

[5] Zou, D. S., Huang, Y., & Wang, H. (2000). Studies on the biological characteristics and main cultivation techniques of Eulaliopsis binata, Acta Agrestia Sinica, 8 (1), 67- 71.

[6] Huang, Y., Zou, D. S., & Wang, H. (2002). Analysis on ecological and economic benefits of Eulaliopsis binata, Journal of Mountain Science, 6, 721-725.

[7] Rijal, A. (2011). Surviving on Knowledge: Ethnobotany of Chepang community from mid-hills of Nepal, Ethnobotany Research & Applications, 9, 181-215.

[8] Basu, M. S., Das, S., & Mahapatra, S. C. (2006). Effect of integrated nutrient management on sabai grass-groundnut intercropping system under lateritic soils of South West Bengal, Environment and Ecology, 24S (9), 190-192.
[9] Manandhar, N. P. (1998). Ethnobotanical census on herbal medicines of Banke district, Contributions to Nepalese studies, 25, 57-63.
[10] Pandey, P. C., Tiwari, L., & Pande, H. C. (2007). Ethnoveterinary plants of Uttaranchal- A review, Indian Journal of Traditional Knowledge, 6 (3), 444-458.
[11] Han, P., Song, G. J., Xu, S. T., Sun, G. B., Yuan, F., & Han, Y. H. (2008). Properties of new natural fibers: Eulaliopsis binata fibers, Journal of Qingdao University, 23, 44–47.
[12] Zou, D., Chen, X., & Zou, D. (2013). Sequencing, de novo assembly, annotation and SSR and SNP detection of sabai grass (Eulaliopsis binata) transcriptome, Genomics, 102, 57–62.
[13] Hathy, P. R., Sahu, U. N., & Satpathy, A. R. (2010). Marketing of Sabai grass in socioeconomic development of tribals in Mayurbhanj district of Orissa (India), International Journal of Business Management, 5 (2), 149-158.
[14] Acharya, S. K., & Pradhan, S. (2019). Mechanical behaviour of Eulaliopsis binata fiber reinforced polymer composite, Materials Today: Proceedings, 19 (2), 344-348.
[15] Dwari, S. K., & Khandual, A. (2018). Sabai grass fiber: an innovative and sustainable textile fiber, Journal of Engineering Technologies and Innovative Research, 5 (7), 230-233.
[16] Gierlinger, N., Goswami, L., Schmidt, M., Burgert, I., Coutand, C., Rogge, T., & Schwanninger, M. (2008). In Situ FT-IR Microscopic Study on Enzymatic Treatment of Poplar Wood Cross-Sections, Biomacromolecules, 9 (8), 2194-2201.
[17] Liu, B., Chen, H., Gao, Y., & Li, H. (2016). Preparation and capacitive performance of porous carbon materials derived from Eulaliopsis binata, Electrochimica Acta, 189, 93-100.
[18] Dehaghi, S. M., Rahmanifar, B., Moradi, A. M., & Azar, P. A. (2014). Removal of permethrin pesticide from water by chitosan–zinc oxide nanoparticles composite as an adsorbent, Journal of Saudi Chemical Society, 18, 348-355.
[19] Kucukgulmez, A., Celik, M., Yanar, Y., Sen, D., Polat, H., & Kadak, A. E. (2011). Physicochemical Characterization of Chitosan Extracted from Metapenaeous stebbingi Shells. Food Chemistry, 126, 1144–1148.
[20] Kumirska, J., Czerwicka, M., Kaczynski, Z., Bychowska, A., Brzozowski, K., Thöming, J., & Stepnowski, P. (2010). Application of spectroscopic Methods for Structural Analysis of Chitin and Chitosan, Marine Drugs, 8, 1567-1636.
[21] Lomadze, N., & Schneider, H. J. A. (2005). Chitosan-based chemo mechanical polymer triggered by stacking effects with aromatic effectors including amino acid derivatives, Tetrahedron, 61, 8694–8698.
[22] Zhang, Y. Q., Xue, C. H., Xue, Y., Gao, R. C., & Zhang, X. L. (2005). Determination of the degree of deacetylation of chitin and chitosan by X-ray powder diffraction, Carbohydrate Research, 340, 1914-1917.
[23] Majumdar, P., & Chanda, S. (2001). Chemical profile of some lignocellulosic crop residues, Indian Journal of Agricultural Biochemistry, 14 (1 & 2), 29–33.
[24] Satyanarayana, K. G., Sukumaran, K., Mukherjee, P. S., & Pillai, S. G. K. (1986). Materials Science of Some Lignocellulosic Fibers, Metallography, 19 (4), 389–400.
[25] Rowell, R. M., Han, J. S., & Rowell, J. S. (2000). Characterization and factors effecting fiber properties, Natural Polymers and Agrofibers Bases Composites, Embrapa Instrumentacao Agropecuaria, P. O. Box 741, Sao Carlos, 13560-970 SP, Brazil, 115-134.

[26] Fuqua, M. A., Huo, S., & Ulven, C. A. (2012). Natural fiber reinforced composites, Polymer reviews, 52 (3), 259-320.
[27] Dalbehera, S., & Acharya, S. K. (2018). Impact of Cenosphere on the Erosion Wear Response of Woven Hybrid Jute–Glass Epoxy Composites, Advances in Polymer Technology, 37 (1): Article 21662.
[28] Pradhan, S., Acharya, S. K., & Prakash, V. (2020). Mechanical, morphological, and tribological behavior of Eulaliopsis binata fiber epoxy composites, Journal of Applied Polymer Science, e50077. https://doi.org/10.1002/app.50077.
[29] Bajpai, P., Chapter 6 - Paper Manufacture—Dry End Operation, Editor(s): Pratima Bajpai, Biermann's Handbook of Pulp and Paper (Third Edition), Elsevier, 2018, Pages 137-158, ISBN 9780128142387, (https://doi.org/10.1016/B978-0-12-814238-7.00006-4 .
[30] Edwards, D. M. (1994). Non-timber Forest Products and Community Forestry, Project report G/Nepal-United Kingdom Community Forestry Project Report 12, Overseas Development Administration, Kathmandu.
[31] Olsen, C. S. (1998). The trade in medicinal and aromatic plants from Central Nepal to Northern India, Economic Botany, 52, 279-292.
[32] Chaudhary, R. P. (1998). Biodiversity in Nepal - Status and Conservation, Craftsman Press, Bangkok, Thailand.
[33] Khan, M. H. (1998). Documentation of indigenous knowledge in the Chepang community of Shakti Khor VDC, Chitwan, pp. 96-101 in Ethnobotany for Conservation and Community Development, Edited by Shrestha, K. K., Jha, P. K., Shengji, P., Rastogi, A., Rajbhandary, S. & Joshi, M., Ethnobotanical Society of Nepal, Kathmandu.
[34] Manandhar, N. P. (1989). Medicinal plants used by Chepang tribes of Makwanpur District, Nepal, Fitoterapia, 60 (1), 61- 68.
[35] Jyotsana, S., Gaur, R. D., Sumeet, G., Painuli, R. M., & Siddiqi, T. O. (2013). Traditional herbal medicines used for the treatment of skin disorders by the gujjar tribe sub-himalayan tract, Uttarkhand, Indian Journal of Traditional Knowledge, 12, 736–746
[36] Tian, M., Qu, L., Zhu, S., Guo, X., Han, G., Sun, Y., Ma, Z., Sun, K., & Tang, X. (2014). Natural Cellulose Fiber from Eulaliopsis binata, Journal of Fiber Bioengineering and Informatics, 7, 181– 188.
[37] Sharma, J., Gairola, S., Sharma, Y. P., & Gaur, R. D. (2014). Ethnomedicinal plants used to treat skin diseases by Tharu community of district Udham Singh Nagar, Uttarakhand, India, Journal of Ethnopharmacology, 158, 140–206.
[38] Baharfar, R., Azimi, R. & Mohseni, M. (2015). Antioxidant and antibacterial activity of flavonoid-, polyphenol- and anthocyanin-rich extracts from Thymus kotschyanus boiss & hohen aerial parts, Journal of Food Science and Technology, 52, 6777–6783.
[39] Xu, Y., Burton, S., Kim, C., & Sismour, E. (2016). Phenolic compounds, antioxidant, and antibacterial properties of pomace extracts from four Virginia-grown grape varieties, Food Science and Nutrition, 4, 125–133.
[40] Sharma, K., Taneja, G., Khanna, D., & Rajput, S. K. (2015). Reactive Oxygen Species: Friend or Foe?, RSC Advances, 5, 57267–57276.
[41] Kunwar, R. M., Lamichhane Pandey, M., Mahat Kunwar, L., & Bhandari, A. (2014). Medicinal plants and ethnomedicine in peril: a case study from Nepal Himalaya, Evidence-Based Complementary and Alternative Medicine.
[42] Acharya, S., Sigdel, S., Kandel, G., & Adhikari, P. (2022). Climate change: threats on the medicinal plants in Nepal, Asian Journal of Pharmacognosy, 1 (4), 41-48.