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Analysis of the Success and Vigour of Cashew Seedlings Through Direct Seed Planting (*Anacardium occidentale* L.) for Sustainable Land Management

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This study investigates the success and vigour of cashew seedlings (*Anacardium occidentale* L.) through direct seed planting, focusing on its potential to support sustainable land management practices. Using a completely randomised design (CRD), the study applied three treatments: seed coat incision (treatment A), seed coat division (treatment B), and no seed coat treatment (treatment C, control), with each treatment repeated three times, involving 270 seeds in total.
The results indicate that the control treatment (C), where seeds were planted intact, led to the highest germination success (97.76%), surpassing the other treatments. This method also resulted in better seedling growth, with superior increases in stem diameter (9.83 cm) and leaf production (3.36 leaves). Additionally, seedlings from the control treatment showed enhanced vigour, with an average height increase of 9.83 cm, indicating the benefits of planting seeds in their natural condition.
These findings highlight the importance of direct seed planting in maintaining ecological balance and promoting sustainable agriculture practices. The intact-seed approach is recommended for future cashew planting, as it improves seedling growth, contributes to forest conservation, and reduces vulnerability to pest attacks. Thus, it supports long-term ecological resilience in land management systems.

Keywords: cashew seedlings, direct seed planting, ecological resilience, seed germination, natural land management

1. Introduction

In line with current global development efforts, the forestry sector is also vitally involved in promoting sustainable growth, particularly through initiatives such as reforestation and afforestation (FAO, 2020; Windyarini & Hasnah, 2015). These projects aim to rehabilitate critical lands, often degraded by shifting cultivation and the unplanned, irresponsible use of forests (Chazdon, 2008). However, challenges in reforestation and greening efforts frequently arise, with one significant issue being the inappropriate selection of plant species (Menz et al., 2016).
Cashew (*Anacardium occidentale* L.) is a promising species for rehabilitating critical land, particularly in non-forest areas. According to Rismunandar (2010), cashew trees are well-suited for reforestation due to their environmental benefits, ability to grow on degraded land, low maintenance requirements, and

resistance to livestock grazing. Furthermore, cashews offer economic benefits to farmers. Abdullah (2018) also highlights that cashew nuts are drought-resistant and thrive in a broad range of soils and climates, making them a viable option for land restoration.

Given the numerous advantages of cashew cultivation, its sustainable development holds significant potential (FAO, 2018). Although cashew trees are typically propagated through seeds, traditional methods involving seedling transfer to the field often result in low growth rates and vigour (Narasimhan et al., 2017). These methods are also associated with logistical challenges, such as transport costs and the risk of root damage during handling (Akinmolandu & Ojo, 2019).

This study aims to explore an alternative propagation method: direct seed planting in the field. It will focus on three treatments: seed coat incision, seed coat splitting, and no treatment (control). The objective is to assess the impact of these treatments on the growth of cashew seedlings and determine which method has the most significant effect on seedling development in the field (Adebayo et al., 2020).

2. Method

The research was conducted in the educational forest area of Hasanuddin University, located in Bengo-bengo, Maros Regency, over a period spanning from November 2022 to February 2023. The study utilised 270 cashew seeds as the primary material and employed various tools to prepare the site and monitor growth. Essential equipment included hoes and shovels for digging planting holes, a machete for clearing vegetation, a ruler and a meter for measuring seedling growth and planting distances, plastic ropes for securing plant fences, and materials such as zinc and plastic for labelling plants. Additionally, insecticides were used for pest control, while stationery was utilised for recording observations (Evans & Turnbull, 2004).

The study adopted a Completely Randomized Design (CRD) approach to assess the effects of three treatments on cashew seed germination and seedling growth. The treatments included slicing the seed coat (treatment A), splitting the seed coat (treatment B), and planting seeds without any intervention as a control (treatment C). Each treatment was repeated three times, with 30 seeds per replication, making a total of 270 seeds. The CRD method was selected due to the uniform and flat field conditions, and seeds were chosen based on consistent weight and size (Gomez & Gomez 1984).

The research began with field identification and preparation, including vegetation clearance and the installation of planting stakes. The planting layout followed an equilateral triangle pattern, with a spacing of 5 metres between planting holes. Each planting hole was prepared with dimensions of 30 cm by 30 cm by 30 cm, ensuring proper separation of topsoil and subsoil to maintain soil nutrient integrity. After allowing the planting holes to stabilise for seven days, they were backfilled with segregated soil layers before planting the seeds at a depth of 1 cm. A total of three seeds were planted in each hole, and a bamboo fence was constructed around the plot to protect the seeds from pests such as pigs.

Watering was conducted twice daily, in the morning and evening, until germination occurred and seedlings established themselves. In the absence of rainfall, each planting hole received 1 litre of water per session, requiring a total of 180 litres daily for all 90 planting holes.

Observations and measurements were carried out over a two-month period. Daily monitoring during the first 30 days focused on seed germination, while the following 30 days assessed seedling growth and vigour. Key parameters included the percentage of seed germination, seedling height, and the number of leaves. Germination percentage was calculated by counting the number of germinated seeds, while seedling height was measured from the base of the plant to the base of the leaves. The number of leaves was recorded from the emergence of the first leaf until the final observation (ISTA, 2020; Leakey, 2012).

The data collected on seed germination and seedling growth were analysed using a CRD statistical method to determine the impact of the treatments on viability and vigour (ISTA, 2020; Blolok et al., 2024). Germination percentage was calculated using a standard formula to quantify seed viability (ISTA, 2020; Leakey, 2012).

$$\mathrm{G} = \frac{Number\ of\ Germinated\ Seeds}{Total\ Seed\ Planted} x100$$

Where:

G = Germinated (%)

Data on the percentage results (%) of germinated seeds were then entered into the Completely Randomized Design formulation with the following formula:

$$Yij = \mu + Pi + eij$$

Where:

Yij = Observation of the 1st treatment and jth replication

μ = General average

Pi = Effect of Treatment i

eij = Error of the ith treatment and ith replication

i = 1, 2, 3,...................................... p

j = 1, 2, 3,...................................... u

$$Correction\ Factor = \frac{(General\ Mean)2}{Replication\ x\ Treatment}$$

$$Sum\ of\ Total\ Squares\ = \sum\sum(yij)2 - CF$$

$$Sum\ of\ Total\ Squares\ Treatment = 1/r(\sum\sum(yi)2 - \mathrm{CF}$$

$$Sum\ of\ Squared\ Eror = STS - STST$$

If the treatment has a significant effect on the viability and vigor of the offspring, then proceed with the Honestly Significant Difference (BNJ) test according to the Turkey procedure at the 5% level using the following formula:

$$NJ = qz\ (p, db\ acak) x\ \sqrt{KTE}/r$$

Where:

BNJ = BNJ Value

qz = Value in Table for 5% level

p = Number of treatments

db = Random Degrees of Freedom

r = Number of observations in each treatment/replication

KTE = Error diversity

3. Result and Discussion

1) Percentage of Sprouts

The results of the diversity analysis of viability (percentage of seed germination) obtained the percentage value of seed germination which is presented in Table 1. The data in Table 1 was then analyzed according to the pattern of variance as can be seen in Table 2.

Tabel 1. Observation data on the percentage of germination of cashew seeds (*Anacardium occidental* L.)

Treatments	Replication			Total (%)	Mean (%)
	I (%)	II (%)	III (%)		
A	86,6	80,0	76,6	243,2	81,06
B	90,0	86,6	90,0	266,6	88,86
C	100,0	100,0	93,3	293,3	97,76
Total	276,6	266,6	259,9	803,1	266,06
Mean	92,2	88,86	86,63	267,7	88,68

Source: Primary Data, 2023

Tabel 2. Analysis of Germination of Cashew Seeds (*Anacardium occidentale* L.)

Source of Diversity	df	Sum of Squares	Meddle Squares	F Count	F Tabel (0,05)
Treatments	2	418,94	209,47	14,06*	5,14
Error	6	89,34	14,89		
Total	8	508,28			

Source: Primary Data, 2023
Information *Really Different

Tabel 3. Analysis of Germination of Cashew Seeds (*Anacardium occidentale* L.)

Treatments	Seed Germination Percentage (%)	BNJ 0,05=9,6
A	81,06	a
B	88,86	ab
C	97,76	b

Note: The same letters are not significantly different

The results of the analysis of the diversity of seed germination percentages showed that the treatments tried showed a real effect (Adebayo et al., 2020). The calculated F value is greater than the table F value at the 5% level (Narasimhan et al., 2017). This means that there are at least a pair of mean germination percentages that are significantly different. Based on the results of the variance analysis, it was shown that the treatments tried had a real effect on the viability and vigor of the seedlings (Akinmoladun & Ojo, 2019).

To determine the real difference between the average percentage of seed germination, statistical testing was carried out using the honest significant difference (BNJ) procedure on the average value of seed germination. The effect of treatment on the percentage of seed germination can be clearly seen in Table 3Based on the test results of differences in the effect of treatment on the percentage of seed germination, it can be seen that treatment C as control treatment is different from treatments A and B, while treatments A and B are not different. For more details, see Figure 1

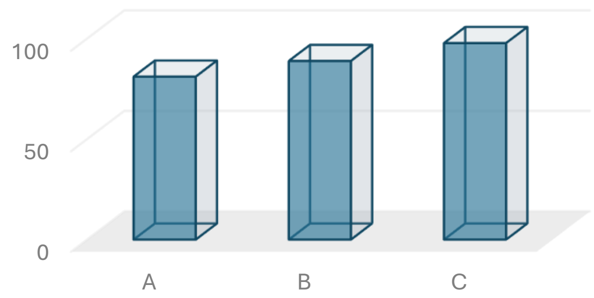

Figure 1. Germination Percentage Of Cashew Seeds In The Field

2) Height Increase

The results of the diversity analysis of vigor (increase in the height of the offspring) obtained the percentage value of the increase in the height of the offspring with observational data presented in Table 4. Based on the observation data in Table 4, it was then processed further using analysis of variance to determine the calculated F value as presented in Table 5.

Tabel 4. Observation data on the percentage of germination of cashew seeds (Anacardium occidental L)

Treatments	Replication			Total (cm)	Mean (cm)
	I (cm)	II (cm)	III (cm)		
A	8,48	8,99	9,61	27,08	9,03
B	9,30	9,63	9,76	28,69	9,56
C	9,88	9,78	9,82	29,48	9,83
Total	27,66	28,40	29,19	85,25	24,45
Mean	9,22	9,42	9,73	28,42	9,48

Source: Primary Data, 2023

Tabel 5. Analysis of various fingerprints for increasing height of cashew saplings (*Anacardium occidentale* L.)

Source of Diversity	df	Sum of Squares	Middle Squares	F Count	F Tabel 0,05
Treatments	2	0,99	0,49	3,95^{ud}	5,14
Error	6	0,76	0,13		
Total	**8**	**1,76**			

Source: Primary Data, 2023
Note: ud = Unreal Different

Based on the data in Table 5, it can be seen that the treatments tried showed no significant effect on vigor (increase in height of the offspring). The calculated F value is smaller than the table F value at the 5% confidence level. Because the results of the variance analysis did not show that the treatments tried had no significant effect on vigor, there was no need to continue with statistical testing. For more deails, see the Figure 2.

3) Increase in the Number of Leaves
The results of the diversity analysis of vigor (increase in the number of leaves) obtained the percentage value of the increase in the number of leaves with observation data presented in Table 6. Based on the observation data in Table 6, it is further processed using analysis of variance to determine the calculated F value as presented in Table 7.

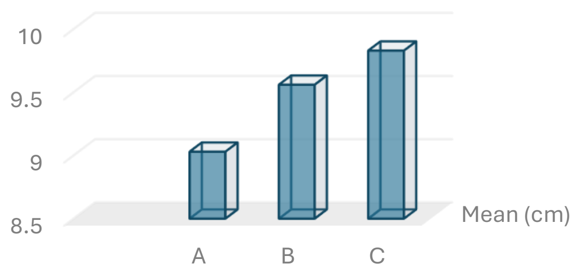

Figure 2. Height increase of cashew seeds

Tabel 6. Observation data on the increase in the number of cashew sapling leaves (*Anacardium occidentale* L.)

Treatments	Replication			Total (Sheet)	Mean (Sheet)
	I (Sheet)	II (Sheet)	III (Sheet)		
A	3,5	3,6	3,7	10,6	3,53
B	3,5	3,4	3,5	10,4	3,46
C	3,2	3,3	3,6	10,1	3,36
Total	10,0	10,3	10,8	31,1	3,36
Mean	3,3	3,4	3,6	10,36	3,45

Source: Primary Data, 2023

Tabel 7. Analysis of various fingerprints for increasing the number of cashew leaves (*Anacardium occidental* L.)

Source of Diversity	df	Sum of Squares	Middle Squares	F Count	F Tabel 0,05
Treatments	2	0,0422	0,0211	0,703^{ud}	5,14
Error	6	0,1799	0,0299		
Total	8	0,2221			

Source: Primary Data, 2023
Information: ud = Unreal Different

The results of the analysis of diversity in the increase in leaf number showed that the treatments tested showed no significant effect. The calculated F is smaller than the F table at the 5% level, this means that there are no pairs of average increases in the number of leaves that are significantly different. For deatails, see tha Figure 3.

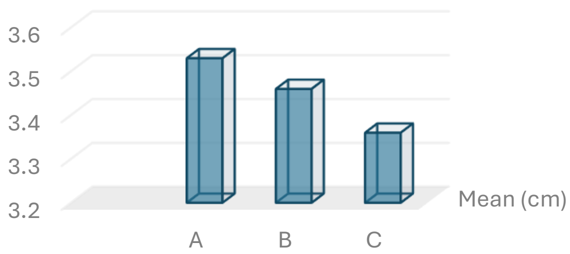

Figure 3. Increas in The Number of Chasew Sapling Leaves (Sheet)

4. Discussion

The statistical analysis in this study demonstrated that slicing and splitting the seed coat significantly impacted the germination percentage of cashew seeds. Specifically, seeds left intact (control, treatment C) exhibited the highest germination rate at 97.76%, significantly outperforming treatment B (splitting) at 88.86% and treatment A (slicing) at 81.06%. The superior performance of the intact seeds can be attributed to their undisturbed tissues, which maintained the integrity of the protoplasm, enabling efficient cell division and elongation. This ensured proper development of the radicle and plumule, vital for successful germination.

The intended purpose of slicing and splitting the seed coat was to enhance water absorption and expedite germination. However, the results reveal that these interventions were counterproductive under field conditions. This can be attributed to environmental factors that were difficult to control, such as fluctuating humidity, temperature, and soil conditions. Seeds consist of three critical components: the protective seed coat, the cotyledon as a food reserve, and the embryo. When the seed coat is sliced or split, it exposes the cotyledon and embryo to external threats, including soil microorganisms such as fungi and bacteria. These microorganisms, particularly in high-humidity conditions, can interfere with the metabolic processes essential for germination, as supported by previous studies. Abdullah (2018) emphasised that excessive humidity fosters fungal growth, while Sutopo (2019) noted that overly wet conditions impede aeration and promote diseases, ultimately causing seed rot.

Furthermore, the detrimental effects of slicing and splitting are likely exacerbated by soil conditions in the field. Damaged seeds are more vulnerable to environmental stressors, such as water saturation, which can accelerate seed decay. Additionally, pathogens such as fungi and bacteria can easily infiltrate through the openings in the seed coat, further compromising seed viability. These observations highlight the importance of maintaining the integrity of the seed coat to protect the embryo and cotyledon from environmental and biological hazards.

The results also suggest that intact seeds not only perform better in terms of germination but also exhibit superior seedling vigor. Vigorous seedlings, characterised by greater stem diameter, leaf count, and height, were observed predominantly in the control treatment. This underscores the importance of undisturbed tissues in supporting early plant development. Moreover, intact seeds are better equipped to withstand pest attacks, such as those from ants, and to endure fluctuating field conditions. The findings strongly advocate for planting cashew seeds in their intact form without any pre-treatment. This approach ensures a higher germination percentage, better seedling vigor, and reduced susceptibility to environmental stressors and pathogens. While the slicing and splitting of seed coats may seem beneficial in controlled laboratory settings, the complexity and variability of field conditions make intact seeds a more reliable choice. Future research should explore additional factors influencing seedling success, such as soil amendments, pest control strategies, and environmental optimisation, to further refine cashew seed planting techniques and enhance plantation productivity

5. Conclusion

The treatments evaluated significantly impacted plant growth, particularly seed germination, stem diameter, leaf production, and seedling height. The control treatment (treatment C), in which seeds were planted intact, exhibited the highest germination rate of 97.76%, outperforming the other treatments that involved slicing or splitting the seed coat, which did not result in substantial improvements in germination.

In addition to superior germination, the control treatment also led to healthier plant development. Compared to the other treatments, seedlings from the control treatment showed an average increase in stem diameter of 9.83 cm and produced an average of 3.36 leaves. The seedling height also increased significantly, indicating better overall vigor and growth.

These results suggest that planting intact seeds is more effective in the field, as it enhances seed protection, improves growth, and offers better resistance to pests. The slicing and splitting treatments, which did not provide clear benefits, can be considered unnecessary, especially in reforestation efforts and other planting initiatives. Planting cashew seeds in their natural, intact condition will likely improve the success of the planting process, reduce seedling mortality, and promote plantation sustainability.

Exploring other factors, such as soil quality and pest management strategies (Irawan & Hidayah, 2017; Blolok et al., 2024; Suryawan & Irawan, 2017), would be valuable in optimizing future planting efforts and could further enhance seedling success. The planting of intact cashew seeds is the most effective strategy to ensure high germination rates, vigorous seedling growth, and increased resilience in the field, contributing to healthier and more productive plantations.

6. Author Contributions

The first author's role involves compiling and analyzing scientific articles derived from research findings. The second author aids the first author in formulating research methodologies and assists in field data collection. The third author contributes by collecting primary data in the field and gathering secondary data as well.

7. Competing Interests

The process of writing scientific articles stems from collaborative research results, ensuring no conflicts of interest among the authors due to their shared responsibility and the collaborative nature of the research.

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