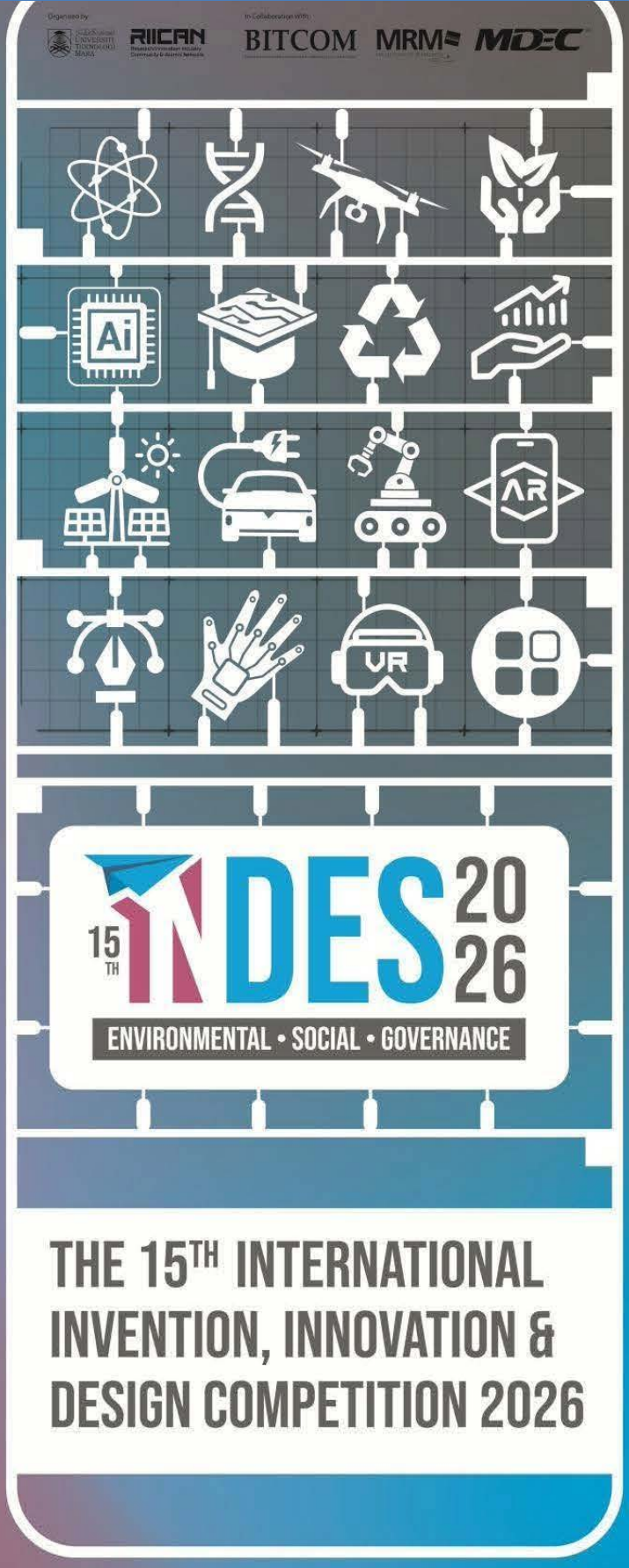


E-BOOK OF

EXTENDED ABSTRACT

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THE 15th INTERNATIONAL
INVENTION, INNOVATION &
DESIGN COMPETITION 2026

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ECO-GROW PAPER: DEVELOPMENT OF RECYCLED SEED PAPER FOR SUSTAINABLE AND ZERO-WASTE APPLICATIONS

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ABSTRACT

Eco-grow paper is developed as a sustainable solution to address excessive paper waste, particularly from educational institutions, while mitigating environmental impacts associated with conventional paper production, including deforestation, waste accumulation and chemical pollution. This study presents the development of recycled seed paper incorporated with natural additives; cornstarch as a binder and aloe vera gel (AVG) as a flexibility-enhancing agent. Four formulations were prepared using different cornstarch-to-AVG ratios (1:2, 3:2, 1:1 and 2:3). Recycled paper pulp was produced from wastepaper, cast into sheets and embedded with *Tagetes erecta* (Marigold) seeds before drying under controlled conditions. The resulting seed paper was evaluated for its thickness, tensile strength, tear resistance and germination potential. The produced paper exhibited a thickness range of 0.20 mm – 0.40 mm. Mechanical testing showed that formulations with balanced or moderate cornstarch content demonstrated higher tensile strength, while samples with higher AVG content showed improved tear resistance due to enhanced flexibility. Germination analysis confirmed that all formulations supported seed viability with minor variations observed across compositions. Overall, variation in cornstarch and AVG composition enables tuning of both mechanical performance and environmental functionality. Eco-grow paper presents a promising zero-waste material that not only reduces reliance on virgin resources but also promotes environmental regeneration through post-use plant growth.

Keyword: Recycled paper, seed paper, environmental sustainability, resource recovery, sustainable materials.

1. INTRODUCTION

The pulp and paper industry exerts significant pressure on global forest resources due to its high demand for raw materials. Large-scale consumption of wood-based inputs contributes to resource depletion, biodiversity loss and climate change (Singh et. al., 2022). According to the Food and Agriculture Organization (FAO), global paper and paperboard production increased from 402 million tonnes in 2020 to 423 million tonnes in 2024 (FAO, 2025). Logging accounts for approximately 23.1 ± 2.2% of global tree cover loss between 2001 and 2024 contributing to habitat destruction, ecosystem imbalance and increased greenhouse gas emissions (Sims et. al., 2025; Furszyfer Del Rio et. al., 2022).

In addition to deforestation, the paper industry contributes significantly to environmental pollution through solid waste generation and wastewater disposals. High paper consumption for printed materials and packaging leads to substantial waste accumulation (Beckline et. al., 2016). Improper disposal of paper waste in landfills results in anaerobic decomposition, producing methane gas and toxic leachate that further impact the environment (Abushammala et. al., 2023). Furthermore, pulp and paper manufacturing processes generate toxic environmental pollutants in its wastewater including toxic chlorinated compounds that can accumulate in fish tissues and lignin derivatives responsible in reducing

transmission of sunlight in wastewater and thus inhibiting phototrophic species growth (Kumar et. al., 2020).

To address these challenges, this study proposes the development of an eco-friendly recycled paper embedded with plant seeds, commonly referred to as seed paper. This approach not only reduces reliance on virgin raw materials but also promotes environmental restoration through plant growth after disposal. The incorporation of plant seeds transforms paper waste into a value-added biodegradable product that supports ecosystem regeneration. Therefore, the objective of this study is to develop and evaluate eco-friendly seed paper produced from recycled paper waste with modification using cornstarch as a natural binder and aloe vera gel (AVG) as a functional additive.

2. METHODOLOGY

This study employed an experimental research design to develop recycled seed paper by incorporating cornstarch and AVG at varying ratios. Wastepaper sourced from educational materials was processed into pulp by soaking and blending with water at an approximate 1:2 paper-to-water ratio to obtain a homogenous mixture. The pulp was then diluted in water and combined with predetermined ratios of cornstarch (binder) and AVG (flexibility-enhancing additive). A natural dye derived from coffee extract was incorporated to improve visual properties.

The pulp mixture was cast using a mould and deckle to form paper sheets. *Tagetes erecta* (Marigold) seeds were evenly distributed onto the wet pulp surface and gently embedded without structural damage. The sheets were pressed to remove excess water and dried in an oven for 24 hours until completely dried.

The produced seed paper was evaluated for its physical and functional properties, including thickness, tensile strength, tear resistance and germination potential over a 14-day period. Four formulations with different cornstarch-to-AVG ratios were prepared. Each formulation was produced in three independent batches, and each batch was analysed in triplicate. All analyses were conducted to ensure reliability and reproducibility.

3. FINDINGS

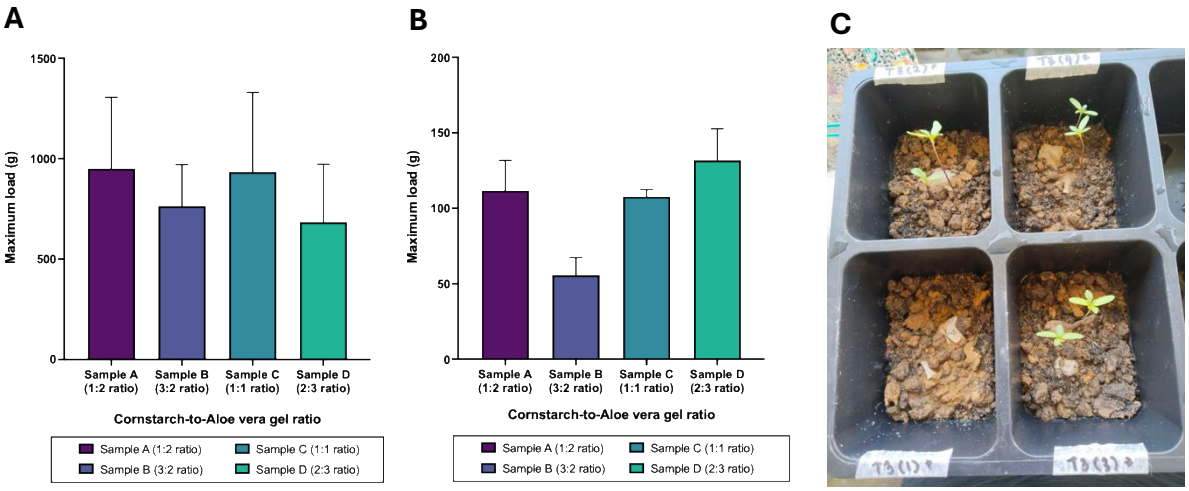


Figure 2 Mechanical analysis and germination test of Eco-Grow seed paper. **(A)** Maximum load under tensile testing, **(B)** Maximum load required for tear propagation and **(C)** Germination of *Tagetes erecta* (Marigold) seeds embedded in the paper after 14 days.

This study successfully developed recycled seed paper through the incorporation of cornstarch and AVG, demonstrating that formulation significantly influences both mechanical performance and biological functionality. The produced seed paper exhibited a thickness range of 0.20 mm – 0.40 mm, with variations attributed to manual pressing during sheet formation. Despite this variability, thickness remained within an acceptable range for comparative analysis.

Mechanical testing revealed that formulations with balanced or moderate cornstarch content exhibited higher tensile strength, with samples at 1:1 and 1:2 ratios achieving maximum load capacities of 950.0 g and 933.3 g respectively. In contrast, formulations with higher AVG content (2:3 ratio) demonstrated lower tensile strength (683.3 g), indicating reduced fibre cohesion under direct tensile loading (Figure 2A). Tear resistance analysis showed a contrasting trend, where samples with higher AVG content exhibited improved resistance to tear propagation despite lower tensile strength (Figure 2B). This behaviour is attributed to the plasticizing effect of AVG, which enhances flexibility and energy absorption within the fibre matrix (Rajamehala et. al., 2024). Such findings indicate that paper durability is determined by a balance between fibre bonding strength and matrix flexibility, explaining the non-linear relationship between tensile strength and tear resistance.

Germination analysis demonstrated that all formulations supported seed viability, confirming that the fabrication process did not adversely affect biological function (Figure 2C). Higher germination rates (50%) were observed in 1:1 and 2:3 formulations, while the 1:2 and 3:2 formulations showed lower germination rates (33.3%), indicating slight variation across compositions without a clear dependence on AVG content alone. Notably, post-use conditions such as writing and folding did not significantly affect germination performance. Overall, these results demonstrate that the composition of natural additives plays a critical role in determining both the mechanical and environmental performance of seed paper.

4. CONCLUSION

In conclusion, this study demonstrates the successful development of eco-friendly seed paper from recycled wastepaper through the incorporation of cornstarch and AVG. The findings indicate that formulation composition significantly influences mechanical properties and germination performance, with balanced ratios of cornstarch and AVG providing an optimal combination of tensile strength, tear resistance and seed viability. This innovation offers a sustainable alternative to conventional paper by reducing reliance on virgin wood pulp, minimising paper waste and promoting environmental restoration through post-use plant growth. The integration of biodegradable materials with functional plant components highlights the potential of seed paper as a value-added product within a circular economy framework. Future work may explore optimisation of formulation consistency and evaluation of long-term performance, particularly in adapting the material for specific end-use applications to enhance its practical and environmental value.

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