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Original Research Article

Assessing the growth potential of Sunn hemp (*Crotalaria juncea* L.) as a cover crop for major coconut-growing soils

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ABSTRACT

The coconut industry has deep historical and economic importance in Sri Lanka, but coconut palms are vulnerable to water stress exacerbated by environmental challenges. This study explored using Sunn hemp (*Crotalaria juncea* L.) in major coconut-growing soils in Sri Lanka to improve resilience to water stress. The study was conducted at the Coconut Research Institute of Sri Lanka to evaluate the growth of Sunn hemp in prominent coconut soils—gravel, loamy, and sandy—to determine its cover crop potential. Sunn hemp was planted in pots with the three soil types, arranged in a randomized, complete design with 48 replicates. Growth parameters like plant height, shoot/root dry weight, root length, and leaf area were measured at 2, 4, 6, and 8 weeks after planting. Soil type significantly impacted all growth parameters. After 8 weeks, sandy soil showed the highest plant height and root length, while loamy soil showed the highest shoot/root dry weight and leaf area, followed by sandy and gravel soils. Nitrogen content at 6 and 8 weeks was highest in loamy soil plants. In summary, Sunn hemp produces more biomass in sandy soils, while loamy soils promote greater nutrient accumulation and growth. This suggests the suitability of Sunn hemp as a cover crop across major coconut-growing soils in Sri Lanka, improving resilience.

Keywords: coconut industry; Sunn hemp; cover crop; soil type; growth performance

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1. Introduction

The coconut palm, revered as the "Tree of Life" in Sri Lanka, claims a rich cultural history spanning over 2000 years. This icon of prosperity is a crucial food source and economic cornerstone, contributing over $400 million in exports in 2020. Supporting livelihoods for 800,000 people, it plays a pivotal role in rural development and poverty alleviation[1–3]. Coconut palms face water stress during dry periods, impacting growth and yield[4]. Optimal soil moisture, crucial for tree health, requires robust root systems and nutrient uptake[5,6]. Amid climate change and water scarcity, sustainable moisture conservation methods like mulching and drip irrigation are vital. Integration of such practices enhances coconut yields, income, and sustainability, emphasizing the importance of moisture conservation for coconut farming viability[7–10].

Cover cropping provides a multifaceted approach to address coconut grower challenges such as land degradation, low land productivity, and water scarcity[11,12]. Appropriate cover crop and management selection should align with climatic conditions and goals.

As eco-friendly agriculture gains prominence, cover crop integration into plantations will ensure long-term coconut sustainability and productivity. Cover crops can enrich soils through nitrogen fixation and organic matter addition[13]. Legumes have been shown to increase nitrogen in coconut soils, benefiting growth and yields[6,14]. Covers with dense roots aid soil stabilization and erosion control in erosion-prone plantations, promoting sustainability[15]. Some live covers can improve moisture retention in inconsistent rainfall[16]. Certain covers exhibit allelopathy, suppressing weed growth and allowing reduced herbicide use, while vigorous covers control weeds through shading[11,17,18]. Some covers attract pollinators, potentially improving pollination, nut set, and coconut yields. Cover crop shade can mitigate temperature and light stress, creating a favourable microclimate and potentially improving flower and nut production[11].

One promising cover crop is Sunn hemp (*Crotalaria juncea* L.). As a legume, *C. juncea* has the ability to fix atmospheric nitrogen, thereby improving soil fertility. Researchers have found that *C. juncea* can produce between 100 and 200 kg per hectare of fixed nitrogen when grown as a cover crop in the southeastern United States[19]. Additionally, *C. juncea* produces significant biomass. This dense biomass can suppress weeds and conserve soil moisture after termination[20]. However, *C. juncea* also produces allelopathic compounds as it decomposes, which may inhibit the germination and growth of some cash crops if not properly managed[19]. Overall, research suggests the nitrogen fixation abilities, biomass production, and weed suppression of *C. juncea* warrant its consideration as a warm-season cover crop. While used before in Sri Lanka, its potential in coconut plantations is underexplored. The primary objective of this research was to assess the feasibility of introducing Sunn hemp as a cover crop in the major coconut-growing soils of Sri Lanka by evaluating its growth performance under different soil types.

2. Materials and methods

The study was carried out at the Agronomy Division of the Coconut Research Institute of Sri Lanka in Lunuwila (located at 7.3559° N, 79.8727° E, with an elevation of 33 meters above sea level) within the Puttalam district. This region falls within the low country intermediate zone (IL1), characterized by an average annual rainfall of 1660 mm and an average temperature range of 23.8 °C–30.4 °C. A pot experiment was conducted inside a controlled plant house and the treatments were laid according to the completely randomized design involving forty-eight replicates. Sunn hemp seeds were planted in various soil types, namely sandy, loamy, and gravel, collected from major coconut-growing areas. Precise records were maintained for plant height, shoot fresh weight, shoot dry weight, root length, root fresh weight, root dry weight, and leaf area at 2, 4, 6, and 8 weeks during the growth stages. For each soil type, 12 replicates underwent destructive sampling. Following the drying process at 60 °C, the dry weights of both shoot and root samples were determined until they reached a constant weight. The analysis of the total nitrogen content of the plants at the 6 and 8-week growth stages was performed using the KjeltecTM 8200 Kjeldhal apparatus.

MINITAB 19 software was used in statistical analysis. Homoscedasticity and normality of all measured parameters were ensured by conducting normality and outlier tests and comparing data distribution across different treatments through box plots. The One-way Analysis of Variance (ANOVA) was employed at a significance level of 5%, followed by Tukey's pairwise comparison test to compare the mean values of the data statistically.

3. Results

3.1. Plant height of *Crotalaria juncea* grown in different soil types

Figure 1 illustrates the height progression of *C. juncea* plants over eight weeks under varying soil conditions. Noteworthy trends emerge, reflecting distinct patterns of plant height development in response to different soil compositions. For instance, at week 2, plants in sandy soil started at 15.28 cm, while those in gravel and loamy soils were at 15.13 cm and 12.30 cm, respectively. Over the subsequent weeks, the plants displayed varied growth rates. By week 8, the most substantial height was recorded in plants grown in sandy soil at 120.96 cm, followed by gravel soil at 74.58 cm and loamy soil at 52.75 cm. This figure provides valuable insights into how plant height evolves over time and across diverse soil conditions, emphasizing the influence of soil type on the growth patterns of *C. juncea* plants.

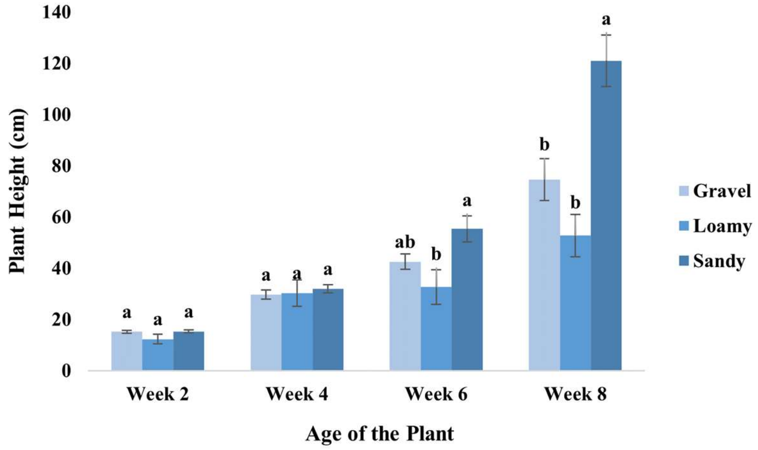

Figure 1. Plant height of *Crotalaria juncea* grown in different soil types.
Means that do not share a letter are significantly different

3.2. Shoot dry weight of *Crotalaria juncea* grown in different soil types

The shoot dry weight of *C. juncea* plants was examined over eight weeks in three distinct soil types (**Figure 2**). In the gravel soil, the shoot dry weight started at 0.057 g in week 2 and progressively increased to 3.299 g by week 8. For the loamy soil, the corresponding values were higher, commencing at 0.142 g in week 2 and peaking at 11.141 g by week 8. In the sandy soil, the shoot dry weight started at 0.072 g in week 2 and reached 6.755 g by week 8. The data reveals a consistent augmentation in shoot dry weight across all soil types as the weeks advanced. The plants in loamy soil consistently demonstrated higher shoot dry weights compared to those in gravel and sandy soils at each time point, emphasizing the influence of soil type on the growth performance of Sunn hemp.

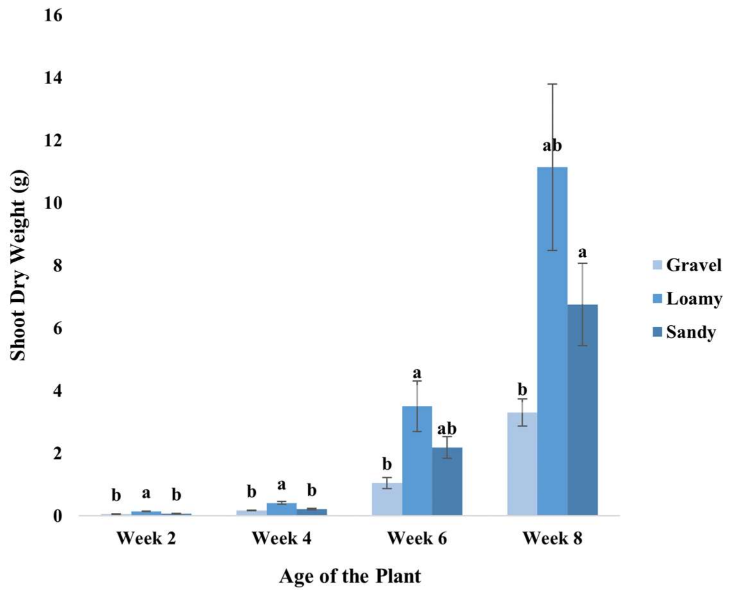

Figure 2. Shoot dry weight of *Crotalaria juncea* grown in different soil types.
Means that do not share a letter are significantly different

3.3. Root length of *Crotalaria juncea* grown in different soil types

Figure 3 represents the root length of *C. juncea* plants cultivated in three distinct soil types across a span of eight weeks. In the gravel soil, root length started at 10.17 cm in week 2 and progressively increased to 17.35 cm by week 8. For the loamy soil, the initial root length was 10.50 cm in week 2 and showed a steady rise, reaching 18.90 cm by week 8. In the sandy soil, the plants exhibited a slightly higher starting point with a root length of 12.61 cm in week 2, and by week 8, the root length had expanded to 21.79 cm. The data illustrates a consistent upward trend in root length for all soil types throughout the observation period. Notably, the sandy soil supported the greatest root length at each time point, suggesting that this soil type may be particularly favourable for the development of Sunn hemp root systems.

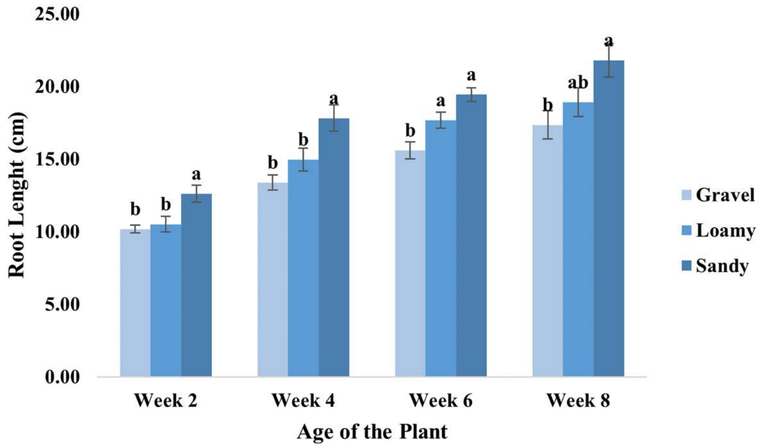

Figure 3. Root length of *Crotalaria juncea* grown in different soil types.
Means that do not share a letter are significantly different

3.4. Root dry weight of *Crotalaria juncea* grown in different soil types

Figure 4 outlines the root dry weight of *C. juncea* plants grown in three distinct soil types over eight weeks. In the gravel soil, the initial root dry weight was 0.011 g in week 2, progressively increasing to 0.475 g by week 8. In the loamy soil, the plants exhibited a higher starting root dry weight of 0.018 g in week 2, and this weight expanded considerably to 1.666 g by week 8. Sandy soil, with an initial root dry weight of 0.016 g in week 2, displayed a moderate increase, reaching 0.816 g by week 8. The data demonstrates a continual augmentation in root dry weight for all soil types as the observation period advanced. The loamy soil consistently supported the highest root dry weights at each time point, indicating its potential as a favourable environment for the accumulation of dry weight in Sunn hemp roots.

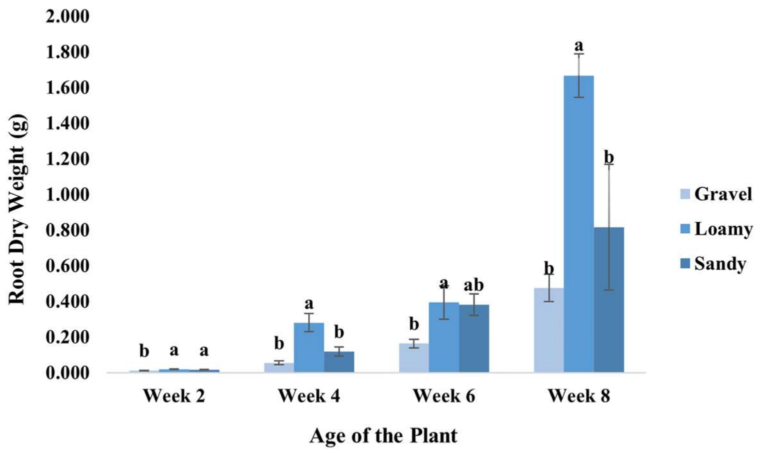

Figure 4. Root dry weight of *Crotalaria juncea* grown in different soil types.
Means that do not share a letter are significantly different

3.5. Leaf area of *Crotalaria juncea* grown in different soil types

Figure 5 presents a comprehensive overview of the leaf area dynamics in *C. juncea* plants across different soil types over eight weeks. Notably, the data reflects a substantial increase in leaf area for each soil type over the observational period. When examining the leaf area data, the highest leaf area was recorded in plants grown in loamy soils, followed by plants in sandy soils and then gravel soils. Specifically, at week 8, the leaf area for plants in loamy soil was 1059.27 cm², which was the highest among the three soil types. In comparison, plants in sandy soil had a leaf area of 882.38 cm², and plants in gravel soil had the smallest leaf area at 352.85 cm². Therefore, the order from highest to lowest leaf area is loamy, sandy, and gravel soils.

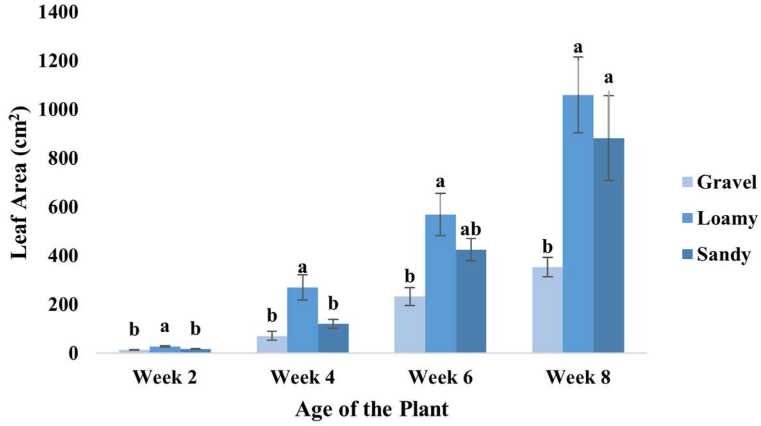

Figure 5. Leaf area of *Crotalaria juncea* grown in different soil types.
Means that do not share a letter are significantly different

3.6. The influence of various soil types on the nitrogen levels in *Crotalaria juncea*

Figure 6 illustrates the nitrogen content of plants at week 6 and week 8, expressed as a percentage and categorized by the soil type in which they were cultivated.

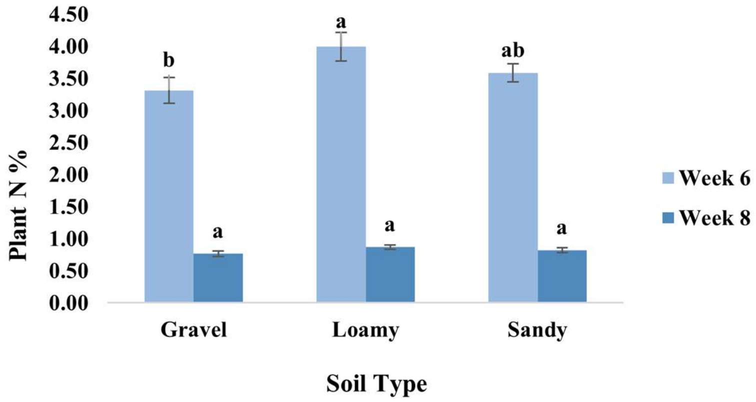

Figure 6. Nitrogen content of *Crotalaria juncea* plants grown in different soil types.
Means that do not share a letter are significantly different

At week 6, plants in gravel soil exhibited the lowest nitrogen content at 3.31%, while those in loamy soil recorded the highest level at 3.99%, followed by sandy soil at 3.59%. Importantly, there were significant differences in the mean nitrogen content among the various soil types at this stage. Moving to week 8, a general decrease in nitrogen content was observed across all soil types, with values of 0.77%, 0.87%, and 0.82% for gravel, loamy, and sandy soils, respectively. There were no significant differences in the mean nitrogen content among the different soil types at week 8.

4. Discussion

The results of this study provide valuable insights into the growth performance and nutrient accumulation of *Crotalaria juncea* under different coconut-growing soil types in Sri Lanka. In terms of growth parameters like plant height and root length, our study found that *C. juncea* performed the best in sandy soils, followed by loamy and gravel soils. The significantly greater plant height and root length observed in sandy soils could be attributed to reduced impedance to root growth in these well-aerated soils[21]. Sandy soils comprise large, loose particles[22]. This coarse texture significantly influences soil aeration, drainage, and its capacity to retain water and nutrients. Consequently, these characteristics challenge effective plant establishment and growth[23]. One of the key challenges that sandy soils pose is their limited water retention capacity. These soils tend to drain quickly, potentially causing water stress for plants, especially during arid periods[24]. This limitation necessitates plants to adapt and efficiently utilize available water resources.

Moreover, sandy soils often suffer from nutrient deficiencies due to their inability to retain essential mineral ions. Nutrient leaching is a common issue, leading to inadequate nutrient supply for plants[25]. Consequently, plants in such soils must develop specific strategies to access and utilize nutrients effectively. Typically, plants thriving in sandy soils develop deep and expansive root systems to tap into water reserves in deeper soil layers[26]. This adaptation enhances their ability to withstand drought conditions.

However, our findings indicate that loamy soils promote greater nutrient accumulation and biomass production (shoot/root dry weight) in *C. juncea*. Results have shown significantly higher plant nitrogen content and leaf area in loamy soils. This aligns with previous research attributing higher nutrient levels and growth in legumes grown in finer-textured soils to improved cation exchange and nutrient retention capacities[27,28]. The greater moisture availability in loamy soils likely also contributed to the increased leaf area and growth[21].

Loamy soils are characterized by their nearly equal proportions of sand, silt, and clay particles[23]. This harmonious texture strikes a balance between water-retention capacity of clay and drainage properties of sand, creating an ideal environment for plant growth. It ensures a consistent supply of water and oxygen to plant roots, promoting their well-being. One of the notable advantages of loamy soils is their ability to retain sufficient moisture while allowing excess water to drain away, effectively preventing waterlogged conditions[23]. This quality reduces the risk of water stress and root suffocation, which is highly beneficial for plant health.

Plants thriving in loamy soils often develop robust, well-branched root systems that efficiently explore the soil for water and nutrients[26]. The balanced texture of loamy soils encourages healthy root growth, supporting the overall health of plants. Loamy soils also foster diverse and abundant microbial communities due to their well-balanced physical and chemical properties[27]. These microbes are crucial in nutrient cycling and contribute to soil fertility, ultimately benefiting plant growth. Moreover, the granular structure of loamy soils promotes effective soil aeration and allows for easy root penetration, ensuring that plant roots have ready access to air and water[23]. This facilitates nutrient uptake and further enhances plant growth in loamy soils.

Gravel soils primarily comprise large, well-draining particles[28]. This coarse texture results in rapid water drainage, posing a challenge for plants to access moisture and nutrients. A primary hurdle of gravel soils is their limited water retention capacity, as water swiftly permeates through these soils, subjecting plants to frequent drought stress[29]. Consequently, plants dwelling in such conditions must employ specialized mechanisms to adapt to water scarcity. Furthermore, gravel soils often suffer from a deficiency in essential nutrients due to their poor cation exchange capacity. This nutrient limitation necessitates plants to develop efficient strategies for nutrient uptake[30]. In response, plants inhabiting gravel soils frequently exhibit drought tolerance through various means, including reducing transpiration rates, developing succulent tissues, and the ability to enter dormancy during periods of water scarcity[31].

The lower nitrogen content and leaf area in gravel and sandy soils highlight the importance of fertilization and irrigation for *C. juncea* cultivation in these coarse-textured soils, as noted earlier. The comparative limitations in gravel and sandy soils point to the need for proper inputs to overcome moisture and nutrient deficits.

Overall, our findings indicate *C. juncea* can be effectively grown as a cover crop across coconut soils in Sri Lanka. With proper management, it can perform well even in marginal soils. As *C. juncea* can enrich soils and improve plantation sustainability, integrating it as a cover crop could benefit diverse coconut regions in Sri Lanka. Further on-farm testing could help optimize its cultivation across soil types[32].

5. Conclusion

The findings from this study provide valuable insights into the performance of *C. juncea* as a cover crop across major coconut-growing soils in Sri Lanka. Overall, *C. juncea* displayed favourable growth attributes and nutrient accumulation across the prominent coconut soil types tested: gravel, sandy, and loamy soils. In terms of vegetative growth parameters like plant height and root length, sandy soils supported the best performance of *C. juncea*. However, plants grown in loamy soils demonstrated superior nutrient uptake, biomass production, and leaf area expansion. *C. juncea* growth in gravel soils was comparatively lower but still substantial. Adequate inputs like irrigation and fertilization could further enhance *C. juncea* cultivation in marginal gravel or sandy soils. With proper management, *C. juncea* can likely perform well as a cover crop across the diverse agroecological regions where coconut is grown in the country. The ability of *C. juncea* to enrich soils through nitrogen fixation, build organic matter, aid moisture conservation, and control weeds and erosion makes it an excellent cover crop candidate for coconut plantations aiming to enhance sustainability and productivity. Integrating *C. juncea* as a cover crop could therefore confer multiple benefits, especially in relation to improving soil health, moisture retention, and erosion control in coconut farms. Further on-farm testing could help refine optimal practices for Sunn hemp cultivation across soil types. Overall, our results highlight the promising potential of *C. juncea* to be established as an effective, multifunctional cover crop throughout major coconut-growing areas in Sri Lanka.

Author contributions

Conceptualization, SSU and AJA; methodology, SSU and EPT; validation, AJA and NSD; formal analysis, TDN; investigation, SSU; writing—original draft preparation, TDN and SSU; writing—review and editing, AJA and NSD; visualization, TDN and SSU; supervision, AJA; project administration, AJA. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare no conflict of interest.

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