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Velvet Bean (*Mucuna pruriens*) Productivity Undershade as a Feed Source

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ABSTRACT
This research, conducted under the shade of Albizia chinensis trees in Kediri, Indonesia, specifically tested whether pruning the beans at different growth stages (80, 100, or 120 days after planting) would boost productivity. Using a rigorous randomized block design across an 800 m² field, the study measured fresh and dry biomass, along with seed yields. The key finding was that the timing of pruning made no significant difference to the final yield. Instead, the most important factor was something more fundamental: access to water. Plots closer to a water source performed better, highlighting that basic resource availability is far more critical than pruning in this type of agroforestry system. While there were slight yield increases in some pruned plots, the results were too inconsistent to be statistically meaningful. Ultimately, the study confirms that velvet bean is a resilient crop, capable of growing with minimal inputs in shaded conditions. To truly optimize its production as a soybean alternative, farmers and agroforesters should focus on integrated strategies like improving irrigation or soil health, rather than investing effort in pruning. This work provides valuable insights for cultivating resilient legumes in challenging environments.

Keywords: Alternative Legumes, Biomass Production, Feed Security, Nitrogen Fixation, Yield Stability.

INTRODUCTION

Soybean remains a foundational component of both human diets and livestock feed on a global scale, yet many nations struggle with a growing reliance on soybean imports that can lead to economic and environmental vulnerabilities (Sun et al., 2018; Liu et al., 2022). For instance, Indonesia has imported most of its soybean supply to fulfill domestic needs (BPS, 2024), exposing producers and consumers alike to price fluctuations and international trade dynamics (Ren et al., 2021). Consequently, various researchers have emphasized the search for alternative protein sources to safeguard food security, reduce import dependency, and mitigate ecological damage (Zhan, 2024).

Agroforestry has emerged as a promising strategy to address some of these concerns by integrating trees with annual or perennial crops, including legumes (Vargas et al., 2021). In contrast to homogeneous monocultures, agroforestry offers diversified land use that can improve soil fertility, enhance pest and weed management, and foster higher overall biodiversity (Alves et al., 2018). Studies also suggest that intercropping with leguminous species can facilitate nitrogen fixation and thereby decrease the need for synthetic fertilizers, contributing to long-term sustainability in agricultural systems (Shoko et al., 2015). Recent research on cacao-based agroforestry in conservation areas and other mixed-crop designs has highlighted farmer participation and local economic benefits, indicating strong potential for scaling up such practices (Murniati et al., 2022). Nonetheless, the performance of alternative protein sources under agroforestry conditions requires deeper investigation, particularly in contexts where water availability and soil conditions vary greatly.

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Within this scope, *Mucuna pruriens* (velvet bean) has attracted attention as a versatile legume with potential to replace or supplement soybean in livestock feed (Muhartatik, 2024). Historically, *Mucuna pruriens* seeds were occasionally processed for human food items like tempeh, although shifts in commodity markets led to diminished cultivation (Rachel, 2021). Ongoing research underscores the seeds' notable protein content and beneficial compounds, including peptides that may offer antioxidant and protective effects (Leo et al., 2019). Certain studies report encouraging results when using fermented or processed velvet bean in feed rations for fish, poultry, and swine (Ibrahim et al., 2018; Santos-Ricalde et al., 2019; Théopihile et al., 2017), while others propose its integration for broader agronomic benefits, such as weed suppression and soil organic matter enhancement (Ezegbe et al., 2023). As with many legumes, *Mucuna pruriens* can contribute to nitrogen fixation, thereby reducing reliance on external fertilizers and potentially improving soil health over time. However, adoption rates remain limited, in part due to knowledge gaps regarding optimal management practices in different agroecological contexts.

Pruning has been proposed as a viable technique to enhance crop growth, encourage flowering, and potentially increase yields by redirecting the plant's energy resources toward reproductive structures (Riyandhini et al., 2023). Previous research on various leguminous species, such as Canavalia ensiformis or Vigna unguiculata, suggests that pruning can bolster biomass and seed production when timed appropriately (Riyandhini et al., 2023). Moreover, competition for water and nutrients between trees and understory species could confound any potential benefits of pruning unless such factors are closely monitored. Despite the emerging consensus that agroforestry can provide ecological and agronomic advantages (Murniati et al., 2022), inconsistencies persist in identifying which agronomic practices optimally support legumes, especially under tree canopies (Vargas et al., 2021). The quantity and quality of biomass, as well as seed nutritional attributes, can vary considerably with environmental gradients and management inputs (Theopihile et al., 2017; Ezegbe et al., 2023). Hence, there is a pressing need for replicated field experiments that meticulously evaluate pruning interventions in relation to water, soil, and shading parameters. Identifying these would inform evidence-based recommendations for farmers seeking to incorporate *Mucuna pruriens* as an alternative protein source, thereby reducing their reliance on soybean meal while enhancing ecological sustainability (Musthafa et al., 2018; Zhan, 2024).

This study, therefore, addresses a critical gap by examining how pruning practices affect the productivity of *Mucuna pruriens*, grown under *Albizia chinensis* shade in a low-input agroforestry setting. By measuring fresh and dry biomass and seed yields, the research aims to clarify whether pruning contributes to productivity improvements or whether factors such as proximity to water sources overshadow potential benefits

RESEARCH METHODS

Experimental Design and Study Site

This research was conducted within a smallholder agroforestry system in Puncu District, Kediri Regency, Indonesia, where *Mucuna pruriens* (velvet bean) was intercropped under *Albizia chinensis* (sengon) canopy. The experimental site (800 m²) was chosen for its representative shaded environment and marginal soil conditions, which align with common smallholder contexts (Akoto et al., 2020). Its shaded setting provided an opportunity to evaluate the performance of velvet bean in conditions like other woody polycultures and tree-based intercropping systems (Lovell et al., 2017; Dupraz et al., 2019).

A randomized block design (RBD) was employed to control for heterogeneity in soil fertility and microclimatic factors across the site, consistent with established protocols for agroforestry field experiments. Four pruning treatments were applied at different growth stages: no pruning (P0), pruning at 80 days after planting (P1), pruning at 100 days after planting (P2), and pruning at 120 days after planting (P3). Each treatment was replicated four times, resulting in 16 experimental units. This design allowed for the statistical evaluation of potential differences in biomass and seed yield among treatments.

Pruning, Planting, and Data Collection

Mucuna pruriens seeds were pre-germinated for five days before transplanting into the experimental plots. Plant spacing was maintained at approximately 75 cm × 40 cm to allow adequate room for vine extension and reduce intraspecific competition (Vargas et al., 2021). No additional fertilizer applications were made, in line with the low-input nature of this agroforestry setting (Murniati et al., 2022; Miller et al., 2019). Manual weeding was conducted every two to four weeks to limit weed interference, although partial weed suppression by velvet bean was also anticipated (Ezegbe et al., 2023).

The pruned sections involved cutting branches 60 cm from the tips, ensuring uniform application of pruning intensity across treatments. The pruning times were 80, 100, or 120 days after planting. Control plots (P0) underwent standard management without pruning, allowing for baseline comparison (Chittapur and Murthy, 2018; Maitra et al., 2021).

Data collection centered on both vegetative growth and seed yield, parameters widely used as indicators of *Mucuna pruriens* productivity (Leo et al., 2019). Vegetative biomass was recorded at harvest in two main forms: fresh biomass and dry biomass. Fresh biomass involved weighing the entire aboveground portion of the plant (leaves and stems) immediately following harvest (Theopihile et al., 2017; Ezegbe et al., 2023). Samples for dry biomass determination were oven-dried at 70°C until a constant weight was attained. Seed yield was similarly measured in fresh and dry forms. Fresh seed mass was determined immediately upon harvesting the pods, while air-drying was used to obtain the dry seed weight (Muhartatik, 2024).

Statistical Analysis

Following data collection, analyses of variance (ANOVA) were performed to detect significant differences in biomass and seed production among the four pruning treatments and across the randomized blocks. When ANOVA results indicated significant variation ($p<0.05$), Duncan's Multiple Range Test (DMRT) was used for post-hoc comparisons.

RESULT AND DISCUSSION

This section presents the outcomes of assessing different pruning treatments (no pruning and pruning at 80, 100, or 120 days after planting) on *Mucuna pruriens* (velvet bean) grown under *Albizia chinensis* (sengon) shading. The results encompass vegetative biomass, seed production, and notable environmental influences, including variations in water availability. Data are organized into subsections addressing biomass accumulation (fresh and dry forms) and seed yield (fresh and dry). Where relevant, comparisons with earlier studies are integrated to contextualize findings within broader research on pruning, agroforestry, and legume physiology.

Biomass Production

Leaves and Stems

Fresh biomass is a vital measure of vegetative growth, essential for understanding potential forage availability and the overall vigor of M. pruriens under shading. As shown in Table 1, average fresh biomass varied from approximately 14.5 kg/24 m² in the non-pruned plots (P0) to 20.0 kg/24 m² in the pruned plots, though these variations did not always reach statistical significance ($p > 0.05$). Plots subjected to pruning at 80 days (P1) and 120 days (P3) tended to exhibit higher fresh biomass than the control (P0), yet the differences among pruning treatments themselves were not definitive.

Table 1. The Average of Fresh Biomass Yield (kg/24 m²)

Treatment	Fresh Yield (kg/24m^2)	DM Yield (kgDM/24m^2)
P0	14.57 $\pm$ 7.77	5.95 $\pm$ 3.16
P1	20.04 $\pm$ 4.65	7.87 $\pm$ 2.21
P2	16.45 $\pm$ 4.74	6.83 $\pm$ 2.03
P3	19.69 $\pm$ 3.72	8.55 $\pm$ 1.41

Source: Data Processed

These results partially parallel findings in cowpea (Vigna unguiculata), where leaf pruning enhanced biomass production under certain environmental conditions (Kilbaren, 2023). However, the modest overall impact here suggests that M. pruriens may exhibit a degree of phenotypic plasticity that offsets the removal of vegetative structures (Basheer-Salimia et al., 2021; Nadeem et al., 2019). Moreover, earlier literature underscores that the success of pruning-induced regrowth depends on timing, intensity, and concurrent resource availability (Ndereyimana et al., 2021; Budiarto et al., 2023). In this study, fluctuating moisture levels and partial shading from sengon trees could have interacted with pruning in complex ways, dampening any substantial effect (Baligar et al., 2020).

While the block effect (e.g., distance to water source) was not the focus, a recurring observation was that plots closer to water access consistently yielded higher fresh biomass. This aligns with prior evidence that adequate water supply is critical for legumes, especially those grown in tropical agroforestry systems with variable rainfall (San et al., 2023). Variations in fresh biomass likely also reflect microclimatic differences, consistent with studies showing that legume performance correlates significantly with localized conditions such as soil moisture, shade intensity, and soil microbial communities (Pausch and Kuzyakov, 2017; Silva et al., 2023).

Dry biomass measurements provide a more stable indicator of the usable portion of the plant, relevant for forage analysis and feed formulations (Theopihile et al., 2017; Ezegbe et al., 2023). In this study, recorded dry biomass followed a similar trend to fresh biomass. Although marginally higher mean values were detected in plots pruned at 80 days (P1) and 120 days (P3), statistical analyses did not reveal significant differences among treatments ($p>0.05$). Average dry biomass ranged from around 5.95 kg/24 m² (P0) to 8.55 kg/24 m² (P3).

Soil fertility levels across blocks could partly explain the lack of clear pruning effects, as nutrient deficits may have masked any gains from resource re-allocation following pruning (Chittapur and Murthy, 2018; Maitra et al., 2021). Moreover, partial shading might mitigate photoinhibition in tropical climates but could also limit the potential to capitalize on post-pruning regrowth surges (Baligar et al., 2020). Notably, the results here corroborate Santos et al. (2016), who reported that pruning benefits in Jatropha sp. were less evident under suboptimal resource conditions.

Seed Production

Immediate Post-Harvest Seed Weights.

Fresh seed yield is central to evaluating *Mucuna pruriens* performance as a potential feedstuff. Observations indicate that pruning treatments did not lead to statistically significant differences in fresh seed yield ($p>0.05$). The highest average fresh seed production, around 11.79 kg/24 m², was observed in P3 (pruning at 120 days), followed closely by P1 (pruning at 80 days). Meanwhile, the control (P0) and the P2 (pruning at 100 days) plots yielded comparably lower values, though the differences were within the margin of statistical variation.

This pattern partially echoes some findings in cowpea, watermelon, and other horticultural crops where timing of pruning can influence fruit or seed set (Ndereyimana et al., 2021; Kilbaren, 2023). However, the overall non-significant result reiterates that M. pruriens, under the given agroforestry conditions, may be less responsive to pruning in terms of immediate reproductive output. Alternatively, external factors such as shading intensity and sporadic rainfall might have overshadowed any incremental gains from pruning (Baligar et al., 2020; Nadeem et al., 2019). The fact that blocks situated nearer to water sources tended to produce higher fresh seed yields further underscores the key role of moisture, suggesting that improved irrigation management might amplify the crop’s productive potential (Maitra et al., 2021).

Dry seed yield ranged from 2.17 to 2.95 kg per 24 m². While pruning treatments did not exert a statistically significant main effect, block-level differences were pronounced ($p < 0.01$), mirroring trends in fresh seed yield. Areas in closer proximity to water sources exhibited consistently higher dry seed outputs, reaffirming that water availability is a limiting factor in legume seed production under agroforestry (Nadeem et al., 2019; Ayalew et al., 2022).

Table 2. Fresh and Dry Seed Yield (kg/24 m²)

Treatment	Seed Fresh Yield (kg/24m^2)	DM Seed Yield (kgDM/24m^2)
T0	8.66 $\pm$ 4.26	2.17 $\pm$ 1.06
T1	10.19 $\pm$ 3.58	2.55 $\pm$ 0.89
T2	9.83 $\pm$ 3.21	2.46 $\pm$ 0.80
T3	11.79 $\pm$ 2.62	2.95 $\pm$ 0.66

Source: Data Processed

The relatively modest dry seed yields also align with historical observations of M. pruriens grown in resource-limited environments, where the crop's adaptability often ensures stable performance but may not always reach maximal yield potential (Shoko et al., 2015; Ibrahim et al., 2018; Musthafa et al., 2018). From a feed perspective, the seed's nutritional profile, including protein content, can be more pertinent than raw yield quantity alone (Ezegbe et al., 2023; Theopihile et al., 2017). Further analyses (e.g., proximate composition or in vitro digestibility) could elucidate the practical implications of these yields for livestock systems, especially where velvet bean is intended to complement or replace soybean (Zhan, 2024; Nadeem et al., 2019).

Discussion

The findings from this study underscore the complexity of managing *Mucuna pruriens* in an agroforestry system under partial shade, low-input conditions, and moderate rainfall. Despite earlier research suggesting that pruning can direct plant energy toward improved seed or biomass production (Ndereyimana et al., 2021; Budiarto et al., 2023), the data here indicate that pruning intervals at 80, 100, and 120 days after planting did not yield statistically significant gains in fresh or dry biomass, nor in seed yield, when compared to non-pruned controls. However, the consistent observation that blocks closer to water resources produced greater biomass and seed yields implies that environmental factors, such as soil moisture, likely overshadowed any potential benefits from pruning. This result aligns with multiple studies documenting that, under stress conditions whether water or nutrient related legume performance becomes more dependent on resource availability than on subtle canopy manipulations (Zhang et al., 2018).

A critical aspect is how pruning timing may interact with canopy architecture and resource reallocation in shaded environments. Although some crops display enhanced productivity when selectively pruned to manage canopy density and facilitate reproductive development (Kilbaren, 2023; Ndereyimana et al., 2021), the absence of such an effect in M. pruriens might reflect a few key factors. First, the sengon (*Albizia chinensis*) canopy provides heterogeneous shade, potentially causing highly localized variations in light intensity that limit uniform plant responses (Baligar et al., 2020; Raai et al., 2020). Second, M. pruriens has a degree of physiological plasticity, indicating it can maintain growth under a range of suboptimal conditions without necessarily displaying dramatic yield fluctuations (Murniati et al., 2022; Umesh et al., 2022). This plasticity may result in the plant compensating for pruned tissues through accelerated lateral shoot or leaf growth when moisture is adequate, thus diluting any net advantage of a single pruning event (Tamele et al., 2017).

The fresh and dry biomass data showed only marginal numerical increases in some pruned treatments (notably at 80 and 120 days) but lacked statistical significance. This outcome partially resonates with studies on other tropical forage legumes exposed to shading, which often demonstrate variable biomass responses depending on shade level, developmental stage, and nutrient availability (Almeida et al., 2019; Cruz et al., 2020; Baligar et al., 2020). Furthermore, the observed seed yields, ranging from 2.17 to 2.95 kg/24 m² in dry form, are in line with historical performance records of M. pruriens in marginal environments (Shoko et al., 2015; Musthafa et al., 2018; Theopihile et al., 2017). While pruning interventions did not clearly enhance seed production, prior research on other legumes such as cowpea shows that a combination of pruning intensity, shading level, and bradyrhizobium inoculation can significantly affect yield (Ayalew et al., 2022; Perez-Fernández, 2024). Thus, the apparent lack of response here does not necessarily invalidate pruning as a management option; it may simply indicate that co-limiting factors, most notably water availability, remain the primary drivers of yield in this setting (Maitra et al., 2021).

An additional interpretive angle is how photosynthetic performance may have been influenced by pruning. Several studies note that leaf removal can trigger compensatory photosynthesis in remaining leaves if sufficient light, water, and nutrients exist (Gujjar et al., 2020; Jing et al., 2018; Ali et al., 2021). However, heavy pruning in tree crops sometimes reduces photosynthetic capacity and growth if the plant's carbohydrate reserves are not robust (Suchocka et al., 2021; Jing et al., 2018). In forage legumes, moderate defoliation can stimulate rapid regrowth, but only when environmental conditions are supportive (Tamele et al., 2017; Basheer-Salimia et al., 2021). Here, partial shading and intermittent moisture likely constrained any potential advantage from pruning-induced regrowth. Altogether, these elements underscore the need to view pruning as just one among multiple agronomic levers, whose efficacy is contingent upon aligned environmental conditions (Zhan, 2024; Rahmati et al., 2015).

The robust performance of *Mucuna pruriens* in low-input, partially shaded systems, even without strong pruning responses, still holds value for agroforestry. Legumes like M. pruriens contribute to soil nitrogen levels, suppress weeds, and offer protein-rich seeds that can reduce reliance on soybean imports, aligning with national food security strategies (Zhan, 2024). Studies on tropical legume species underscore that shade tolerance in these plants can sustain moderate yields in intercropped scenarios, thus broadening the ecological services of agroforestry setups (Almeida et al., 2019; Raai et al., 2020; Cruz et al., 2020). The present results expand on this foundation by emphasizing that environmental parameters, specifically water accessibility, often dictate yield outcomes more decisively than a single practice like pruning. Future research could explore how irrigation regimes, combined with strategic pruning, might unlock greater yield stability or enhanced biomass, consistent with suggestions to integrate water management in pruning-related experiments (Santos et al., 2016; Ali et al., 2021).

CONCLUSION

This study illustrates that *Mucuna pruriens* can successfully adapt to shaded and marginal agroforestry conditions, providing stable biomass and seed yields even without intensive external inputs. Contrary to reports suggesting that pruning can strongly enhance production, the results here showed no statistically significant differences in fresh or dry biomass, nor in seed yield, when comparing non-pruned plants to those pruned at 80, 100, or 120 days after planting. Instead, environmental variables, particularly water availability, emerged as more decisive factors in shaping crop outcomes. These findings indicate that pruning alone may not be sufficient to boost productivity in resource-constrained settings, underscoring the importance of integrated management approaches that consider site-specific conditions. Based on these findings, farmers should prioritize securing water access for velvet bean in shaded agroforestry, as it is more critical for yield than pruning. Efforts are better directed toward improving irrigation and soil fertility rather than implementing pruning practices.

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