

GENETIC DIVERSITY OF PINEAPPLE (*ANANAS COMOSUS*) AND ITS POTENTIAL RELATIONSHIP WITH LEAF-FIBRE TRAITS: A REVIEW AND FIBRE CHARACTERIZATION IN MEGHALAYA

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ABSTRACT

Pineapple (*Ananas comosus* L.L. Merr.) is an important tropical fruit crop that generates substantial leaf biomass after harvesting. These leaves represent a potential source of lignocellulosic fibre for textile, paper, nonwoven and composite applications. Molecular-marker studies using simple sequence repeats (SSRs), inter-simple sequence repeats (ISSRs) and single-nucleotide polymorphisms (SNPs) have demonstrated the usefulness of DNA-based approaches for characterizing pineapple germplasm and identifying genetic redundancy. However, the relationship between pineapple genetic diversity and leaf-fibre quality remains insufficiently investigated, particularly for pineapple cultivated in Meghalaya. This paper reviews published evidence on pineapple genetic diversity and pineapple leaf fibre (PALF), compares reported literature values with fibre properties observations and identifies priorities for future research. Wang et al. (2017) reported polymorphic bands of 93.65% for ISSR and 96.50% for SSR markers in a collection of 36 accessions. Lin et al. (2015) identified 51 alleles using 16 SSR markers across 27 pineapple cultivars and lines. Zhou et al. (2015) validated 57 polymorphic SNP markers and identified duplicate groups within a collection of 170 accessions. A review by Asim et al. (2015) reported substantial variation in PALF mechanical properties, including tensile-strength values of approximately 413–1,627MPa across cited studies and cellulose contents commonly reported around 70–82%. Fiber properties include a tensile-strength value of 380 MPa, average fineness of 7.57denier, maximum fibre length of up to 92 cm and cellulose content of 77.7%. The available evidence does not establish a genetic–fibre association in Meghalaya. Integrating molecular characterization with standardized fibre measurements from the same identified plants is proposed as a pathway for future germplasm evaluation and sustainable utilization of pineapple leaves.

KEYWORDS: *Ananas comosus*; genetic diversity; pineapple leaf fibre; molecular markers; tensile strength; cellulose; Meghalaya; agricultural-residue utilization

1. INTRODUCTION

Pineapple (*Ananas comosus* L.L. Merr.), a member of the family Bromeliaceae, is cultivated widely in tropical and subtropical regions. In Meghalaya, pineapple cultivation represents an important agricultural resource, and the leaves remaining after fruit harvesting offer an opportunity to explore additional uses for crop residues. Pineapple leaf fibre (PALF) has attracted research interest because of its lignocellulosic composition, useful physical characteristics and potential applications in textiles, paper, nonwovens and fibre-reinforced composites. The suitability of PALF for a particular application depends on several factors, including plant source, leaf maturity, extraction procedure, fibre cleaning, chemical treatment, moisture content and testing conditions. Fibre length, fineness, tensile strength, elongation and chemical composition are therefore important parameters for assessing processing performance and end-use potential. Asim et al. (2015) reviewed PALF properties and composite applications, highlighting both its potential as a renewable reinforcement material and the variation observed among studies.

Genetic diversity is another important dimension of crop-resource evaluation. Molecular markers can distinguish genetically different plants, characterize relationships among cultivars and identify duplicate accessions that may otherwise be maintained under different names. Wang et al. (2017) investigated 36 pineapple accessions using ISSR and SSR markers, while Lin et al. (2015) examined relationships among 27 cultivars and lines using SSR markers. Zhou et al. (2015) demonstrated the use of SNP markers for germplasm identification and duplicate detection. These studies establish methodological precedents for pineapple germplasm characterization, but their results cannot be interpreted as estimates of genetic diversity in Meghalaya.

Genetic diversity and fibre performance should not be assumed to be directly related. Molecular markers can reveal differences among plants without necessarily predicting fibre quality. Establishing a genetic association requires molecular information and fibre measurements from the same identified plants, adequate biological replication and appropriate statistical analysis.

Accordingly, this paper reviews published pineapple genetic-diversity research, summarizes literature on PALF properties, interprets preliminary fibre observations supplied by the authors and proposes a framework for future investigations in Meghalaya. The manuscript is intended as a review supported by preliminary characterization records; it does not claim a completed molecular-genetic study of Meghalaya pineapple.

The study aims to review published evidence on the genetic diversity and molecular characterization of pineapple, summarize the physical, mechanical and chemical characteristics relevant to PALF utilization, and present and interpret preliminary fibre observations available to the authors. It also seeks to identify research priorities for investigating potential associations between genetic variation in pineapple and leaf-fibre traits under the agro-climatic conditions of Meghalaya.

2. Methodological approach

2.1. Literature review

The review draws on identified peer-reviewed publications concerning pineapple genetic diversity, molecular-marker methods, PALF composition and fibre-reinforced composite applications. Particular attention is given to published studies using SSR, ISSR and SNP markers and to review literature summarizing PALF mechanical and chemical properties. Numerical results are attributed to their original publications. The literature values are used for contextual comparison rather than as substitutes for experimental measurements from Meghalaya. As the present manuscript is a narrative review, it should not be interpreted as a systematic review or meta-analysis.

2.2. Preliminary fibre observations

The preliminary fibre-characterization records supplied by the authors include tensile strength, peak and breaking loads, elongation, fineness, maximum fibre length and cellulose content. The available information does not yet establish consistent specimen dimensions, gauge length, testing speed, verified force units, cross-sectional area or replicate-level statistics.

Consequently, the recorded values are presented as provisional observations. The tensile-strength value is not treated as a validated result until the original instrument output and calculation method have been checked.

2.3. Proposed framework for future research

Future work should identify representative pineapple plants from relevant growing areas in Meghalaya and assign a unique code to each plant. The same code should link the plant's geographical and cultivation information, molecular-marker profile and fibre measurements. Fibre extraction, conditioning and testing should follow a documented and reproducible procedure. Biological replicates should be distinguished from repeated tests on the same material. The analysis should account for plant relatedness, environmental conditions and processing effects before any genetic-fibre association is inferred.

3. Genetic diversity in pineapple

3.1. Significance of molecular characterization

Genetic diversity provides a basis for germplasm identification, conservation and crop improvement. Pineapple is commonly propagated vegetatively, so collections may include closely related plants and clonal duplicates. Conversely, plants with similar appearances or different local names may not necessarily represent distinct genetic material.

Molecular markers provide a way to examine such relationships independently of visible characteristics. The level of diversity detected depends on the sampled plants, marker system, number of loci and analytical procedures. Therefore, diversity statistics must be interpreted within the context of the study population.

3.2. Published evidence from SSR and ISSR markers

Wang et al. (2017) characterized 36 pineapple accessions introduced from 10 countries or regions. Thirteen ISSR primers amplified 96 bands, of which 91 were polymorphic. Twenty SSR primers amplified 73 bands, of which 70 were polymorphic.

Table 1. Published molecular-marker results for pineapple germplasm

Study	Material and method	Published result
Wang et al. (2017)	36 accessions; 13 ISSR primers	91 of 96 bands polymorphic; 93.65%
Wang et al. (2017)	36 accessions; 20 SSR primers	70 of 73 bands polymorphic; 96.50%
Lin et al. (2015)	27 cultivars and lines; 16 SSR markers	51 alleles; mean 3.19 alleles per marker
Zhou et al. (2015)	170 accessions; SNP-marker validation	57 polymorphic SNP markers; 24 duplicate groups encompassing 130 accessions

Sources: Wang et al. (2017), Lin et al. (2015) and Zhou et al. (2015).

In Wang et al. (2017), the reported SSR polymorphism percentage exceeded the ISSR value by 2.85 percentage points. This difference indicates that both marker systems were informative in the collection examined, but it does not establish that SSR markers are universally superior. Marker performance depends on marker selection, sample composition and analytical conditions. Lin et al. (2015) reported 51 alleles from 16 SSR markers across 27 cultivars and lines, demonstrating that SSR profiles can distinguish many pineapple cultivars. Their findings also indicate a limitation: vegetatively propagated material may share marker profiles even when maintained as

separate accessions. These results support molecular characterization as a useful first step in documenting pineapple germplasm. They do not directly predict fibre length, fineness, cellulose content or tensile strength.

3.3. SNP markers and detection of genetic redundancy

Zhou et al. (2015) developed 213 candidate SNP markers and validated 96 markers in the United States Department of Agriculture–Agricultural Research Service pineapple germplasm collection. The authors identified 57 polymorphic SNP markers. Their analysis detected 24 groups of duplicate accessions, encompassing 130 of the 170 accessions examined. This finding illustrates how molecular data can reveal redundancy in germplasm collections. It also highlights the relevance of recording plant identity and propagation history when evaluating local pineapple material. The reported duplicate groups apply to the collection investigated in that study; they do not indicate the extent of redundancy among pineapple plants in Meghalaya.

3.4. Implications for Meghalaya

The reviewed studies demonstrate that SSR, ISSR and SNP approaches can characterize pineapple germplasm. However, the magnitude and distribution of genetic diversity among pineapple plants cultivated in Meghalaya remain undetermined by the evidence reviewed here. A regional study should document plant origin, geographical location, local naming, propagation history where known and cultivation conditions. Molecular analysis could then establish genetic relationships among sampled plants. Fibre measurements from those same plants would allow a subsequent investigation of whether genetic differences are associated with fibre traits.

4. Pineapple leaf fibre: composition and performance

4.1. Chemical composition

PALF is a lignocellulosic material containing cellulose, hemicellulose, lignin and other constituents. Cellulose contributes to fibre structural integrity, while the composition and arrangement of other cell-wall components may affect flexibility, moisture response and processing behaviour.

Asim et al. (2015) reviewed published information on PALF composition, mechanical characteristics and composite applications. Their review describes cellulose contents commonly reported around 70–82%, although values vary with the source material and analytical procedure. Cellulose content should not be used as a stand-alone measure of fibre quality. Fibre morphology, bundle separation, surface defects, moisture content and the method used to determine cross-sectional area can also affect measured performance.

4.2. Fiber mechanical properties

PALF mechanical properties vary across studies because of differences in plant source, fibre extraction, specimen preparation, conditioning and testing methods. Asim et al. (2015) summarized tensile-strength values of approximately 413–1,627 MPa and Young's modulus values of 34.5–82.51 GPa across cited studies. The review also presents elongation-at-break values that vary among source studies.

Table 2. Literature-reported PALF characteristics and comparison with preliminary observations

Property	Published literature evidence	Observation
Cellulose content	Commonly reported around 70–82% in the review by Asim et al. (2015)	77.7%
Tensile strength	Approximately 413–1,627 MPa across studies summarized by Asim et al. (2015)	380 MPa,
Fineness	Depends on fibre source, extraction and measurement method	7.57 denier,
Maximum fibre length	Depends on sampling and fibre extraction	Up to 92 cm

The preliminary cellulose content of 77.7% lies within the broad range commonly reported in the PALF review by Asim et al. (2015). If A cellulose-rich composition alone does not demonstrate high tensile strength, spinnability or suitability for a particular textile or composite product. The preliminary records report an average fineness of 7.57 denier and a maximum fibre length of up to 92 cm. Fineness influences fibre packing, yarn uniformity and handle. Length affects fibre cohesion and the feasibility of forming yarns or fibre assemblies. The preliminary tensile-strength value of 380 MPa is not directly comparable with the literature range of 413–1,627 MPa summarized by Asim et al. (2015). The discrepancy may reflect differences in specimen type or testing method, but the present records do not establish its cause.

The original testing notes contain inconsistent specimen dimensions and testing speeds. In addition, the recorded peak load of 5.25 kg and breaking load of 1.05 kg have not been verified as force units. The effective cross-sectional area has also not been established.

5. Potential relationship between genetic diversity and fibre traits

5.1. Biological rationale

Genetic variation may contribute to differences in plant morphology, leaf structure and cell-wall composition. These differences provide a rationale for testing whether genetically distinguishable pineapple plants vary in fibre recovery, fineness, length, tensile properties or cellulose content.

Nevertheless, the presence of molecular diversity does not demonstrate that any particular fibre trait is genetically associated with it. The molecular-marker studies reviewed here primarily examined germplasm identity and relationships; they did not establish a genetic association with the preliminary fibre observations reported for Meghalaya.

5.2. Environmental and processing effects

Leaf maturity, cultivation conditions, harvesting practices, extraction intensity, cleaning and drying can influence measured fibre characteristics. Such factors may obscure or imitate plant-associated differences. A robust study should standardize fibre processing where feasible and record relevant environmental and handling variables. Individual plants should be treated as the principal biological units for genotype–trait analysis. Multiple fibre specimens from one plant are subsamples or technical replicates and should not be treated as independent genotypes.

5.3. Proposed framework for integrated analysis

A future study could proceed through the following stages:

1. Collect representative pineapple plants from relevant growing areas in Meghalaya and document their source and cultivation conditions.
2. Generate reproducible molecular-marker profiles for each identified plant.
3. Measure fibre recovery, length distribution, fineness, tensile strength, elongation and cellulose content from the same plants.
4. Use biological and technical replicates and report sample sizes, means and appropriate measures of variability.
5. Examine trait associations using suitable statistical models that account for population structure, relatedness, environment and processing effects.
6. Report effect sizes, confidence intervals and adjusted significance values, and validate promising findings in an independent sample where feasible.

This approach could identify plants deserving further fibre evaluation. Any claim of a genetic association must, however, be supported by matched plant-level data and appropriate statistical analysis.

6. Research gaps and future prospects

The literature establishes that molecular markers can support pineapple germplasm characterization and that PALF has potential as a renewable industrial material. However, a direct relationship between genetic diversity and fibre performance in Meghalaya remains to be established.

Priority research areas include documentation of locally grown pineapple types, molecular characterization of representative plants, standardized fibre extraction and testing, and chemical analysis using documented methods. The integration of molecular profiles with fibre measurements from the same plants would provide the evidence needed to test genotype–trait relationships.

Further work should also assess fibre recovery, processing performance, product suitability, biomass availability and processing costs. The potential contribution to rural livelihoods should be evaluated through documented production, employment and market outcomes rather than assumed from fibre availability alone.

7. CONCLUSION

Published research demonstrates that ISSR, SSR and SNP markers can distinguish pineapple germplasm and identify genetic redundancy in particular collections. In one study, ISSR and SSR markers produced polymorphic-band percentages of 93.65% and 96.50%, respectively. A separate study identified 51 alleles across 27 cultivars and lines, while SNP analysis detected duplicate groups within a collection of 170 accessions. These findings provide useful methodological precedents but are not estimates of genetic diversity in Meghalaya.

The preliminary fibre records supplied for the present work include a cellulose content of 77.7%, fineness of 7.57 denier, maximum fibre length of up to 92 cm and a tensile-strength value of 380 MPa. The cellulose value falls within the broad range discussed in the PALF literature, but the analytical method must be confirmed. The tensile-strength value is substantially below the range summarized in one major review and cannot be considered validated until the original force output, specimen dimensions, testing speed and cross-sectional area are checked. The evidence reviewed does not establish a genetic–fibre relationship in Meghalaya. Future work should combine molecular characterization with standardized fibre measurements from the same identified plants and account for environmental and processing influences. This integrated approach would provide a scientifically defensible basis for evaluating local pineapple germplasm and exploring the sustainable use of pineapple leaves as a renewable fibre resource.

ACKNOWLEDGMENTS

The authors acknowledge the financial and technical support provided by ICAR–NASF, New Delhi, for facilitating the research. The authors also acknowledge the support of the Director of Research, Central Agricultural University (Imphal), and the collaborating institutions, extension personnel and farmer producer organizations in Meghalaya, subject to confirmation of their specific contributions.

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