Agricultural Sciences, 2026, 17(11), 1340-1353
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

# Ethnomedicinal Uses and Effects of Seed Pretreatments on the Germination and Early Growth of *Sclerocarya birrea* (A. Rich.) Hochst. in the Sudano-Sahelian Zone of Burkina Faso

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**How to cite this paper:** Ouoba, Y.H., Zoungrana, A., Guébré, D., Tiendrébeogo, N.R., Hien, S., Adana, S., Ouoba, P., Bastide, B. and Boussim, I.J. (2026) Ethnomedicinal Uses and Effects of Seed Pretreatments on the Germination and Early Growth of *Sclerocarya birrea* (A. Rich.) Hochst. in the Sudano-Sahelian Zone of Burkina Faso. *Agricultural Sciences*, **17**, 1340-1353.
https://doi.org/10.4236/as.2026.1711076

**Received:** October 1, 2026
**Accepted:** November 22, 2026
**Published:** November 25, 2026

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## Abstract

*Sclerocarya birrea* supports rural livelihoods and traditional medicine, but seedling production and the documentation of local medicinal knowledge remain limited. This study compared seed pretreatments for germination and early seedling growth and documented the medicinal uses reported by traditional healers in the Sudano-Sahelian zone of Burkina Faso. A nursery trial compared untreated seeds (T0), hot-water soaking (T1), sulfuric acid scarification (T2) and naturally animal-ingested seeds (T3), with 100 pots per group. Emergence was monitored from 10 to 54 days after sowing, and seedling growth was assessed weekly for six weeks. Semi-structured interviews with 21 healers recruited through snowball sampling documented the plant organs used and the ailments treated. Data were analysed with binomial regression, a log-rank test and mixed-effects models. The Results showed final emergence was 61.0% for animal-ingested seeds, compared with 27.0% for untreated seeds, 26.0% after hot-water soaking and 22.0% after acid scarification, and emergence curves differed among groups ($P < 0.001$). Mean germination time ranged from 13.4 days for animal-ingested seeds to 19.6 days after acid scarification. Growth responses differed by trait, with seedlings from hot-water-

treated and acid-scarified seeds gained more height per week than controls, whereas acid-scarified seedlings showed a smaller weekly increase in root-collar diameter. Healers reported 32 use reports covering 21 ailments in nine categories, and bark was the most frequently cited medicinal organ. Animal-ingested seeds had the highest final emergence and the shortest mean germination time. Germination and growth responses were not uniform across treatments. The diversity of reported medicinal uses supports locally grounded conservation and propagation research but does not establish therapeutic efficacy.

## Keywords

*Sclerocarya birrea*, Biodiversity Conservation, Seedling Emergence, Sustainable Rural Livelihoods, Ethnobotany, Burkina Faso

## 1. Introduction

Non-timber forest products (NTFPs) contribute to rural livelihoods in West Africa, providing food, health care, energy and income [1] [2]. Their sustainable use is included in Burkina Faso's national adaptation planning [3]. More broadly, conserving and managing forest resources is integral to a green economy [4]. Documenting local uses provides a basis for management that takes livelihood needs into account.

*Sclerocarya birrea* (A. Rich.) Hochst., commonly known as marula, exemplifies these interdependent livelihood and conservation concerns. With biogeographic roots linked to ancient dryland floras [5] [6], the species is widespread in the Sudano-Sahelian zone, where its fruits are consumed and traded [7]. Studies of its bark, leaves and fruits have reported antidiarrhoeal, antidiabetic, anti-inflammatory, antimicrobial, antiplasmodial, antihypertensive and antioxidant activities associated with polyphenols, tannins, coumarins and flavonoids [8]. Reported uses vary with gender, ethnic group and local availability [2], warranting documentation at the local scale.

Propagation is constrained by the lignified endocarp enclosing the seeds. Its mechanical resistance can delay and reduce germination even when water is available [9]. Large herbivores contribute to dispersal [10], and digestive passage can improve germination [11]. Nursery trials of dormancy-breaking techniques have produced contrasting results across provenances and experimental conditions [12] [13]. In Burkina Faso, harvesting pressures and uneven regeneration across land-use types raise concerns about the persistence of *S. birrea* populations [14].

In the Sudano-Sahelian zone, seedling production is limited by insufficiently standardised pretreatment methods, while orally transmitted medicinal knowledge remains inadequately documented. These concerns are linked: medicinal practices influence which organs are harvested and the pressure on the resource, while propagation provides a means of replenishment. Examining both can inform sus-

tainable resource management.

This study aimed to 1) assess seed-preparation treatments in relation to germination parameters; 2) compare early seedling growth among treatments; and 3) document traditional healers' knowledge of the medicinal uses of *S. birrea*. We hypothesised that (H1) germination would differ among treatments, with hot-water soaking (the technique most accessible to farmers) expected a priori to be the most effective; (H2) early seedling growth would differ among treatments; and (H3) traditional healers would hold diverse knowledge of the species' medicinal uses.

## 2. Materials and Methods

### 2.1. Study Area

The study was conducted in the municipality of Ziniaré, the capital of the Oubri Region, approximately 35 km northeast of Ouagadougou in the Nakambé River basin (**Figure 1**). The climate is characterized by a long dry season from October to May and a short rainy season from June to September. From 1995 to 2024, mean annual rainfall was 862.75 ± 117.02 mm and mean temperature was 28.24 ± 0.32˚C [15]. Poorly developed, coarse-textured soils predominate, covering approximately 80% of the urban area, alongside lithosols (2.65%) and hydromorphic soils in low-lying areas (17%). The vegetation consists of tree and shrub savanna characterized by *Sclerocarya birrea* (A. Rich.) Hochst., *Parkia biglobosa* (Jacq.) R. Br. ex G. Don, *Vitellaria paradoxa* C. F. Gaertn., *Lannea microcarpa* Engl. & K. Krause and *Tamarindus indica* L.

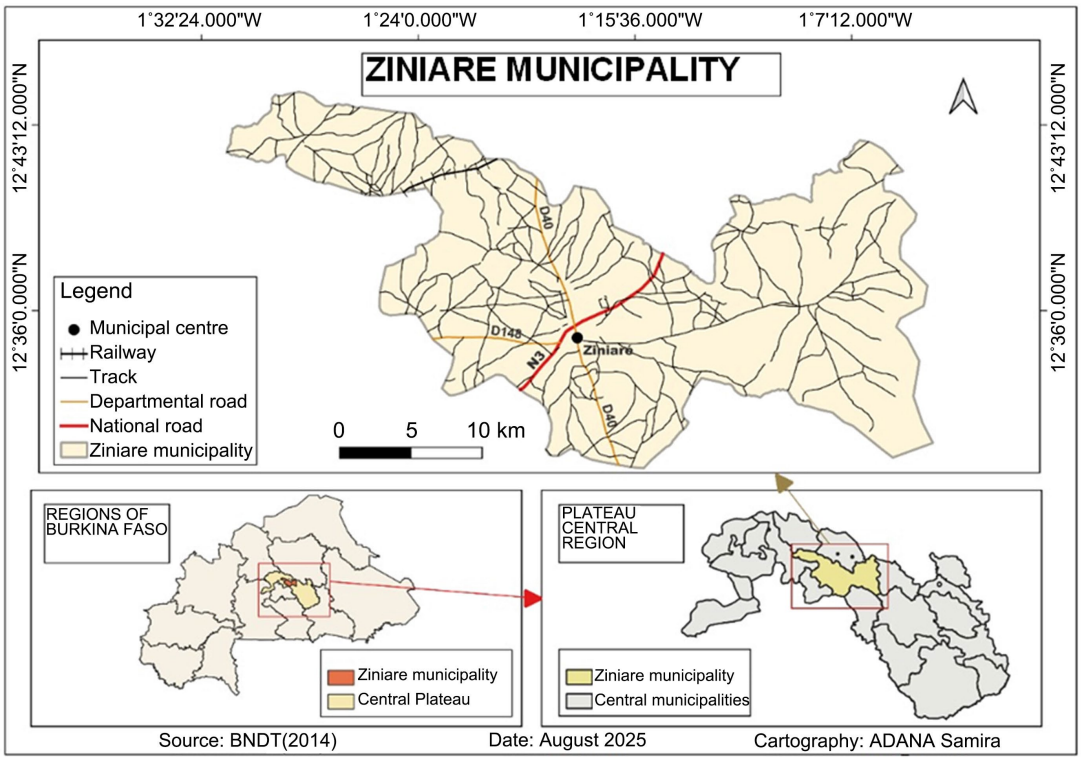


**Figure 1.** Location of the study area in Ziniaré municipality, Burkina Faso.

## 2.2. Sampling and Experimental Design

Seeds of *S. birrea* were collected in Ziniaré (Figure 2). The nursery trial used a completely randomised design with four seed groups, each comprising 100 pots with one seed sown per pot.



Figure 2. *Sclerocarya birrea* (A. Rich.) Hochst. fruits.

Pretreatments were as follows:

- T0 (control): fresh, untreated seeds.
- T1 (hot water): seeds were soaked in hot water (approximately 98˚C) for 30 min, rinsed, and then soaked in cold water (approximately 30˚C) for 24 h.
- T2 (sulfuric acid): seeds were scarified in 98% $H_2SO_4$ for 15 min, thoroughly rinsed, and then soaked in cold water (approximately 30˚C) for 24 h.
- T3 (animal-ingested): seeds that had passed naturally through the digestive tract of domestic animals (cattle) received no additional pretreatment.

For the ethnobotanical survey, the target population comprised traditional healers belonging to an association practising in the municipality of Ziniaré. The association, which has 50 members, authorised the documentation of traditional medicinal knowledge. Twenty-one practitioners were interviewed across ten neighbourhoods: Barkouitenga (n = 4), Barkoumba (n = 3), Sector 2 (n = 3), Kouila (n = 2), Sector 3 (n = 2), Guiloungou (n = 2), Sector 1 (n = 2), Sector 4 (n = 1), Toumba (n = 1), and Somnawaye (n = 1). Participants were recruited through snowball sampling, with each participant referring the interviewer to other practitioners recognized by their peers. This non-probability approach enabled access to an unregistered population through peer referral.

## 2.3. Data Collection and Trial Management

The potting substrate consisted of topsoil, compost, and sand mixed at a volumetric ratio of 2:1:1 and placed in 20 cm × 10 cm nursery pots. Pots were watered and maintained daily from sowing until the end of the trial. Seedling emergence was counted daily from 10 days after sowing (DAS) until the number of emerged seedlings stabilized at 54 DAS. Cumulative counts were recorded for each pretreatment. Growth monitoring began on 19 July 2025, when the first seedlings had reached a measurable stage, and continued weekly for six weeks. At each assessment, seedling

height (cm), root-collar diameter (mm), number of leaves were recorded.

Ethnobotanical data were collected through individual semi-structured interviews using an interview guide. Interviews covered respondents' sociodemographic characteristics (neighbourhood, gender, age, ethnic group, occupation, residence status, years of experience, and education level); knowledge of the species, its perceived availability, and harvesting frequency; the plant organs used, distinguishing general from medicinal uses; ailments treated; preparation and administration methods; reported adverse effects; and practices, constraints, and proposed solutions related to seedling production.

### 2.4. Data Analysis

Final emergence at 54 DAS was analysed using a binomial generalised linear model with a logit link, seed group as the sole predictor and T0 as the reference. Odds ratios compared each seed group with T0; confidence intervals were calculated by profile likelihood, and P values were obtained from unadjusted Wald tests. Exact binomial intervals were used for emergence percentages.

Emergence dynamics were described by the first recorded emergence day, mean germination time (MGT), the first observed day on which cumulative emergence reached 50% of that group's final emergence (T50), and the sample standard deviation (SD) of assigned emergence days. MGT was calculated as $\Sigma n_i t_i / \Sigma n_i$, where $n_i$ was the number recorded as newly emerged at day $t_i$. The complement of the Kaplan-Meier estimate was used to describe cumulative emergence under this coding; groups were compared using a log-rank test [16]. Seedlings already emerged at the first count were assigned an emergence time of 10 DAS. MGT and the SD of emergence timing therefore describe assigned recording days. T50 refers to half of each group's final emerged count, rather than half of the 100 seeds sown. No seed was censored before 54 DAS.

Height and root-collar diameter were analysed using linear mixed-effects models with seed group, continuous assessment week, their interaction, and a random intercept for seedling. Leaf number was analysed using a Poisson generalised linear mixed-effects model.

Relative frequency of citation (RFC) was defined as the number of distinct informants citing an organ or ailment divided by all 21 informants [17]. Fidelity level (FL) was calculated as the number of informants citing an ailment divided by the 18 informants citing at least one ailment, multiplied by 100. Ailment use value (UV) was the total number of ailment records divided by 21. The organ UV similarly expresses the number of organ records per informant.

All analyses were performed in R version 4.4 [18], with the significance level set at $\alpha = 0.05$. Pairwise comparisons were conducted using Tukey's test.

## 3. Results

### 3.1. Seed Pretreatment and Germination

Cumulative emergence curves differed among seed groups ($P < 0.001$; **Figure 3**).

Final emergence reached 61.0% for animal-ingested seeds (T3), compared with 27.0% for untreated seeds (T0), 26.0% for hot-water-treated seeds (T1) and 22.0% for acid-scarified seeds (T2). Relative to the control, the odds of emergence were higher for T3 ($P < 0.001$), with no difference detected for T1 ($P = 0.873$) and T2 ($P = 0.412$). Emergence had begun by the first count (10 DAS) in T0, T1 and T3, and began at 11 DAS in T2. Mean germination time was shortest for T3 (13.4 d), followed by T0 (14.6 d), T1 (15.5 d) and T2 (19.6 d). Half of the final emerged count had emerged by 13 DAS in T3, 14 DAS in T0 and T1, and 18 DAS in T2. Emergence was more spread out in T2 (SD, 6.5 days) and T1 (5.2 days) than in T0 (2.7 days) and T3 (2.9 days) (Table 1).

**Table 1.** Recorded emergence timing of *Sclerocarya birrea* by seed group.

| Seed group | First recorded emergence (DAS) | MGT (day) | T50 (DAS) | Timing SD (day) |
|---|---|---|---|---|
| T0 Control | 10 | 14.6 | 14 | 2.7 |
| T1 Hot water | 10 | 15.5 | 14 | 5.2 |
| T2 Sulfuric acid | 11 | 19.6 | 18 | 6.5 |
| T3 Animal-ingested | 10 | 13.4 | 13 | 2.9 |

DAS, days after sowing; MGT, mean germination time; SD, standard deviation. Each group contained 100 sown seeds. T0, untreated control; T1, hot water for 30 min followed by cold water for 24 h; T2, 98% sulfuric acid for 15 min followed by cold water for 24 h; T3, naturally animal-ingested material without additional treatment, from a separate batch. MGT and SD use assigned recording days, including day 10 for emergence already present at the first count. T50 is the first observed day on which cumulative emergence reached 50% of each group's final emerged count.

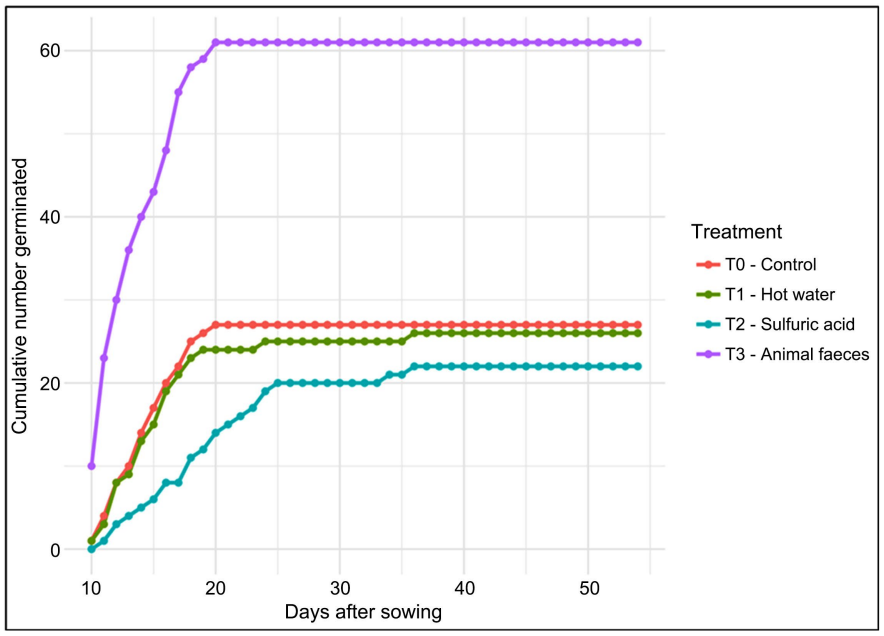


**Figure 3.** Cumulative seedling emergence of *Sclerocarya birrea* by seed pretreatment from 10 to 54 days after sowing.

Lines show the cumulative number of emerged seedlings recorded daily. Because 100 seeds were sown per treatment, this equals the cumulative percentage emergence. No seed was censored before 54 DAS, so the curves are the complement of the Kaplan-Meier estimates. Emergence curves differed among treatments (log-rank test, $\chi^2 = 61.08$, df = 3, $P < 0.001$). Counts began at 10 DAS, so values at 10 DAS include any earlier emergence. T0, untreated control; T1, hot-water soaking; T2, concentrated sulfuric acid scarification; T3, seeds recovered after passage through domestic animals; DAS, days after sowing.

### 3.2. Seed Pretreatment and Early Seedling Growth

Mean root-collar diameter ranged from 2.30 ± 0.74 mm (T0) to 2.79 ± 0.76 mm (T1) at the first assessment and from 5.59 ± 0.76 mm (T0) to 6.03 ± 0.69 mm (T1) at the sixth (Figure 4). The modelled weekly increase in the control was 0.665 mm. The increase was smaller in T2, with no difference detected for T1 or T3 ($P > 0.001$).

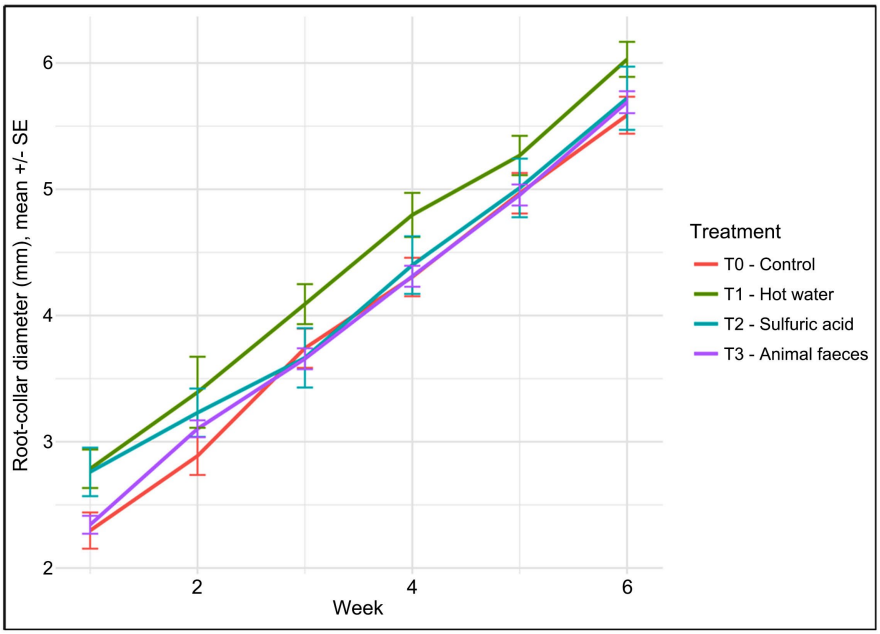


Figure 4. Root-collar diameter of *Sclerocarya birrea* seedlings over six weekly assessments by seed group. Values are observed means; error bars indicate ± standard error. Diameter is expressed in millimetres. T0, untreated control; T1, hot-water soaking; T2, 98% sulfuric acid scarification; T3, naturally animal-ingested seeds without additional treatment.

At the first assessment, mean seedling height ranged from 9.9 ± 2.8 cm (T2) to 12.3 ± 2.8 cm (T3); at the sixth assessment, it ranged from 19.0 ± 4.5 cm (T2) to 20.2 ± 3.5 cm (T1) (Figure 5). The modelled weekly height gain in control seedlings was 1.573 cm. Weekly gain was greater than in the control for T1 (difference, 0.256 cm/week) and T2 (0.322 cm/week), with no difference detected for T3.

Mean leaf number was 10.6 ± 2.6 in control seedlings and ranged from 8.0 ± 1.6 to 8.5 ± 2.5 in the other groups at the first assessment. At the sixth assessment, the corresponding values were 18.0 ± 2.7 and 16.4 ± 2.9 to 16.9 ± 1.1 (Figure 6). In the

Poisson mixed model, leaf number in the control increased by 0.091 log units per week. The weekly rate of increase was higher than in the control for T2 and T3, with no difference detected for T1 (difference, 0.019 log units/week; P > 0.001).

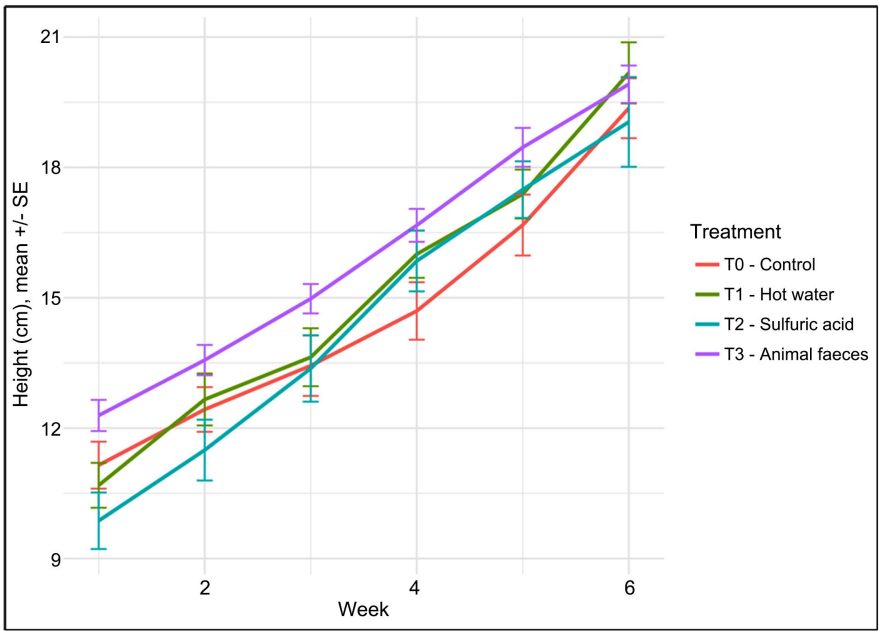


**Figure 5.** Height of *Sclerocarya birrea* seedlings over six weekly assessments by seed group. Values are observed means; error bars indicate ± standard error. Height is expressed in centimetres. T0, untreated control; T1, hot-water soaking; T2, 98% sulfuric acid scarification; T3, naturally animal-ingested seeds without additional treatment.

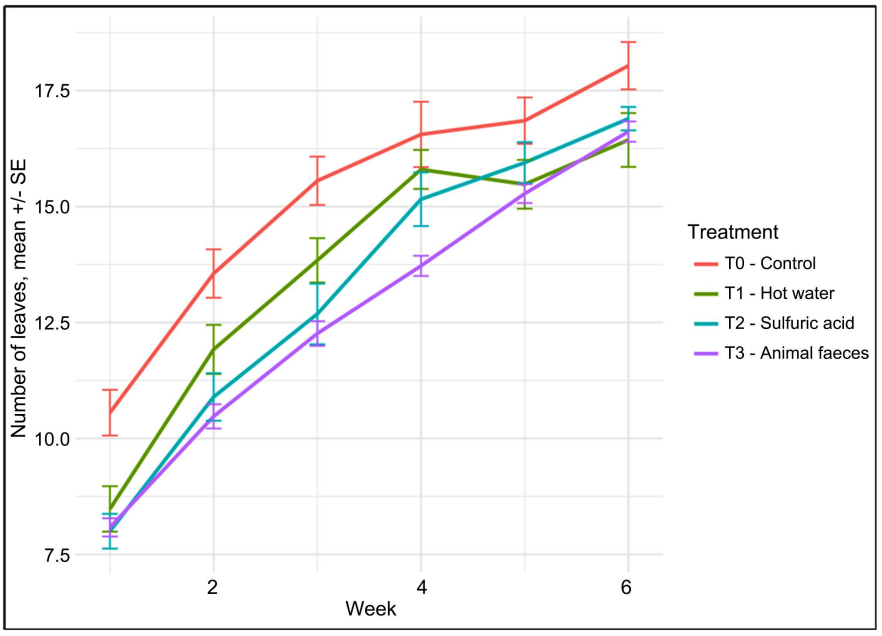


**Figure 6.** Leaf number of *Sclerocarya birrea* seedlings over six weekly assessments by seed group. Values are observed means; error bars indicate ± standard error. T0, untreated control; T1, hot-water soaking; T2, 98% sulfuric acid scarification; T3, naturally animal-ingested seeds without additional treatment.

### 3.3. Indigenous Knowledge of Medicinal Uses

Eighteen of the 21 healers cited at least one organ used medicinally, and 18 cited at least one ailment treated with *S. birrea*. Bark was the most frequently cited organ (18 citation records; reported RFC, 0.86), followed by leaves (3; RFC, 0.14), branches and roots (2 each; RFC, 0.10) and fruit (1; RFC, 0.05) (Table 2).

Table 2. Plant organs reported for medicinal use by traditional healers.

| Plant organ | Citation records (n) | Reported RFC |
|---|---|---|
| Bark | 18 | 0.86 |
| Leaves | 3 | 0.14 |
| Branches | 2 | 0.10 |
| Roots | 2 | 0.10 |
| Fruit | 1 | 0.05 |

RFC, relative frequency of citation; N = 21 informants. Multiple organs could be cited.

Table 3. Reported ailments and citation indices for *Sclerocarya birrea* among 21 traditional healers.

| Category (use reports) | Reported ailment | RFC | FL (%) |
|---|---|---|---|
| Psycho-cultural/ritual | Mourning illness | 0.33 | 38.9 |
| Psycho-cultural/ritual | Nightmares about the dead | 0.05 | 5.6 |
| Psycho-cultural/ritual | Fear | 0.05 | 5.6 |
| Digestive/hepatic | Abdominal pain | 0.14 | 16.7 |
| Digestive/hepatic | Abdominal bloating | 0.10 | 11.1 |
| Digestive/hepatic | Colopathy | 0.05 | 5.6 |
| Digestive/hepatic | Chronic diarrhoea | 0.05 | 5.6 |
| Digestive/hepatic | Hepatitis | 0.05 | 5.6 |
| Digestive/hepatic | Infant crying | 0.05 | 5.6 |
| Metabolic/cardiovascular | Diabetes | 0.10 | 11.1 |
| Metabolic/cardiovascular | Childhood diabetes | 0.05 | 5.6 |
| Metabolic/cardiovascular | Hypertension | 0.05 | 5.6 |
| Dermatological | Itching | 0.05 | 5.6 |
| Dermatological | Oedema | 0.05 | 5.6 |
| Dermatological | Ringworm | 0.05 | 5.6 |
| Ear, nose, throat/oral | Toothache | 0.05 | 5.6 |
| Ear, nose, throat/oral | Sinusitis | 0.05 | 5.6 |
| General tonic use | General illness | 0.10 | 11.1 |
| Haematological | Anaemia | 0.05 | 5.6 |
| Infectious/parasitic | Malaria | 0.05 | 5.6 |

RFC, relative frequency of citation; FL, fidelity.

The healers provided 32 use reports covering 21 ailments in nine categories (Table 3). Psycho-cultural/ritual and digestive/hepatic disorders each accounted for 9 reports, followed by metabolic/cardiovascular disorders (4), dermatological disorders (3), ear, nose, throat and oral disorders (2), and general tonic use (2). Haematological, infectious/parasitic and undetermined conditions each accounted for one report. Mourning illness was the most frequently cited ailment (7 informants; RFC, 0.33; FL, 38.9%), followed by abdominal pain (RFC, 0.14; FL, 16.7%) and abdominal bloating, diabetes and general illness (RFC, 0.10; FL, 11.1%). The remaining 16 ailments were each cited by one informant (RFC, 0.05).

## 4. Discussion

### 4.1. Germination Responses to Seed Pretreatment

Animal-ingested material had the highest final emergence and the shortest recorded mean germination time. Hot-water soaking did not produce the expected improvement over untreated seeds, and acid-scarified seeds had the lowest final emergence and the most dispersed emergence times. Thus, the findings do not support the hypothesis that hot-water soaking would be the most effective treatment under the conditions tested. The marked advantage of the animal-ingested group is nevertheless a comparison between seed groups: because this material came from a separate batch, digestive passage cannot be isolated from other batch characteristics.

The direction of this association is consistent with the germination enhancement following antelope ingestion reported by [11]. Differences between wild antelopes and the domestic animals involved here limit direct transfer of that finding. [12] also found that acid scarification and hot-water treatments did not promote germination under their experimental conditions, while after-ripening, light and cold stratification influenced germination. Their work on *S. birrea* subsp. caffra provides a useful comparison, although differences in plant material and nursery conditions preclude assuming equivalent responses in Burkina Faso.

Digestive processing could alter tissues surrounding the seed, but this mechanism was not measured. Seed maturity, storage history or initial viability could also contribute to the observed batch difference. The results therefore justify further controlled comparisons using a common seed source, rather than an unconditional recommendation to use animal-ingested material. Likewise, the poorer emergence observed after acid treatment does not establish embryo damage or identify an optimal scarification protocol.

Equal numbers of pots and daily emergence counts strengthened comparisons of final emergence and its recorded timing. However, observation began only at 10 DAS, when seedlings were already present in three groups. Assigning these seedlings to the first observation day limits the precision of early emergence times and of derived timing indices. The single nursery setting also limits extrapolation across seasons, seed sources and production conditions. These qualifications are particularly relevant when comparing laboratory germination studies with seed-

ling emergence under nursery conditions.

### 4.2. Early Growth and Implications for Nursery Production

The emergence advantage of animal-ingested material was not accompanied by uniformly greater growth across all traits. Hot-water-treated and acid-scarified seedlings had greater weekly height gains than controls, whereas acid-scarified seedlings had a smaller weekly increase in root-collar diameter. Control seedlings retained the highest mean leaf number at the final assessment, despite faster modelled increases in some other groups. These patterns show why emergence, initial seedling size and subsequent growth rate should be considered separately when evaluating propagation methods.

[13] examined both germination and initial growth of *S. birrea* in Niger, providing a regional precedent for assessing establishment beyond emergence alone. Their nursery observations and the present repeated measurements concern early development rather than long-term field performance. Differences in growing conditions and observation periods restrict direct comparison of absolute growth values. The present findings support evaluating pretreatments across several seedling traits instead of treating final emergence as a sufficient measure of nursery performance.

Differences in emergence timing may contribute to differences in size at a common assessment date. Seedlings emerging later could be developmentally younger, and differences in initial size can coexist with faster subsequent growth. These are plausible explanations, not mechanisms demonstrated by this study. Growth measurements were obtained from living seedlings, so growth comparisons describe the observed survivors rather than all seeds originally sown. Consequently, a treatment associated with low emergence may still yield seedlings with relatively rapid growth without providing the greatest overall establishment success.

Weekly measurements and mixed-effects models allowed within-seedling dependence to be considered when estimating growth trajectories. Nevertheless, a continuous week term represents average change over the observed period, and six weeks of nursery monitoring cannot establish persistence of these differences after transplanting. The findings do not demonstrate differences in drought tolerance, field survival or eventual productivity. Longer follow-up across contrasting nursery and field conditions would be needed before selecting a treatment on the basis of lasting seedling performance.

### 4.3. Medicinal Knowledge and Conservation Implications

The healers described a broad range of medicinal uses, with bark predominating and psycho-cultural/ritual and digestive/hepatic uses contributing the largest category totals. This supports the hypothesis of diverse local medicinal knowledge while showing that knowledge is not limited to biomedical disease categories. Mourning illness, the most frequently cited term, should be understood as a re-

ported local category rather than equated with a specific clinical diagnosis.

The predominance of bark and reports of digestive uses agree with the ethnobotanical study by [2] in Benin, where bark was widely used for complaints including stomach ache and diarrhoea. That study also documented funeral-related cultural uses and variation in use patterns between communities. These parallels place the Ziniaré findings within a wider regional tradition without implying identical practices. Differences in interview populations, terminology and category definitions may explain differences in the uses emphasised across studies; citation indices should therefore not be compared as if their denominators and coding were interchangeable.

Experimental pharmacological research on *S. birrea* provides a rationale for investigating some reported uses, but ethnobotanical frequency is not evidence of treatment effectiveness. [8] reviewed phytochemical, pharmacological and toxicological findings alongside traditional uses. Such evidence cannot establish the efficacy or safety of the particular preparations reported in Ziniaré, which were not evaluated clinically here. The prominence of bark in medicinal knowledge warrants attention to harvesting practices, although citation frequency alone does not measure the amount removed or demonstrate population-level damage.

Individual interviews across ten neighbourhoods documented specialist knowledge that may be missed in general household surveys. Snowball recruitment, however, may favour connected practitioners and shared knowledge networks; the sample cannot be treated as representative of all healers or residents. Reported uses are also subject to recall and differences in how ailments are described. The distinction between citation records and informants is especially important for bark, whose reported ratio includes repeated records. The indices describe this interview sample and should not be interpreted as prevalence estimates for the municipality.

Together, the medicinal survey and nursery trial provide complementary evidence for locally informed resource management. The survey identifies organs and uses relevant to practitioners, while the nursery observations identify propagation questions requiring controlled follow-up. They do not establish a quantitative relationship between medicinal demand and regeneration. Further work linking harvesting practices, tree condition and seedling establishment could clarify whether particular management approaches maintain both the resource and its cultural uses.

## 5. Conclusion

Naturally animal-ingested *Sclerocarya birrea* material had the highest final emergence and the shortest recorded mean germination time, whereas hot-water soaking and sulfuric acid scarification did not improve final emergence over untreated seeds. The separate origin of the animal-ingested batch prevents attributing its advantage solely to digestive passage. Early growth responses differed among traits, indicating that germination success and subsequent seedling performance

require distinct evaluation. Traditional healers reported diverse medicinal uses, particularly of bark, with prominent psycho-cultural/ritual and digestive/hepatic applications. These findings support further controlled propagation studies and locally grounded documentation of medicinal knowledge, without establishing therapeutic efficacy or a universally superior pretreatment.

## Acknowledgements

We would like to express our gratitude to Florence Ouédraogo and the people of Ziniaré for their hospitality and support.

## Author Contributions

The authors confirm their contributions to the paper as follows: conceptualization, Y.H. Ouoba, A. Zoungrana and D. Guébré; methodology, Y.H. Ouoba, A. Zoungrana, D. Guébré, N.R. Tiendrébeogo and S. Hien; software, Y.H. Ouoba, A. Zoungrana, D. Guébré, N.R. Tiendrébeogo, S. Hien and S. Adana; validation, Y.H. Ouoba, A. Zoungrana and D. Guébré; formal analysis, A. Zoungrana, D. Guébré, N.R. Tiendrébeogo, S. Hien and S. Adana; investigation, Y.H. Ouoba and S. Adana; resources, P. Ouoba, B. Bastide and I.J. Boussim; data curation, Y.H. Ouoba, A. Zoungrana, D. Guébré, N.R. Tiendrébeogo, S. Hien and S. Adana; writing—original draft preparation, Y.H. Ouoba, A. Zoungrana and D. Guébré; writing—review and editing, Y.H. Ouoba, A. Zoungrana and D. Guébré; visuali-zation, Y.H. Ouoba, A. Zoungrana and D. Guébré; supervision, P. Ouoba, B. Bastide and I.J. Boussim; project administration, .H. Ouoba, A. Zoungrana and D. Guébré; funding acquisition, .H. Ouoba, A. Zoungrana and D. Guébré. All authors have read and agreed to the published version of the manuscript.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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