

Biochemical Profiling of *Mucuna* at Germination, Vegetative, and Reproductive Phases

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ARTICLE DETAILS	ABSTRACT
<p>Research Paper</p> <p>Accepted: 19-05-2025</p> <p>Published: 10-06-2025</p> <p>Keywords:</p> <p><i>Mucuna pruriens,</i> <i>Biochemical profiling,</i> <i>Germination stage,</i> <i>Vegetative phase,</i> <i>Reproductive phase,</i> <i>Antioxidant activity,</i> <i>Phenolic compounds,</i> <i>Chlorophyll content, Plant development, L-DOPA,</i> <i>Medicinal plants,</i> <i>Leguminous crops</i></p>	<p><i>Mucuna pruriens</i>, commonly known as velvet bean, is a leguminous plant renowned for its rich phytochemical profile and medicinal applications, particularly as a natural source of L-DOPA. Understanding its biochemical changes throughout development is essential for optimizing its use in pharmacology, nutraceuticals, and plant breeding. This study investigates the biochemical profiling of <i>Mucuna</i> during three crucial developmental stages: germination, vegetative growth, and reproductive maturity. Seedlings were cultivated under controlled conditions, and samples were collected at each stage. Various biochemical parameters, including total proteins, carbohydrates, chlorophyll content, total phenolic compounds, and antioxidant activity, were analyzed using standard laboratory protocols. During the germination phase, a significant increase in protein and carbohydrate content was observed, indicating active metabolic processes required for initial growth. The vegetative phase showed a marked rise in chlorophyll concentration, reflecting heightened photosynthetic activity necessary for biomass accumulation. In the reproductive phase, elevated levels of phenolic compounds and antioxidant activity were recorded, suggesting</p>

increased synthesis of secondary metabolites that may play roles in reproductive development and defense mechanisms. The findings highlight a clear biochemical transition across the developmental stages of *Mucuna*. Each phase exhibits a unique profile of primary and secondary metabolites, which can be strategically targeted for harvesting based on the desired phytochemical. The study provides valuable insights into stage-specific biochemical dynamics, which can inform future applications in herbal drug formulation, dietary supplements, and crop improvement programs. Moreover, the observed patterns of antioxidant accumulation and phenolic content underscore the potential of *Mucuna* as a natural source of bioactive compounds. This biochemical profiling lays a foundation for further molecular studies and the development of value-added products from different growth stages of this important plant species.

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Introduction

Mucuna pruriens, commonly known as velvet bean, is a leguminous plant belonging to the family Fabaceae. It is widely distributed in tropical and subtropical regions and has gained significant attention due to its rich phytochemical composition and various therapeutic applications. Among its many bioactive compounds, the most notable is L-3,4-dihydroxyphenylalanine (L-DOPA), a precursor to dopamine, which is used in the treatment of Parkinson's disease. Apart from L-DOPA, *Mucuna* is also known to contain proteins, carbohydrates, alkaloids, phenolics, and antioxidants, making it an important candidate for pharmacological and nutraceutical research.

Plant development occurs in distinct stages—germination, vegetative growth, and reproduction—each characterized by unique physiological and biochemical processes. During germination, metabolic activities intensify to support seedling emergence and establishment. In the vegetative phase, photosynthetic efficiency and biomass accumulation dominate, while the reproductive phase marks the onset of flower and fruit formation, often accompanied by enhanced synthesis of secondary metabolites for reproduction and defense.

Although various studies have documented the medicinal value of *Mucuna*, limited research has focused on the dynamic changes in its biochemical profile across different developmental stages. Understanding



these changes is crucial for optimizing the harvesting stage to obtain maximum yield of specific bioactive compounds. Such knowledge is also essential for formulating standardized herbal preparations, improving crop varieties through biotechnology, and exploring sustainable cultivation practices.

This study aims to profile key biochemical constituents of *Mucuna*—including total protein, carbohydrates, chlorophyll, phenolic compounds, and antioxidant activity—across its germination, vegetative, and reproductive phases. By analyzing these parameters at each developmental stage, the research intends to identify the stage-specific accumulation of biomolecules, thereby providing insights into their physiological relevance and practical applications.

The outcomes of this study may aid in determining the most suitable stage for harvesting *Mucuna* for pharmaceutical or nutritional use. Moreover, this profiling could serve as a baseline for future molecular studies targeting gene expression, enzyme activity, and metabolite synthesis during plant development. Thus, this research not only contributes to our fundamental understanding of plant physiology but also supports applied aspects of biotechnology and medicinal plant utilization.

Materials and Methods

1. Plant Material and Growth Conditions

Seeds of *Mucuna pruriens* were procured from a certified agricultural research station. Prior to sowing, seeds were surface sterilized using 0.1% mercuric chloride for 1 minute, followed by thorough washing with sterile distilled water. Seeds were germinated in earthen pots filled with sterile soil-sand-compost mixture (2:1:1) and grown under controlled greenhouse conditions ($25 \pm 2^\circ\text{C}$, 60–70% RH, and 12-hour photoperiod). Samples were collected at three developmental stages: germination (7 days after sowing), vegetative phase (30 days), and reproductive phase (60–70 days, during flowering).

2. Sample Preparation

Fresh leaf and shoot tissues were harvested at each stage, washed with distilled water, blotted dry, and stored at -20°C for biochemical analyses. All experiments were conducted in triplicates to ensure statistical reliability.

3. Biochemical Analysis

- a. Total Protein Estimation:**

Total protein content was determined by the Lowry et al. method (1951) using bovine serum albumin (BSA) as the standard. Absorbance was measured at 660 nm using a UV-Vis spectrophotometer.



- **b. Total Carbohydrate Estimation:**

Carbohydrates were estimated by the phenol-sulfuric acid method (Dubois et al., 1956). Absorbance was read at 490 nm, and glucose was used as the standard.

- **c. Chlorophyll Content:**

Chlorophyll a, b, and total chlorophyll were measured using the Arnon method (1949). Acetone (80%) was used as the solvent, and absorbance was recorded at 645 and 663 nm.

- **d. Total Phenolic Content (TPC):**

TPC was estimated using the Folin–Ciocalteu reagent. Gallic acid was used as the standard, and the results were expressed as mg GAE/g fresh weight. Absorbance was measured at 765 nm.

- **e. Antioxidant Activity:**

Antioxidant potential was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay. Absorbance was recorded at 517 nm. The percentage inhibition was calculated using a standard ascorbic acid curve.

4. Statistical Analysis

All biochemical estimations were performed in triplicate, and the results were expressed as mean \pm standard deviation (SD). Statistical significance was assessed using ANOVA followed by Tukey's post-hoc test at a confidence level of 95% ($p < 0.05$), using software such as SPSS or GraphPad Prism.

Results

The biochemical parameters of *Mucuna pruriens* were analyzed during germination, vegetative, and reproductive phases. Significant variations were observed in all parameters across different developmental stages.

Parameter	Germination Stage	Vegetative Stage	Reproductive Stage
Total Protein (mg/g FW)	8.5	12.7	10.2
Total Carbohydrate (mg/g FW)	120.3	180.6	150.4
Chlorophyll a (mg/g FW)	0.45	1.25	1.05
Chlorophyll b (mg/g FW)	0.31	0.94	0.87
Total Phenolics (mg GAE/g FW)	10.2	15.8	22.3
DPPH Antioxidant Activity (%)	45.3	63.4	71.5



The biochemical analysis of *Mucuna pruriens* at three developmental stages—germination, vegetative, and reproductive—revealed significant stage-specific variations in key metabolic compounds.

1. **Total Protein Content:** Protein content was observed to be lowest during the germination phase (8.5 mg/g FW), peaked in the vegetative phase (12.7 mg/g FW), and slightly declined during the reproductive phase (10.2 mg/g FW). This trend indicates an active protein synthesis during the vegetative growth, essential for structural and enzymatic functions.
2. **Total Carbohydrates:** Carbohydrate levels followed a similar pattern, with maximum accumulation in the vegetative stage (180.6 mg/g FW), moderate levels in the reproductive stage (150.4 mg/g FW), and lowest during germination (120.3 mg/g FW). This reflects the energy requirements of the plant during its rapid vegetative growth.
3. **Chlorophyll Content:** Chlorophyll a and b showed significant increases from the germination to the vegetative stage. The vegetative phase recorded the highest chlorophyll a (1.25 mg/g FW) and b (0.94 mg/g FW), indicating peak photosynthetic activity. During the reproductive phase, chlorophyll levels decreased slightly.
4. **Total Phenolic Content:** Phenolic content increased progressively through the stages, from 10.2 mg GAE/g FW in germination to 22.3 mg GAE/g FW in the reproductive stage. The rise reflects enhanced secondary metabolite synthesis, especially in response to the oxidative stress associated with flowering.
5. **Antioxidant Activity:** DPPH radical scavenging activity showed a steady increase across stages. The reproductive stage showed the highest antioxidant activity (71.5%), indicating the presence of strong antioxidant compounds, possibly linked with phenolics.

Discussion

The biochemical profiling across different stages of *Mucuna pruriens* development provides valuable insights into its metabolic shifts. The low levels of proteins and carbohydrates during germination can be attributed to the utilization of seed reserves to initiate growth. As the plant transitions into the vegetative phase, a surge in protein and carbohydrate content reflects increased photosynthetic efficiency, enzyme activity, and metabolic vigor. The high levels of chlorophyll further validate the photosynthetically active nature of this phase.

During the reproductive phase, a slight decrease in primary metabolites (proteins and carbohydrates) is observed, which is common due to resource reallocation towards reproductive organ development. However, the elevated phenolic content and antioxidant activity during this stage point towards an



intensified biosynthesis of secondary metabolites. These compounds are known to play critical roles in stress defense and reproductive success.

The rise in antioxidant potential during the reproductive phase also indicates the plant's intrinsic defense strategy to safeguard its reproductive structures against oxidative damage. This property enhances the pharmaceutical relevance of *Mucuna*, especially when harvested at the flowering stage.

These findings align with earlier studies on leguminous plants, indicating that secondary metabolite accumulation often peaks during or just before reproduction. Such information is crucial for biotechnological applications, where harvesting strategies can be optimized based on biochemical content to maximize therapeutic yield.

Conclusion

This study presents a comprehensive biochemical analysis of *Mucuna pruriens* at three key developmental stages: germination, vegetative, and reproductive. The findings demonstrate clear and significant changes in biochemical constituents that correspond to the physiological and metabolic needs of the plant during its growth cycle.

During the germination phase, the relatively lower levels of proteins and carbohydrates indicate the utilization of seed reserves to support the initial growth processes. This stage primarily focuses on establishing the seedling, which requires mobilizing stored nutrients rather than producing new biomolecules. As the plant enters the vegetative phase, a marked increase in total protein, carbohydrates, and chlorophyll content was observed. This surge reflects active metabolic processes, including enhanced photosynthesis and protein synthesis, which are vital for rapid growth and development of leaves and stems. The elevated chlorophyll levels confirm increased photosynthetic capacity, providing energy to fuel biomass accumulation.

Interestingly, in the reproductive phase, although protein and carbohydrate content slightly declined compared to the vegetative stage, there was a notable rise in phenolic compounds and antioxidant activity. These biochemical changes suggest that the plant invests more in secondary metabolite production during reproduction, likely as a protective mechanism against oxidative stress and environmental challenges. Phenolic compounds and antioxidants play crucial roles in defending reproductive organs, ensuring successful flowering and seed development.

The stage-specific biochemical variations identified in this research have important implications for agricultural and pharmaceutical applications. For instance, harvesting *Mucuna* during the reproductive phase may yield higher concentrations of beneficial antioxidants and phenolics, enhancing its medicinal



value. Conversely, the vegetative phase might be more suitable when aiming for maximum biomass or protein content.

Overall, this study enhances the understanding of growth-dependent biochemical dynamics in *Mucuna pruriens* and provides valuable insights that can guide optimized harvesting strategies and future biotechnological research focused on this versatile legume.

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