Asian Journal of Research in Agriculture and Forestry

Volume 10, Issue 3, Page 13-20, 2024; Article no.AJRAF.119135
ISSN: 2581-7418

Innovative Seed Treatment for *Cassia siamea* Lam. Germination and Carbon Stock Analysis in Varied Stem Sizes for Sustainable Land Management and Climate Change Mitigation

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Authors' contributions

This work was carried out in collaboration between both authors. Author LAP contributed by conceptualization, statistical analysis, supervision and writing of the manuscript. Author PD contributed by field work, laboratory analysis and data collection. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajraf/2024/v10i3296

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/119135

Original Research Article

Received: 28/04/2024
Accepted: 02/07/2024
Published: 04/07/2024

ABSTRACT

This study investigates seed treatment effects on *Cassia siamea* germination and assesses carbon stock potential across stem size classes. The germination test involved six treatments, including immersion in various water temperatures and chemical solutions. Carbon stock potential across eleven stem size classes of *Cassia siamea* was assessed through air drying, oven drying, and ash

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Cite as: *Pragasan, L. Arul, and P. Dhanavel. 2024. "Innovative Seed Treatment for Cassia Siamea Lam. Germination and Carbon Stock Analysis in Varied Stem Sizes for Sustainable Land Management and Climate Change Mitigation". Asian Journal of Research in Agriculture and Forestry 10 (3):13-20. https://doi.org/10.9734/ajraf/2024/v10i3296.*

weight measurements following standardized methods. Results highlight significant variation in germination rates among treatments, with immersion in concentrated H_2SO_4 showing the highest efficacy. Carbon stock in wood varies significantly across stem size classes. However, regression analysis revealed that there was no significant relationship observed between the wood carbon stock and stem size class of *C. siamea*. Findings suggest non-linear growth patterns in carbon accumulation, influenced by factors beyond stem size. Insights from this research aid in optimizing seedling establishment and maximizing carbon sequestration potential in *Cassia siamea*, supporting climate change mitigation efforts through afforestation initiatives. Moreover, implications for sustainable land management, particularly in contexts like roadside tree planting in India, underscore the practical relevance of these findings in combating rising atmospheric carbon concentrations.

Keywords: Cassia siamea; seed germination; afforestation; wood carbon stock; climate change mitigation.

1. INTRODUCTION

The escalation in carbon dioxide emissions, primarily from burning fossil fuels and deforestation, is a major driver of global warming [1]. This process, exacerbated by human activities, leads to a sustained rise in Earth's average surface temperature, intensifying the dynamics of climate change [2]. It is crucial to prioritize initiatives aimed at bolstering carbon stocks and increasing carbon absorption capacity to effectively mitigate climate change [3].

Trees play a vital role in the global carbon cycle as natural carbon sinks, absorbing atmospheric carbon dioxide through the process of photosynthesis [4]. The planting of trees is widely recognized as a crucial strategy in mitigating climate change by reducing the concentration of greenhouse gases in the atmosphere. Despite this understanding, there remains a notable gap in our understanding of the carbon accumulation potential of exotic tree species, highlighting the need for further research in this area [5]. One such exotic species of interest is *Cassia siamea* Lam., commonly known as Siamese cassia or Siamese senna, native to Southeast Asia. This fast-growing evergreen tree species, belonging to the family Fabaceae (Caesalpinioideae), is valued for its versatility, with applications ranging from timber production to soil improvement [6,7]. Notably, it exhibits resilience in degraded environments, making it a promising candidate for agroforestry and reforestation initiatives.

The study by Mukhopadhyay and Masto [5] sheds light on the potential of *C. siamea* in carbon sequestration and mine site reclamation. Their findings indicate a significant increase in biomass carbon stock over a 16-year period, underscoring the species' ecological value. However, accurately quantifying tree carbon stock remains a challenge due to the limitations of direct measurement methods. While direct methods involve cutting down trees and weighing their components, providing precise results, they are often costly, labor-intensive, and ecologically disruptive. Consequently, researchers often turn to indirect methods, such as allometric equations, to estimate biomass without the need for tree destruction [8,9,10]. Allometric equations establish empirical relationships between tree biomass and easily measurable structural parameters such as diameter, height, and crown area. However, the choice between using generic or species-specific allometric equations is subject to ongoing debate, with proponents and detractors for each approach [11,12].

In India, Ragula and Chandra [4] conducted a study on the carbon stock of roadside trees in Bilaspur, emphasizing their role in urban carbon sequestration and climate mitigation efforts. Given India's extensive road network, which is experiencing rapid expansion to accommodate the increasing demands of passenger traffic, the importance of roadside tree plantations cannot be overstated [13]. Trees along roadways serve as crucial carbon sinks, absorbing pollutants such as carbon dioxide emitted by vehicles and mitigating the adverse effects of urbanization on local climate and air quality.

In light of the aforementioned context, understanding the seed germination characteristics and carbon stock potential of *C. siamea* is of paramount importance. Therefore, this study aims to investigate seed germination under various conditions and assess the carbon stock potential of *C. siamea* across various stem size classes. By elucidating these aspects, the research seeks to contribute to the effective management and utilization of *C. siamea* in environmental conservation efforts, agroforestry initiatives, and reforestation programs. Moreover, insights gained from this study can inform policymakers and practitioners on the role of *C. siamea* in enhancing carbon sequestration and climate resilience, particularly in regions experiencing environmental degradation and land-use changes. Ultimately, advancing our knowledge of *C. siamea* towards ecological attributes and carbon sequestration potential can facilitate informed decision-making and promote sustainable land management practices in the face of climate change.

2. MATERIALS AND METHODS

We have selected the tree species *Cassia siamea* for the present study. The seeds of *C. siamea*, collected from Bharathiar University campus (located in Coimbatore, India, Fig. 1) were subjected to germination tests under varied treatment conditions. Also, the carbon stock potential of wood samples of *C. siamea* across different stem size classes was assessed using standardized methodologies.

2.1 Experiment on Seed Germination with Different Treatments

The germination test was done by sowing the seeds in plastic pots (9 cm height and 7 cm diameter). We filled each pot with 100 g of soil, which is a mixture of topsoil (50%), coarse sand (30%), and fine sand (20%). Six seed treatments (T) were set for the experiment, i.e., T1: control (normal water), T2: immersion in cold water (4°C) for 12 h, T3: immersion in hot water (80°C) for 10 min, T4: seeds immersed in hot water (80°C) for 1 min, followed in cold water soaking for 12 h, T5: immersion in concentrated H_2SO_4 (80%) for 20 min, T6: instead of water KNO_3 was sprayed once in 2 days in the concentration of (0, 3, 6, 9, 12, 15 mg/L). One seed was sown in each pot and pots were kept in shade throughout the experiment. Twenty such pots were done for all the six treatments. The seeds were sown in the depth of 0.5-1.5 cm. Cassia species generally require less water, watering can be limited to once in 2 days. Temperature and humidity were recorded in the pot soil every day.

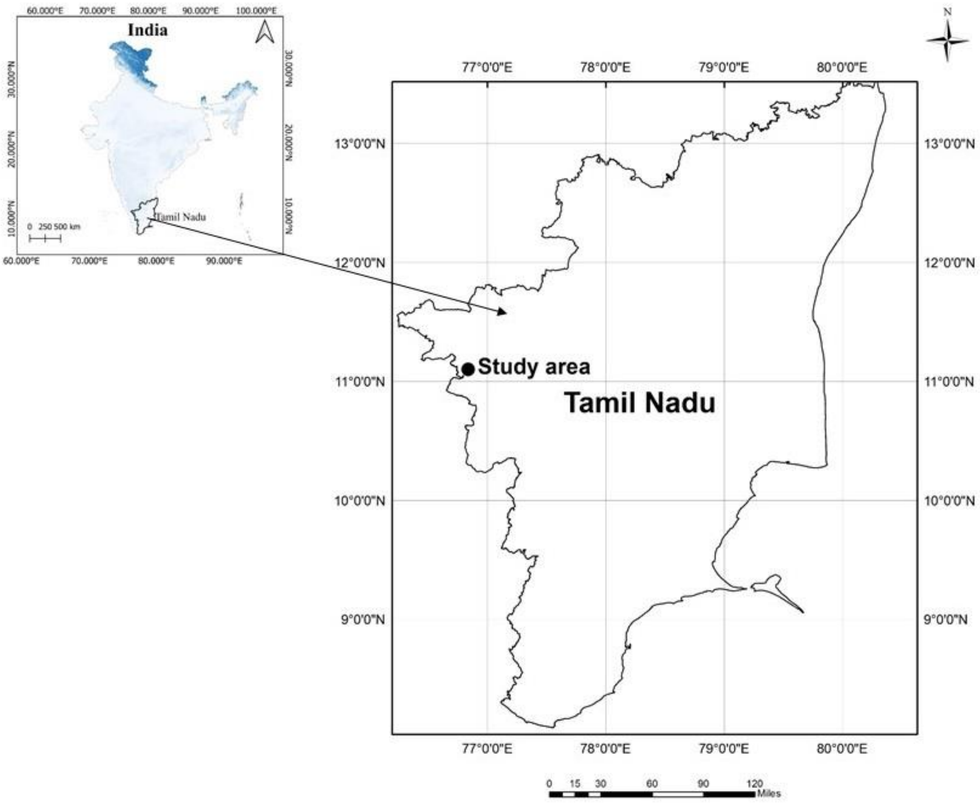

Fig. 1. Location map of Bharathiar University campus, Coimbatore, India

2.2 Carbon Stock Potential Across Different Stem Size Classes

The wood part of *Cassia siamea* belonging to eleven stem size class (in cm) viz. 5-10, 10-15, 15-20, 20-25, 25-30, 30-35, 35-40, 40-45, 45-50, 50-55, 55-60, were collected and were air dried for two days. Then, the samples were dried in the hot air oven for 24 hours at 105°C to get dried weights. Then, 1 gram of oven dried grind samples leaf and wood were taken separately in pre-weighted crucibles. The crucibles were placed in the furnace at 550 ± 5°C for 2 hours. Then, the crucibles were cooled slowly inside the furnace. After cooling, the crucibles with ash were weighted for calculation of percentage of carbon stock using the following equations [14,15].

Estimation of carbon stock (C):

C (%) = (100 - ash %) x 0.58
Calculation of ash (%) for estimation of carbon stock:
Ash (%) = (W3 – W1)/ (W2 – W1) x 100
Where W1 is the weight of crucibles
W2 the weight of oven dried grind samples + Crucibles
W3 is the weight of ash + Crucibles

2.3 Statistical Analysis

One-way analysis of variance (ANOVA) was used to check the variation in seed germination of *C. siamea* among the six treatments, and carbon stock potential of *C. siamea* belonging to different stem size classes. Also, regression analysis was performed to check the relationship between the wood carbon stock and stem size class of *C. siamea*.

3. RESULTS AND DISCUSSION

3.1 Seed Germination

Among the six seed treatments, the percentage of seed germination was maximum recorded for T5 (95 %) followed by T4 (Table 1). The seed germination results show that the seeds of *C. siamea* treated with immersion in concentrated H_2SO_4 (80%) for 20 min had the maximum (19) seedlings out of the 20 seeds sown (Fig. 2). Statistically, one-way ANOVA showed that seed germination of *C. siamea* varied significantly ($F_{(5,114)}$ = 44.345, $p < 0.001$) among the six treatments (Table 1).

3.2 Carbon Stock Potential

Table 2 provides the carbon stock in wood of *C. siamea* categorized by the eleven stem size classes. The carbon stock value was recorded maximum (56.43 ± 0.34%) at the 55-60cm size class and it was minimum recorded for 40-45cm size class (Table 2). One-way ANOVA showed that the carbon stock potential in wood of *C. siamea* among the eleven stem size classes varied significantly ($F_{(10,22)}$ = 7.196, $p < 0.001$). However, regression analysis revealed that there is no relationship (R^2 = 0.020) between the wood carbon stock and stem size class of *C. siamea* (Fig. 3).

Cassia siamea, primarily displays seed coat-induced dormancy, due to intricate seed coat structures [16]. Findings of the present study underscore the significance of treatment conditions in influencing seed germination. Immersion in concentrated H_2SO_4 emerged as the most effective treatment, yielding a remarkable 95% seedling emergence. Further, one-way ANOVA revealed that seed germination of *C. siamea* varied significantly ($p < 0.001$) among the six treatments. These results suggest the importance of targeted pre-germination treatments to enhance seedling establishment in reforestation efforts. Earlier, Ogungbesan et al. [16] carried out a study on the effect of hot water on the germination rate of *C. siamea* seeds, and reported that hot water (100℃) has shown to effectively break seed dormancy in *C. siamea* seeds, indicating a brief treatment time (12 min) is sufficient for dormancy removal. Whereas, in the present study, treatment T3 immersion in hot water (80°C) for 10 min had just 10% of seed germination for *C. siamea*. This can be attributed to the variation in hot water temperature and seed soaking time.

Table 1. Percentage of seed germination for *Cassia siamea* among the six treatments

Treatment	Seed germination (at the end of 20th day)	(%)
T1	3	15
T2	3	15
T3	2	10
T4	7	35
T5	19	95
T6	2	10

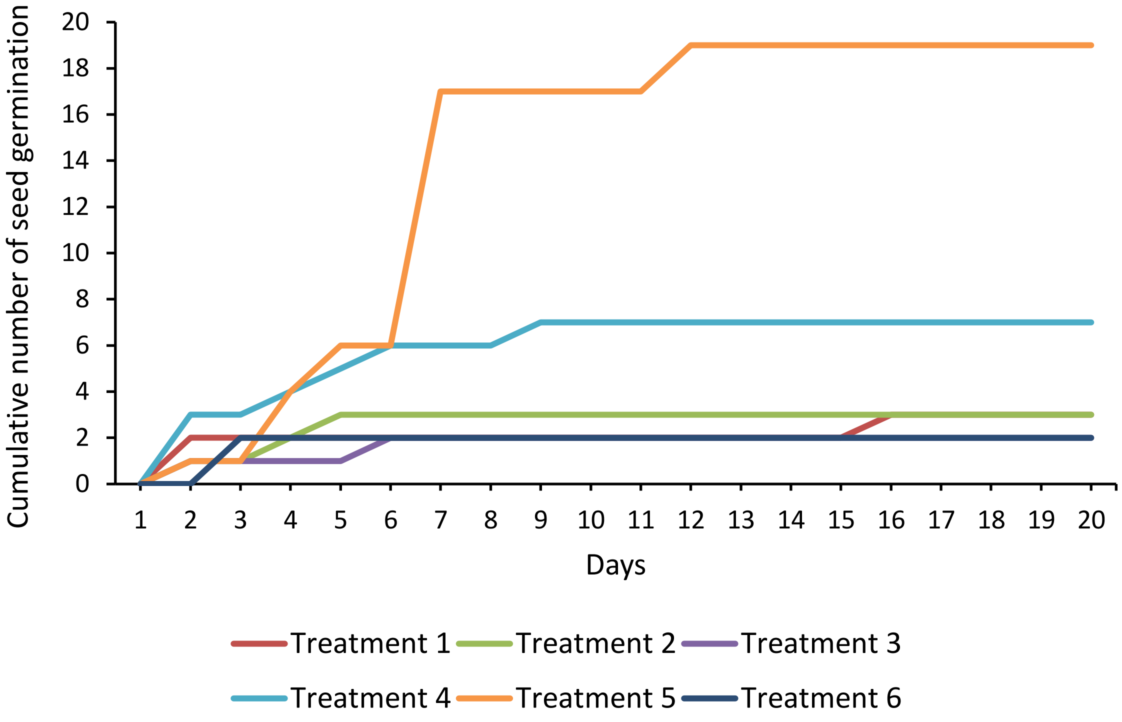

Fig. 2. Results of seed germination experiment of *Cassia siamea*

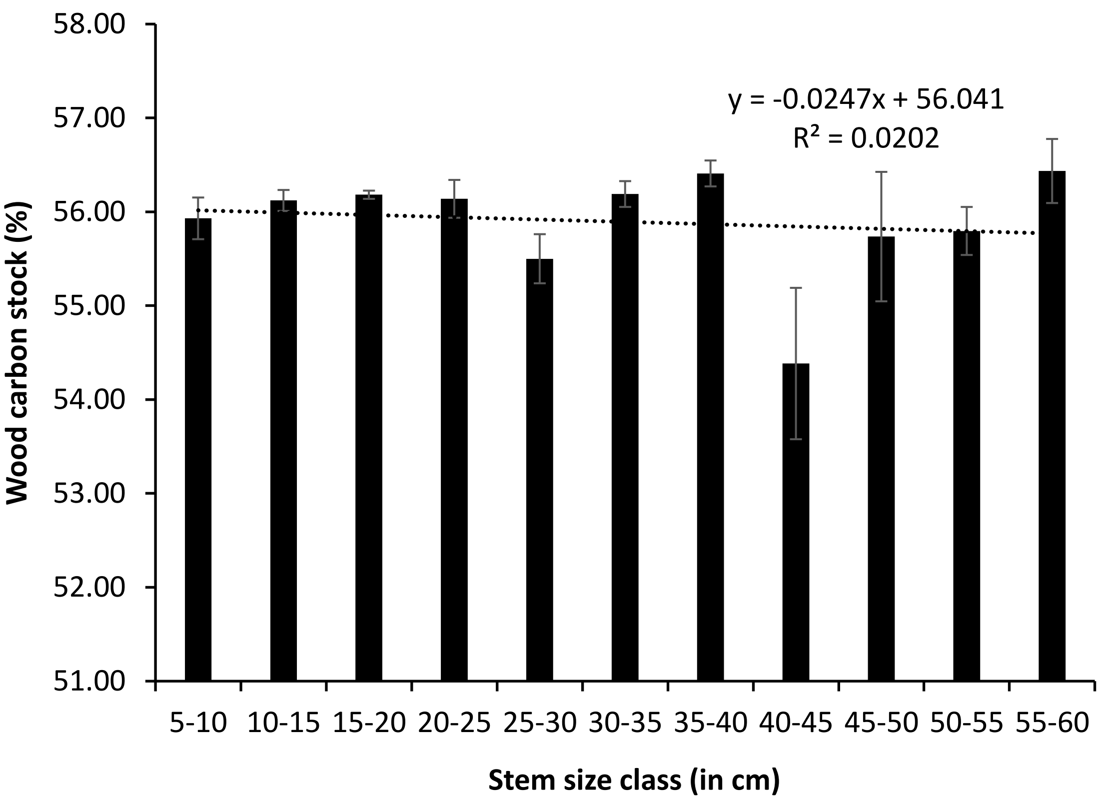

Fig. 3. Carbon stock potential of wood of *Cassia siamea* categorized by different stem size class

Table 2. Carbon stock potential of wood of *Cassia siamea* categorized by 11 stem size classes

Stem size class (in cm)	Wood carbon stock (%)	±S.D.
5-10	55.93	0.22
10-15	56.12	0.11
15-20	56.18	0.04
20-25	56.14	0.20
25-30	55.50	0.26
30-35	56.19	0.14
35-40	56.41	0.14
40-45	54.38	0.81
45-50	55.74	0.69
50-55	55.80	0.26
55-60	56.43	0.34

Further, in this study we found that the carbon stock potential in wood of *C. siamea* across 11 stem size classes had significant variation ($p < 0.001$). However, no relationship was observed between the wood carbon stock and stem size class of *C. siamea*. We point that *C. siamea* might exhibit non-linear growth patterns concerning carbon accumulation. While larger trees generally have more biomass and thus more carbon stock [17], the rate of carbon accumulation might not directly correlate with stem size.

Factors such as age, health, and environmental conditions could influence carbon stock rates independently of stem size. As trees age, their root systems often experience increased growth, enabling them to delve into fresh soil volumes and extract nutrients from deeper layers [5]. Trees allocate resources differently at various growth stages. Smaller trees might allocate more resources to vertical growth and foliage development rather than radial growth, which contributes more significantly to wood carbon stock. This allocation strategy could lead to a lack of correlation between stem size and carbon stock. Understanding these dynamics is crucial for accurately estimating forest carbon stocks and informing sustainable forest management practices.

Worldwide lots of measures have been take to curb the rising atmospheric carbon concentration, such as Clean Development Mechanism (CDM) forestry projects began from 2006 in light of carbon offsetting targets, then, the Climate Action Reserve (CAR) projects, Verified Carbon Standard (VCS) and the American Carbon Registry (ACR) came into action [18]. Although, several policies (carbon tax and subsidy) and carbon market business were taken, the rise in atmospheric carbon concentration and its consequence are at alarming rate [17].

India has the second-largest road network globally, following the United States [4]. It is reported that, India's road network spans 5.5 million kilometers, serving 90% of total passenger traffic, and is expanding at a rate of 26.93 kilometers per day [13]. Hence, planting roadside trees, particularly *C. siamea* is one of the best options in India to reduce the atmospheric carbon loads, besides afforestation and reforestation programs. Although *C. siamea* is an exotic tree, it is proved to be a good candidate for restoration in mining area [19], even it is better performer than the native tree species *Albizia lebbeck* (L.) Benth. (commonly known as Indian siris) in terms of biomass carbon stock, soil carbon stock and soil available nitrogen stock in post mining lands of Jharia Coalfield in Jharkhand, India [5].

Overall, this research contributes valuable insights into optimizing seedling establishment and enhancing carbon stock potential in *Cassia siamea*, supporting efforts to mitigate climate change through afforestation initiatives for the nation.

4. CONCLUSION

The present study concludes that seed germination of *C. siamea* was found high (95%) for the treatment, T5 (immersion in concentrated H_2SO_4 (80%) for 20 min). Among the eleven stem size classes, carbon stock potential was high for the 55-60 cm size class (56.43 ± 0.34%) for the wood sample. This study contributes valuable insights into optimizing seed germination protocols for *C. siamea* and understanding its carbon stock potential. The findings of this study offer invaluable guidance to policymakers and practitioners regarding the pivotal role of *C. siamea* in bolstering carbon sequestration and fortifying climate resilience, especially in areas grappling with environmental degradation and shifts in land use. By elucidating the mechanisms through which *C. siamea* contributes to carbon storage and ecosystem stability, this research equips decision-makers with actionable insights to implement targeted strategies for sustainable land management and mitigation of climate-related challenges. Ultimately, embracing the potential of *C. siamea* stands as a promising avenue towards fostering ecological health and resilience in vulnerable regions worldwide.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that no generative ai technologies such as large language models (chatgpt, copilot, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENTS

The authors thank their institution, Bharathiar University for providing infrastructural support for this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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