

Effect of Dormancy-Breaking Techniques on Seedling Emergence and Growth of Cashew (*Anacardium occidentale* L.) in the Nursery

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Abstract

Cashew (*Anacardium occidentale* L.) seed propagation is frequently hampered by irregular and delayed seedling emergence, particularly in larger-seeded biotypes, yet systematic evaluation of dormancy-breaking techniques across nut size categories remains limited in the literature. The study evaluated pre-sowing dormancy-breaking treatments on nursery performance of three cashew nut biotypes. A 3 × 3 factorial experiments arranged in a Completely Randomized Design (CRD) was conducted at the Cocoa Research Institute of Nigeria (CRIN), Ibadan. Three dormancy-breaking treatments include control, 3% H₂O₂ immersion (16 hours) and mechanical scarification were applied to three cashew biotypes (medium, large and extra-large). Emergence, morphological, biomass and root parameters were recorded and analyzed using ANOVA with Tukey's HSD test ($p \leq 0.05$). Mechanical scarification consistently reduced days to emergence (13 days in extra-large seeds versus 20 days in the untreated control), achieved the highest cumulative emergence percentages across all biotypes (100% in medium; 77.50% in extra-large) and produced superior seedling height, leaf area, shoot biomass and root development indices. H₂O₂ treatment accelerated early emergence in large and extra-large seeds but exhibited phytotoxic effects in medium biotypes, suppressing final emergence percentage (51.00%) and seedling vigour. Extra-large seeds recorded the most severe physical dormancy under untreated conditions (49.00% final emergence at 28 days after sowing). Mechanical scarification is the most reliable and broadly applicable dormancy-breaking technique for cashew nursery production across the three biotypes, improving both emergence uniformity and seedling quality for field transplanting. Mechanical scarification is recommended for cashew nursery production across the three nut size biotypes.

Keywords: Cashew, Biotype, Dormancy-Breaking, Hydrogen Peroxide, Mechanical Scarification, Nursery Management.

Introduction

Cashew (*Anacardium occidentale* L.) is a tropical perennial tree cultivated mainly for its edible nut and fleshy apple, contributing significantly to export earnings and rural income in many producing countries, including Nigeria (FAOSTAT, 2021). Global cashew nut production reached approximately 3.85 million metric tonnes in 2022, with West Africa

contributing nearly 45% of total output and Nigeria among the leading producing nations (FAOSTAT, 2021). In Nigeria, cashew cultivation spans over 220,000 hectares, contributing substantially to rural income, export earnings and agro-industrial raw material supply (Adeigbe *et al.*, 2015). Seed propagation remains the most common method of establishing cashew plantations due to its cost-effectiveness; however, challenges persist with respect to seedling emergence in the nursery, especially when large nut sizes are used.

Cashew nuts are not typically classified as dormant in the strict botanical sense; yet, field observations and nursery records consistently indicate that larger-sized nuts take longer to emerge compared with smaller ones (Adeyemi *et al.*, 2016; Hammed, 2012). Delays in seedling emergence often led to irregular plant stands, weak early growth and rotting of viable seeds in the soil. These delays are attributed to the physical and physiological properties of large nuts, including seed coat thickness, internal moisture dynamics and reduced gaseous exchange (Hammed and Adeyemi, 2005). Upretee *et al.*, (2024) confirmed that seed coat thickness is a primary determinant of water permeability across species, with larger seeds exhibiting lower permeability and greater susceptibility to physical dormancy, a pattern consistent with the physical dormancy framework documented in the *Anacardiaceae* family, to which cashew belongs (Baskin and Baskin, 2000). In the *Anacardiaceae*, impermeability is additionally mediated through the pericarp, compounding resistance to imbibition in larger-seeded genotypes. Lamont *et al.*, (2023) demonstrated that seed coat thickness scales positively with dormancy intensity across species, further supporting the rationale for size-stratified evaluation of dormancy-breaking treatments in cashew.

Nursery operators and researchers have attempted to improve germination uniformity through dormancy-breaking methods. Mechanical scarification, involving abrasion or slight cracking of the seed coat, weakens physical resistance and enhances water absorption (Kimura and Islam, 2012). This method has been shown to significantly improve germination percentage and reduce days to emergence in hard-seeded tropical and subtropical species (Attri *et al.*, 2025; Nazih *et al.*, 2024). Its consistency across seed sizes is attributed to its direct mechanical mode of action, independent of biochemical or concentration-dependent thresholds (Kimura and Islam, 2012). Attri *et al.*, (2025) reported that mechanical scarification outperformed chemical treatments in both germination percentage and seedling vigour index across seed size categories in *Senegalia catechu*. Chemical treatment with hydrogen peroxide (H_2O_2) has also been explored for its role in initiating biochemical signals that favour germination (Wojtyla *et al.*, 2016). At sub-toxic concentrations, H_2O_2 functions as a reactive oxygen species (ROS) signaling molecule, promoting the degradation of abscisic acid (ABA) and upregulating gibberellin biosynthesis to shift the hormonal balance in favour of germination (Wojtyla *et al.*, 2016; Cheng *et al.*, 2022). Li *et al.*, (2022) established that low-level ROS promote dormancy release and trigger germination in crops, while excessive ROS accumulation causes seed deterioration. This concentration-dependent dual nature of H_2O_2 is stimulatory at low concentrations but phytotoxic at higher concentrations (Chu *et al.*, 2022; Jurdak *et al.*, 2022).

The interaction between seed size and dormancy-breaking treatment response has received limited attention in cashew research. Kadjo *et al.*, (2025) reported significant genotypic variation in vigour-related nursery traits in cashew hybrids, suggesting that morphological responses to pre-sowing treatments are likely to vary by biotype. Hammed (2012) showed that larger seeds conferred initial establishment advantages that dissipated by field transplanting, highlighting the nursery phase as the critical window for dormancy-breaking treatment decisions. Morphological traits such as seedling height, number of leaves, stem diameter and root development are important early indicators of cashew vigour (Adeyemi *et al.*, 2016) and seedling vigour is increasingly recognized as a key determinant of field transplant success in perennial tree crops (Basu and Groot, 2023). Root development parameters such as tap root length, root score and fresh root weight determine soil anchorage, water acquisition and early establishment resilience after transplanting (Bewley and Black, 2013). Finch-Savage and Leubner-Metzger (2006) established that post-germination growth is more dependent on inherent seed vigour than on pre-sowing priming, reinforcing the importance of achieving optimal germination during the nursery stage. Where emergence is improved without compromising seedling quality, dormancy-breaking techniques can be recommended for wider use.

Statement of the Problem

Despite the acknowledged importance of cashew (*Anacardium occidentale* L.) to Nigeria's agricultural export economy, seed propagation of the crop remains hampered by irregular and delayed seedling emergence, particularly in larger-seeded biotypes. The physical dormancy imposed by thick seed coats in large and extra-large cashew nuts reduces emergence uniformity, prolongs the nursery period and increases seed wastage with consequences that collectively undermine the efficiency of cashew nursery production systems. While dormancy-breaking techniques have been applied in other hard-seeded species, systematic comparative evaluation of their effectiveness across distinct cashew nut biotypes remains absent from the literature. This gap limits the capacity of nursery operators and extension services to make evidence-based decisions on pre-sowing treatment selection, particularly when multiple biotype classes are handled simultaneously. If left unaddressed, this knowledge gap will continue to constrain seedling quality, planting material uniformity and ultimately field establishment success in cashew production systems across West Africa.

Research Questions

This study was guided by the following research questions:

1. Do mechanical scarification and hydrogen peroxide (H₂O₂) treatment differ significantly in their effect on days to seedling emergence and cumulative emergence percentage across cashew nut biotypes?
2. Does the effectiveness of each dormancy-breaking treatment vary with cashew nut size (medium, large and extra-large biotypes)?

3. What is the interaction effect of dormancy-breaking treatment and nut biotype on seedling morphological growth, vigour and root development parameters?

Conceptual Framework

The conceptual basis of this study rests on the physical dormancy framework described by Baskin and Baskin (2000), wherein impermeable seed coats restrict water imbibition and gaseous exchange, thereby delaying or preventing radicle protrusion. In cashew, the pericarp thickness increases with nut size, making larger biotypes more susceptible to physical dormancy (Hammed and Adeyemi, 2005). The two dormancy-breaking treatments tested in this study address this constraint through contrasting mechanisms. Mechanical scarification acts by physically abrading the testa to create a direct pathway for water uptake, bypassing the impermeability barrier entirely (Kimura and Islam, 2012). Hydrogen peroxide (H_2O_2) operates through an oxidative mode of action: at sub-toxic concentrations, it weakens seed coat tissues through chemical degradation and simultaneously initiates reactive oxygen species (ROS) signaling pathways that promote gibberellin biosynthesis and enzymatic activation of germination (Wojtyla *et al.*, 2016; Kubala *et al.*, 2015). These distinct mechanisms predict that treatment efficacy will interact with seed coat morphology and by extension with biotype size.

Objective of the Study

The objective of this study is to assess the influence of mechanical scarification and hydrogen peroxide treatment on the seedling emergence and early growth of cashew nut biotypes of different sizes under nursery conditions, with a view to providing evidence-based recommendations for cashew nursery management, particularly for operations handling large-seeded biotypes.

Hypotheses

The following null hypotheses were tested in this study:

H₀₁: There is no significant difference between mechanical scarification and hydrogen peroxide treatment in their effect on seedling emergence and early growth of cashew nut biotypes.

H₀₂: There is no significant effect of cashew nut biotype size on seedling emergence and early growth parameters.

H₀₃: There is no significant interaction effect between dormancy-breaking treatment and cashew nut biotype on seedling emergence and early growth parameters.

Materials and Methods

Study Area, Experimental Design and Treatment Description

The study was conducted in the nursery of the Cocoa Research Institute of Nigeria (CRIN), Ibadan, Nigeria. A 3 × 3 factorial experiment was arranged in a Completely Randomized Design (CRD) with two factors: dormancy-breaking method and cashew nut size.

Dormancy-breaking method comprised three levels: control (no pre-sowing treatment), chemical treatment with 3% hydrogen peroxide (H_2O_2) and mechanical scarification. Nut size similarly comprised three levels: medium, large and extra-large, classified primarily by individual seed weight. Each of the nine treatment combinations was replicated three times, yielding 27 experimental units. Each unit comprised six seeds, giving 54 seeds per replicate and a cumulative total of 162 seeds for the entire experiment.

Cashew Biotype Selection

Mature, healthy cashew nuts (*Anacardium occidentale* L.) of known provenance were obtained and manually sorted into three size categories: medium (6.0 g -7.9 g), large (8.0 g – 11.9 g) and extra-large (12.0 g – 15.9 g) according to Adeigbe *et al.*, 2015, using a calibrated digital weighing scale to ensure precision. Prior to sorting, all nuts were visually inspected; deformed, shriveled or visibly damaged seeds were discarded to ensure uniformity and maintain seed viability. Only physically sound, well-formed seeds were retained for the experiment.

Dormancy-Breaking Treatments

All dormancy-breaking treatments were applied immediately prior to sowing. In the control treatment, seeds were sown directly without any pre-sowing intervention. For the chemical treatment, seeds were fully immersed in a freshly prepared 3% H_2O_2 solution for 16 hours at ambient room temperature, after which they were briefly rinsed with clean water to remove residual chemical before sowing. The 3% H_2O_2 concentration and 16-hour immersion duration adopted in this study were informed by prior dosage work demonstrating stimulatory effects of H_2O_2 at sub-toxic concentrations on seed germination in hard-seeded species (Wojtyla *et al.*, 2016; Chu *et al.*, 2022), whilst remaining below phytotoxic thresholds reported at higher concentrations and longer exposure durations. For mechanical scarification (Fig. 1), each seed was oriented with the basal end (broader attachment point) facing downward and the distal tip was gently abraded using a fine metal file until the lighter inner integument became visible, indicating sufficient testa removal without embryo damage. All treated seeds were sown immediately after treatment application to prevent desiccation or secondary dormancy induction.

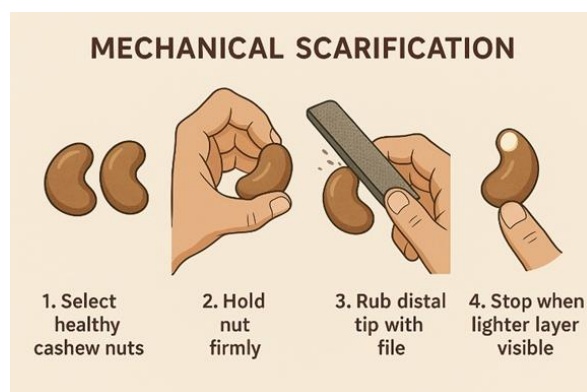


Fig. 1: Cashew mechanical scarification process

Nursery Operations

Seeds were sown individually in perforated polyethylene nursery bags (12.5 cm by 25 cm) filled with well-textured topsoil sourced from cultivated farmland and sieved to remove debris, stones and coarse organic matter prior to use. Nursery bags were arranged on raised nursery benches. Uniform cultural practices, including watering three times a week, were maintained throughout the experimental period to eliminate confounding management effects.

Data Collection

Emergence data comprised days to first seedling emergence and cumulative percentage seedling emergence, recorded at two-day intervals from 12 to 28 days after sowing (DAS). Seedling vigour was assessed visually using a standardized vigour rating scale (Olasan *et al.*, 2018) at 12 weeks after sowing (WAS). Morphological growth parameters such as seedling height (cm), number of leaves, stem diameter (mm), leaf area (cm²) and number of branches were measured fortnightly from 4 WAS to 12 WAS. Leaf area was estimated using the formula: Leaf area = length × width × correction factor (0.71), as described by Rao and Sebastian (1994). Destructive harvesting at 12 WAS yielded data on fresh shoot weight (g), fresh root weight (g), tap root length (cm) and root score, the latter assessed on a standardized 1–5 scale based on root density and branching.

Data Analysis

Data were subjected to descriptive and inferential statistical analyses. Analysis of Variance (ANOVA) was performed to evaluate the treatments on emergence and morphological traits of cashew seedlings. Where ANOVA revealed significant treatment effects, mean separation was conducted using Tukey's Honest Significant Difference (HSD) test at the 5% probability level ($p \leq 0.05$). All statistical analyses were performed using Minitab® Version 17 (Minitab LLC, Pennsylvania, USA).

Results and Discussion

Days to First Emergence after Sowing

The number of days to first seedling emergence varied significantly across seed sizes and dormancy-breaking treatments (Fig. 2). Extra Large seeds under the control treatment (XL.Ct) recorded the longest emergence period (20 days), suggesting that larger seed coat thickness imposes greater physical dormancy, thereby delaying germination. In contrast, H₂O₂ treatment and scarification markedly reduced days to emergence in Extra Large seeds (XL.HO and XL.SR: 13 days each), indicating that both chemical oxidation and mechanical disruption of the testa effectively enhanced water imbibition and gaseous exchange, prerequisites for radicle protrusion.

Large seeds under control conditions (L.Ct) emerged at 16 days, while H₂O₂ treatment (L.HO: 14 days) and scarification (L.SR: 15 days) both reduced emergence time relative to the control. The marginal superiority of H₂O₂ over scarification in Large seeds suggests that

chemical softening of the pericarp may be more effective than mechanical abrasion at intermediate seed sizes, possibly due to more uniform oxidative penetration across the seed coat surface (Varier *et al.*, 2010).

Medium seeds recorded a control emergence of 15 days (M.Ct), with scarification (M.SR: 14 days) slightly outperforming H₂O₂ treatment (M.HO: 17 days). The delayed emergence observed under M.HO relative to its control is noteworthy and may reflect phytotoxic effects of H₂O₂ at the applied concentration on smaller seeds with thinner integuments, as excessive oxidative stress has been reported to inhibit rather than promote germination when seed mass is low (Wojtyla *et al.*, 2016). Overall, scarification demonstrated consistent dormancy-breaking efficacy across all seed sizes, whereas H₂O₂ response was size-dependent, highlighting the importance of matching treatment type to seed morphology in cashew nursery management (Bewley *et al.*, 2013).

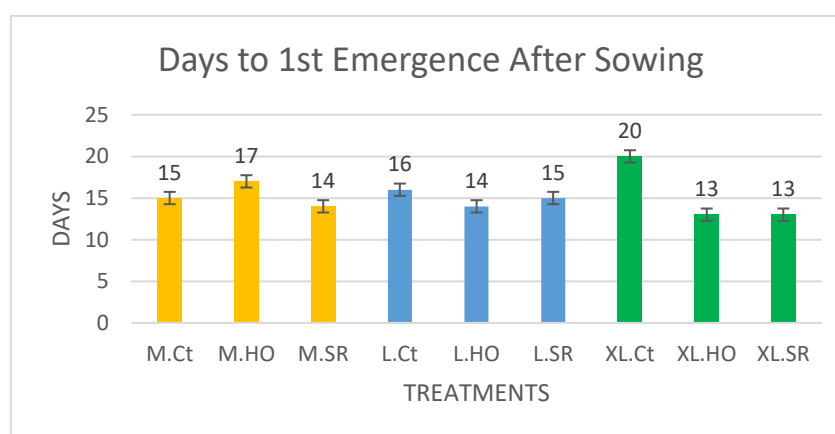


Fig. 2: Days to 1st emergence of cashew seedlings after sowing

Note: M.Ct= Medium Control; M.HO= Medium + H₂O₂; M.SR= Medium + Scarification; L.Ct= Large Control; L.HO= Large + H₂O₂; L.SR= Large + Scarification; XL.Ct= Extra Large Control; XL.HO= Extra Large + H₂O₂; XL.SR= Extra Large + Scarification

Percentage Seedling Emergence across Assessment Days

Seedling emergence percentage differed considerably among seed sizes and dormancy-breaking treatments across all assessment days (Table 1). For Medium seeds, scarification (M.SR) consistently recorded the highest emergence values from D15 (51.00%) through to D28, achieving complete emergence (100%) by D25, significantly surpassing both the control (M.Ct: 52.50% at D28) and H₂O₂ treatment (M.HO: 51.00% at D28). The notably poor performance of M.HO, which recorded 0% emergence at D15 and only 6.00% by D17, further corroborates the earlier observation of possible phytotoxic inhibition in smaller seeds treated with H₂O₂ (Wojtyla *et al.*, 2016). By final assessment, M.SR attained full emergence while M.Ct and M.HO plateaued well below capacity, indicating that scarification is the superior dormancy-breaking method for Medium-sized cashew seeds. For Large seeds, the control (L.Ct) recorded no emergence at D15 but achieved 100% by D23, eventually matching scarification (L.SR: 100% by D25). H₂O₂ treatment (L.HO) showed earlier emergence at D15 (24.00%) compared to L.Ct and L.SR (both 0% and 22.50%

respectively), suggesting an initial stimulatory effect of oxidative treatment on seed coat permeability (Varier *et al.*, 2010). However, L.HO plateaued at 75.00% from D23 onwards, significantly below the full emergence achieved by both L.Ct and L.SR. This indicates that while H₂O₂ accelerated early germination in Large seeds, it ultimately suppressed final emergence percentage, possibly due to cumulative oxidative damage to the embryo at the applied concentration (Wojtyla *et al.*, 2016).

Extra Large seeds demonstrated the most pronounced treatment-dependent emergence pattern. XL.Ct recorded zero emergence from D13 through D17, with a maximum of only 49.00% at D28, reflecting severe physical dormancy associated with the thicker pericarp of larger biotypes (Baskin and Baskin, 2000). XL.HO initiated emergence earlier (D13: 22.50%) than the control, with values increasing steadily to 52.00% by D28, marginally exceeding XL.Ct. XL.SR outperformed both treatments throughout, recording 25.00% at D13 and reaching 77.50% at D28, the highest final emergence among Extra Large seeds. The progressive superiority of scarification across all seed size categories affirms that mechanical disruption of the seed coat remains the most reliable dormancy-breaking strategy for cashew, consistent with findings in other hard-seeded tropical species (Baskin and Baskin, 2000; Bewley *et al.*, 2013).

Table 1: Cumulative seedling emergence (%) of cashew across biotypes and dormancy-breaking treatments after sowing

Biotype	Treat	% SEEDLING EMERGENCE								
		D13	D15	D17	D19	D21	D23	D25	D27	D28
Medium	M.Ct	0.00	22.50 ^b	37.5 ^b	42.50 ^b	52.50 ^b	52.50 ^b	52.50 ^b	52.50 ^b	52.50 ^b
	M.HO	0.00	0.00 ^c	6.00 ^c	27.50 ^c	48.00 ^b	48.00 ^b	49.00 ^b	51.00 ^b	51.00 ^b
	M.SR	0.00	51.00 ^a	73.00 ^a	74.00 ^a	76.50 ^a	95.00 ^a	100.00 ^a	100.00 ^a	100.00 ^a
Large	L.Ct	0.00	0.00 ^b	27.00 ^b	72.50 ^a	73.00 ^a	100.00 ^a	100.00 ^a	100.00 ^a	100.00 ^a
	L.HO	0.00	24.00 ^a	50.50 ^a	64.50 ^a	73.50 ^a	75.00 ^b	75.00 ^b	75.00 ^a	75.00 ^a
	L.SR	0.00	22.50 ^a	49.50 ^a	63.0 ^a	74.00 ^a	98.50 ^a	100.00 ^a	100.00 ^a	100.00 ^a
E.Large	XL.Ct	0.00	0.00 ^c	0.00 ^b	0.00 ^a	25.50 ^b	26.50 ^b	26.50 ^b	40.00 ^b	49.00 ^b
	XL.HO	22.50 ^a	25.50 ^b	47.50 ^a	48.00 ^a	49.00 ^a	49.00 ^a	50.00 ^{ab}	51.00 ^{ab}	52.00 ^b
	XL.SR	25.00 ^a	47.50 ^a	47.50 ^a	48.00 ^a	49.00 ^a	50.00 ^a	63.50 ^a	75.00 ^a	77.50 ^a

Note: M.Ct= Medium Control; M.HO= Medium + H₂O₂; M.SR= Medium + Scarification; L.Ct= Large Control; L.HO= Large + H₂O₂; L.SR= Large + Scarification; XL.Ct= Extra Large Control; XL.HO= Extra Large + H₂O₂; XL.SR= Extra Large + Scarification; D= Days after sowing. Treatment(s) with the same letter are not significantly different @0.05% probability.

Seedling Growth Parameters across Biotypes and Dormancy-Breaking Treatments

Seedling height, number of leaves, stem diameter and leaf area were assessed across biotypes and dormancy-breaking treatments at the end of the nursery period (Table 2). For Medium seeds, no significant differences were observed among treatments for all four growth parameters, though M.SR recorded the tallest seedlings (41.93 cm) followed by M.HO (39.45 cm) and M.Ct (34.38 cm). The non-significance across medium biotype

treatments suggests that dormancy-breaking methods influenced emergence timing more than subsequent vegetative development, implying that seedling growth after germination may be more dependent on inherent seed vigour than pre-sowing treatment (Finch-Savage and Leubner-Metzger, 2006).

For Large seeds, seedling height differed significantly among treatments, with L.HO producing the tallest seedlings (43.38 cm), significantly exceeding L.Ct (36.33 cm), while L.SR (41.73 cm) was intermediate. This suggests that H₂O₂ seed priming conferred a growth advantage beyond dormancy breakage in large seeds, possibly through enhanced mobilization of seed reserves and upregulation of antioxidant enzyme activity during early seedling establishment (Wojtyla *et al.*, 2016). Stem diameter was significantly reduced under L.SR (5.75 mm) compared to L.Ct and L.HO (both 7.04 mm), which may indicate a trade-off between height gain and stem girth when scarification accelerates early resource allocation to shoot elongation rather than radial growth (Bewley *et al.*, 2013). Number of leaves and leaf area showed no significant differences among large biotype treatments.

Extra Large seeds showed no significant treatment differences in seedling height, number of leaves or stem diameter, though XL.SR consistently produced the numerically tallest seedlings (47.65 cm). Leaf area, however, differed significantly, with XL.SR recording the largest leaf area (78.42 cm²), substantially exceeding XL.HO (61.20 cm²) and XL.Ct (56.34 cm²), both of which were statistically similar. The superior leaf area development under scarification in Extra Large seeds may be attributed to improved early water uptake and nutrient translocation facilitated by testa disruption, promoting greater photosynthetic surface establishment during the nursery phase (Baskin and Baskin, 2000; Varier *et al.*, 2010). Overall, scarification demonstrated the most consistent positive influence on seedling growth across biotypes, particularly for height and leaf area, reinforcing its suitability as a preferred pre-sowing treatment for cashew nursery production.

Table 2: Effect of dormancy-breaking treatments on seedling growth parameters of cashew across biotypes in the nursery.

Treat	Medium Biotype			
	PH (cm)	NL	SD (mm)	LA (cm ²)
M.Ct	34.38 ^a	15.3 ^a	5.79 ^a	67.5 ^a
M.HO	39.45 ^a	26.0 ^a	6.24 ^a	59.76 ^a
M.SR	41.93 ^a	14.0 ^a	5.94 ^a	47.94 ^a
Treat	Large Biotype			
	PH (cm)	NL	SD (mm)	LA (cm ²)
L.Ct	36.33 ^b	20.3 ^a	7.04 ^a	60.38 ^a
L.HO	43.38 ^a	18.0 ^a	7.04 ^a	65.82 ^a
L.SR	41.73 ^{ab}	24.0 ^a	5.75 ^b	59.43 ^a
Treat	Extra Large Biotype			
	PH (cm)	NL	SD (mm)	LA (cm ²)
XL.Ct	38.05 ^a	29.0 ^a	6.23 ^a	56.34 ^b
XL.HO	41.42 ^a	26.3 ^a	6.81 ^a	61.20 ^b
XL.SR	47.65 ^a	20.3 ^a	6.19 ^a	78.42 ^a

Note: M.Ct= Medium Control; M.HO= Medium + H₂O₂; M.SR= Medium + Scarification; L.Ct= Large Control; L.HO= Large + H₂O₂; L.SR= Large + Scarification; XL.Ct= Extra Large Control; XL.HO= Extra Large + H₂O₂; XL.SR= Extra Large + Scarification; PH= Plant height; NL= Number of leaves; SD= Stem diameter; LA= Leaf area. Treatment(s) with the same letter are not significantly different @0.05% probability.

Cashew Seedling Vigour

Seedling vigour scores varied across biotypes and dormancy-breaking treatments (Fig. 3). Among Medium seeds, H₂O₂ treatment (M.HO: 4.5) recorded the highest vigour score, substantially exceeding both the control (M.Ct: 2.5) and scarification (M.SR: 3.5). This suggests that oxidative priming with H₂O₂ enhanced metabolic readiness and early seedling establishment in medium biotypes, possibly through stimulation of antioxidant defense mechanisms that improve post-germination performance (Li *et al.*, 2022).

For Large seeds, scarification (L.SR: 4.0) outperformed both H₂O₂ treatment (L.HO: 3.5) and the control (L.Ct: 3.0), indicating that mechanical testa disruption conferred the greatest seedling vigour advantage at this size class, consistent with improved nutrient and water mobilization during early establishment (Gong *et al.*, 2025).

Among Extra Large seeds, XL.SR recorded the highest vigour (4.3), followed by XL.HO (4.0), with XL.Ct scoring the lowest (3.3). The consistent superiority of both treatments over their respective controls across all biotypes affirms that dormancy-breaking interventions improve not only emergence but overall seedling quality, with scarification demonstrating the most reliable vigour enhancement across seed size categories (Finch-Savage and Leubner-Metzger, 2006).

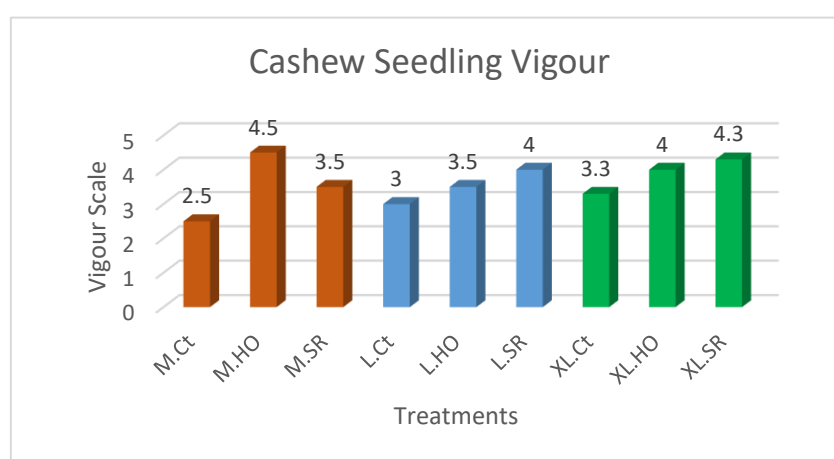


Fig. 3: Vigour scores of cashews (*Anacardium occidentale* L.) seedlings as influenced by dormancy-breaking treatments across biotypes

Seedling Biomass and Root Development Parameters

Fresh shoot weight, fresh root weight, total root length and root score were evaluated across biotypes and treatments (Table 3). Among Medium seeds, no significant differences

were recorded for fresh shoot weight, fresh root weight or root score, though M.HO produced the heaviest shoots (15.95 g) and roots (3.75 g). Total root length differed significantly, with M.HO (21.05 cm) surpassing both M.Ct (19.10 cm) and M.SR (18.23 cm), suggesting that H₂O₂ priming stimulated root elongation in Medium biotypes through enhanced gibberellin biosynthesis and cell wall loosening during early root development (Kubala *et al.*, 2015).

For Large seeds, fresh shoot weight differed significantly, with L.SR recording the heaviest shoots (18.48 g), significantly exceeding L.Ct (15.33 g), while L.HO (17.48 g) was intermediate. Root score was also significantly higher under L.SR (4.0) compared to both L.Ct and L.HO (2.8 each), indicating that scarification promoted superior root system architecture in Large biotypes, consistent with improved soil anchorage and nutrient acquisition capacity reported in scarified hard seeded species (Longjam and Kotiyal, 2024). Among Extra Large seeds, total root length differed significantly, with XL.SR recording the longest roots (24.50 cm), exceeding XL.HO (20.70 cm) and XL.Ct (15.65 cm). Fresh shoot weight, fresh root weight and root score showed no significant differences, though XL.SR numerically outperformed other treatments in shoot biomass (19.15 g). The consistent advantage of scarification in root development across Large and Extra-Large biotypes suggests mechanical treatment optimizes below-ground establishment, a critical determinant of nursery seedling quality and field transplant success (Bewley and Black, 2013).

Table 3: Effect of dormancy-breaking treatments on seedling biomass and root development of cashew (*Anacardium occidentale* L.) across biotypes in the nursery

Treat	Medium Biotype			
	FSW (g)	FRW (g)	TRL (cm)	RS
M.Ct	12.48 ^a	2.88 ^a	19.10 ^b	2.5 ^a
M.HO	15.95 ^a	3.75 ^a	21.05 ^a	1.5 ^a
M.SR	13.43 ^a	3.13 ^a	18.23 ^b	3.3 ^a
Treat	Large Biotype			
	FSW (g)	FRW (g)	TRL (cm)	RS
L.Ct	15.33 ^b	3.83 ^a	13.57 ^a	2.8 ^b
L.HO	17.48 ^{ab}	4.68 ^a	19.28 ^a	2.8 ^b
L.SR	18.48 ^a	4.48 ^a	23.95 ^a	4.0 ^a
Treat	Extra Large Biotype			
	FSW (g)	FRW (g)	TRL (cm)	RS
XL.Ct	18.30 ^a	4.13 ^a	15.65 ^b	2.75 ^a
XL.HO	16.68 ^a	5.05 ^a	20.70 ^{ab}	3.75 ^a
XL.SR	19.15 ^a	4.05 ^a	24.50 ^a	3.75 ^a

Note: M.Ct= Medium Control; M.HO= Medium + H₂O₂; M.SR= Medium + Scarification; L.Ct= Large Control; L.HO= Large + H₂O₂; L.SR= Large + Scarification; XL.Ct= Extra Large Control; XL.HO= Extra Large + H₂O₂; XL.SR= Extra Large + Scarification; FSW= Fresh Shoot Weight; FRW= Fresh Root Weight; TRL= Tap Root Length; RS= Root Score. Treatment(s) with the same letter are not significantly different @0.05% probability.

Limitations of the Study

The experiment was conducted at a single location over one nursery season and responses may differ under the varying agro-ecological conditions of Nigeria's cashew-producing zones. Only three of the six recognized cashew nut biotype classifications were evaluated, excluding the madras, small and jumbo biotypes, which limits the comprehensiveness of conclusions regarding dormancy-biotype interactions across the full nut size spectrum (Adeigbe *et al.*, 2015). The H₂O₂ concentration (3%) and immersion duration (16 hours) were fixed parameters; the phytotoxic effects observed in medium seeds suggest that dosage optimization across biotype classes is warranted, given the well-established concentration-dependent dual nature of H₂O₂ action on seed germination (Chu *et al.*, 2022; Li *et al.*, 2022).

Conclusion

This study investigated the effect of dormancy-breaking techniques which include mechanical scarification and 3% hydrogen peroxide (H₂O₂) treatment on seedling emergence, vigour, morphological growth and root development of three cashew (*Anacardium occidentale* L.) nut biotypes (medium, large and extra-large) in the nursery. The findings reveal that seed size exerts a significant influence on the duration and uniformity of seedling emergence, with extra-large seeds exhibiting the most pronounced physical dormancy under untreated conditions, as evidenced by delayed and incomplete emergence in the control. Mechanical scarification consistently outperformed H₂O₂ treatment across all biotypes, recording the shortest emergence periods, highest cumulative emergence percentages, superior seedling height and leaf area and more favourable root development indices, particularly in large and extra-large seed categories. The application of H₂O₂, while stimulating early emergence in large and extra-large seeds, demonstrated size-dependent phytotoxic effects in medium biotypes, culminating in suppressed final emergence percentages and reduced seedling vigour. These results underscore the importance of matching pre-sowing treatment to seed morphology in cashew nursery management. Mechanical scarification of the distal testa tip is therefore recommended as the most reliable and broadly applicable dormancy-breaking technique for cashew nut biotypes across size categories, offering practical advantages in achieving uniform plant stands and quality seedlings for field transplanting.

Recommendations

- Mechanical scarification of the distal testa tip is recommended as the primary pre-sowing treatment for cashew nursery production across all nut size categories, given its consistent superiority in reducing days to emergence, improving cumulative emergence percentage and promoting root development across biotypes. The technique is simple, low-cost and requires no specialized equipment, making it accessible to both smallholder and commercial nursery operators.
- Where hydrogen peroxide (H₂O₂) is considered as an alternative, its use should be restricted to large and extra-large biotypes, as its application on medium-sized

seeds at the concentration and duration tested suppressed final emergence and reduced seedling vigour.

- Extension services should incorporate mechanical scarification into cashew nursery management training programmes to improve planting material uniformity, reduce seed wastage and shorten the nursery cycle across cashew-producing zones in West Africa.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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