

Research Article

Varietal insights into the allelopathic arsenal of *Mucuna pruriens* (L.) DC.

Upama Kalita¹, Arun Chettri¹ and N. Sathyanarayana^{2*}

1. Department of Botany, Sikkim University, 6th Mile, Gangtok, Sikkim, India.

2. Department of Life Science, Central University of Karnataka, Kadaganchi, Karnataka, India.

Abstract: The allelopathic activity of different *Mucuna pruriens* (L.) DC. varieties hold considerable potential for developing bioherbicidal cover crops. This study assessed varietal differences in the allelopathic potential of two *M. pruriens* varieties on rice, *Oryza sativa* L., and maize, *Zea mays* L. A Petri dish bioassay was performed using aqueous extracts from dried tissues of each variety, and the L-DOPA content of various plant parts was quantified by HPLC. Although seed germination was less sensitive to allelopathic effects, seedling growth showed dose-dependent inhibition, with root growth more strongly affected than shoot growth. A significant inter-varietal difference in L-DOPA content was recorded; both varieties demonstrated strong allelopathic effects. Notably, leaf extracts—despite having the lowest L-DOPA levels—exhibited the highest inhibitory activity. These findings suggest that the allelopathic effects of *M. pruriens* are not solely mediated by L-DOPA, contradicting the earlier hypothesis. Instead, other factors, such as plant organ type and extract concentration, strongly influence them.

Keywords: *Mucuna pruriens*, allelopathy, cover crop, intraspecific variation, L-DOPA

Introduction

Allelopathy, a specialized form of plant–plant interaction, involves the release of bioactive chemical compounds by one plant that influence the growth, development, or survival of neighboring plant species. These compounds, collectively termed allelochemicals, are predominantly plant secondary metabolites (Wardle *et al.*, 2011) and occur in various plant organs, including leaves, seeds, flowers, roots, and stems. Depending on their nature and concentration, allelochemicals may exert either

stimulatory effects, such as promoting weed suppression, facilitating crop establishment, and offering biotic stress protection, or inhibitory effects, including autotoxicity and enhanced competitive advantage in invasive species (Cheng and Cheng, 2015). They can enter the environment through several mechanisms, including root exudation, volatilization from aerial parts, leaching from senescent foliage, and microbial decomposition in the rhizosphere (Albuquerque *et al.*, 2011).

Recent studies suggest that intraspecific variation within a single species can

Handling Editor: Yaghoub Fathipour

*Corresponding authors: sathyan@cuk.ac.in

Received: 07 January 2026, Accepted: 20 July 2026

Published online: 06 October 2026

significantly modulate allelopathic outcomes. For example, genetically and morphologically distinct varieties of *Parthenium hysterophorus* exhibit significant differences in their phytotoxic activity and allelochemical profiles (Kaur *et al.*, 2022). Similarly, geographically distinct populations of *Heracleum mantegazzianum* have shown significant heterogeneity in both allelopathic efficacy and metabolite composition (Jandová *et al.*, 2015). Kalinova (2008) documented differential allelopathic responses among tissues of various *Fagopyrum esculentum* (common buckwheat) varieties. These studies collectively highlight the ecological, functional, and agronomical importance of evaluating intraspecific diversity when assessing allelopathic potential (Meiners *et al.*, 2012).

Mucuna pruriens (L.) DC., commonly referred to as velvet bean (var. *utilis*) or cowitch (var. *pruriens*), is a self-pollinated tropical legume of the Fabaceae family. The cultivated form (var. *utilis*) is widely used as a green manure and cover crop in tropical and subtropical regions because it can fix nitrogen and suppress weeds (Ceballos *et al.*, 2012). The primary allelochemical of interest in *M. pruriens* is L-3,4-dihydroxyphenylalanine (L-DOPA), a non-proteinogenic amino acid. L-DOPA has shown potent bioactivity, including herbicidal properties, pest deterrence, and nematode suppression (Fuji *et al.*, 1992). Experimental comparisons between commercial L-DOPA and *M. pruriens* seed extracts have shown equivalent allelopathic potency (Bido *et al.*, 2018), a finding further supported by evidence that L-DOPA exuded from *M. pruriens* roots mimics the inhibitory effect of its synthetic counterpart (Nishihara *et al.*, 2005).

While the allelopathic properties of *M. pruriens* have been relatively well characterized, the role of intraspecific variation in modulating its allelopathic effects remains underexplored. Importantly, attributing allelopathic activity solely to a single compound may oversimplify the underlying biological interactions. For instance, artemisinin—despite being a principal metabolite in *Artemisia annua*—was found to be less inhibitory than the crude leaf extract of the

plant, suggesting synergistic interactions among multiple compounds (Lydon *et al.*, 1997; Inderjit *et al.*, 2005).

This study thus investigates intraspecific variation in the allelopathic potential and L-DOPA concentration of *M. pruriens* by comparing two botanical varieties: *M. pruriens* var. *pruriens* (wild type) and *M. pruriens* var. *utilis* (cultivated type). The wild variety is distinguished morphologically by highly irritant trichomes on its pods, whereas the cultivated variety has non-irritant, smooth pods (Sathyanarayana *et al.*, 2016). We hypothesize that (1) the allelopathic activity in *M. pruriens* is not solely attributable to L-DOPA, and (2) varietal differences result in differential allelopathic effects and allelochemical profiles, warranting further investigation into the chemical ecology of this species.

Materials and Methods

Plant materials and extract preparation

Our study used the methodology outlined by Rugare *et al.* (2020). The two *M. pruriens* varieties were cultivated in the greenhouse facility at Sikkim University. Plants were harvested at the full-flowering stage, and a portion of the plants was retained in the greenhouse until maturity to collect dried seeds. After harvesting, the plant parts were oven-dried at 60 °C for 48 hours, ground separately into a fine powder, and stored at 4 °C until further use. The wild variety (*pruriens*) bore purple flowers and black seeds, while the cultivated variety (*utilis*) had white flowers and white seeds.

Aqueous extracts were prepared from individual plant parts of both varieties. Additionally, a mixed extract was prepared from plant material collected at the full-flowering stage for each variety separately. Four grams of powdered plant material were soaked in 100 mL of distilled water and agitated on a rotary shaker at 100 rpm for 24 hours at 27 °C. The resulting mixtures were filtered using Whatman No. 1 filter paper, and the clear filtrates were considered as 4% (w/v) stock solutions. These stock solutions

were subsequently diluted with distilled water to obtain 1% and 2% concentrations.

Seed germination bioassay

Rice *Oryza sativa* L. and maize *Zea mays* L. were selected as recipient plants because of their high germination rates and vigorous seedling growth. Seeds of variety Sikkim Dhan (rice) and variety SKMC (maize) were obtained from the Indian Council of Agricultural Research (ICAR), Sikkim unit. Before sowing, seeds were surface-sterilized in 0.1% HgCl_2 for 3 minutes, rinsed 5–6 times with distilled water, and soaked overnight to break dormancy. Seeds were then treated with aqueous plant extracts at concentrations of 0% (control), 1%, 2%, and 4%. Fifteen rice seeds and ten maize seeds were sown at equal intervals in separate 90 mm Petri dishes lined with cotton, and 20 mL of the respective extracts was applied to each plate. The Petri dishes were incubated in a seed germinator maintained at 25 °C, 65% relative humidity, a 14/10-hour light/dark photoperiod, and a light intensity of 170 $\mu\text{mol m}^{-2} \text{s}^{-1}$. The germination experiment used a completely randomized design (CRD) with nine replicates for maize and six for rice. Germination was recorded daily for five days. Following the germination test, twenty seedlings were randomly selected from the pooled seedlings of each concentration, and their root length, shoot length, and fresh weight were measured (Xie and Wang, 2024). Samples were then oven-dried at 70 °C for 48 hours to determine shoot and root dry weights. Seeds were considered germinated when the radicle protruded at least 1 mm from the seed coat.

Germination percentage (GP), mean germination time (MGT), and response index (RI) were calculated following Xie and Wang (2024), whereas the coefficient of velocity of germination (CVG) was calculated according to Guragain *et al.* (2023) using the equations below.

$$\text{GP} = (G / T) \times 100$$

Where G = Number of germinated seeds, and T = Total Number of seeds

$$\text{MGT} = \Sigma (G_i \times T_i) / \Sigma G_i$$

Where G_i = Number of germinated seeds on day i , T_i = Day number, ΣG_i = total Number of seeds germinated

$$\text{CVG} = (\Sigma G_i / \Sigma (G_i \times T_i)) \times 100$$

Where G_i = Number of germinated seeds on day i , and T_i = Day number

$$\text{RI} = 1 - C/T \text{ (if } T \geq C) \text{ or } \text{RI} = T/C - 1 \text{ (if } T < C)$$

Where C and T represent the values from the control and treatment groups, respectively. $\text{RI} > 0$ indicates stimulation, and $\text{RI} < 0$ indicates inhibition.

HPLC Analysis

The extraction and quantification of L-DOPA were performed according to Singh *et al.* (2018) with minor modifications. High-performance liquid chromatography (HPLC) grade L-DOPA, methanol, formic acid, and water were procured from Sigma-Aldrich. Ten milligrams of dried powdered plant material (in six replicates) were mixed with 1 mL of 0.1% (v/v) formic acid in water. The mixture was sonicated for 20 minutes and subsequently centrifuged at 15,000g for 10 minutes. The supernatant was filtered through a 0.45 μm syringe filter and analyzed by HPLC-photodiode array (HPLC-PDA).

L-DOPA was quantified using a Luna C18 reversed-phase column (Phenomenex) with an isocratic mobile phase consisting of 0.1% formic acid in water (solvent A) and 0.1% formic acid in methanol (solvent B) in a ratio of 95:5 (v/v). The column temperature was maintained at 27 °C, the flow rate was 1 mL/min, and 20 μL of sample was injected. Chromatographic separation was run for 10 minutes, and detection was performed at 280 nm. Quantification was performed using an external calibration curve constructed from peak area measurements of standard L-DOPA solutions. The calibration curve followed $y = 273.74x + 86.165$, with an R^2 of 0.999. The LOD (limit of detection) and LOQ (limit of quantitation) were calculated as per the ICH guidelines (ICH, 2005) using the following equations: $\text{LOD} = 3.3 \sigma/S$ and $\text{LOQ} = 10 \sigma/S$, where σ is the residual standard deviation of the regression line, and S is the slope of the calibration curve. The LOD and LOQ values were 9.55 and 28.94 $\mu\text{g/mL}$, respectively. L-

DOPA content in the plant samples was subsequently calculated and expressed as mg g^{-1} dry weight.

Statistical analysis

All analyses were performed using R v4.2.1. Box–Cox transformation was applied to the data using the optimal λ for each dataset, and homogeneity of variances and normality were assessed using Levene's test and the Shapiro–Wilk test, respectively. The data were analyzed by two-way ANOVA, followed by Tukey's post hoc test, for each plant part separately. Results were visualized using ggplot2 boxplots. A three-way factorial ANOVA (plant part $\times$ variety $\times$ concentration) was performed, excluding the untreated samples (control), and parameters that did not meet the ANOVA assumptions were analyzed using the non-parametric aligned rank transform (ART) model. The random forest classification model was used to assess variable importance. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was used to rank the samples based on their allelopathic potential. All seedling growth parameters were standardized and assigned equal weights before calculating the TOPSIS scores.

Results

1. Effect on germination parameters

Two-way ANOVA followed by Tukey's post hoc test revealed that aqueous extracts from both varieties did not inhibit rice germination percentage (GP) across any plant part or concentration ($p > 0.05$). However, different plant parts showed differential effects on the mean germination time (MGT) and coefficient of velocity of germination (CVG) in rice (Table S4). In the leaf extract, MGT increased and CVG decreased at 4% for both varieties. In flower and mixture, all concentrations from both varieties, except 2% utilis, showed delayed germination. In root extract, all concentrations, except 1% and 2% pruriens, showed higher MGT and lower CVG. In stem and seed extracts, none of the treatments from either variety differed significantly from the control in MGT or CVG

for rice (Fig. 1). In maize, germination percentage was not affected by any plant part or concentration, except for 4% utilis stem extract, which showed significant inhibition. However, MGT and CVG did not differ significantly from the control across any plant part or concentration according to Tukey's test (Fig. 2).

2. Effect on seedling length

Both varieties reduced the root length of rice significantly in a dose-dependent manner across all plant parts ($\text{RI} < 0$, $p < 0.05$) (Tables S1 and S4). At 1%, leaves and flower extracts from utilis were more inhibitory than those from pruriens, while the utilis mixture showed more inhibition than the pruriens mixture across all concentrations. However, at 2% seed extract and 4% root and flower extract, pruriens was more inhibitory than utilis, whereas for the stem at 2% and 4% concentration, utilis was found to be more inhibitory than pruriens (Fig. 3A). Similarly, a strong concentration-dependent reduction was observed in maize root length in all plant parts ($\text{RI} < 0$, $p < 0.05$) (Table S2). For leaves and mixture, utilis was more inhibitory than pruriens across all concentrations. However, at 1% and 2% root concentrations, pruriens was more inhibitory than utilis. In flower, stem, and seed, both varieties showed similar effects at each concentration, exhibiting dose-dependent responses (Fig. 3C).

For rice shoot length, all plant parts at 1% concentration, except for leaves and flower extracts, showed no inhibitory effect. In fact, at 1% concentration, root extracts of both varieties, pruriens seed extract, and utilis mixture showed a stimulatory effect (Fig. 3B). However, a concentration-dependent inhibition was observed at 2% and 4% for both varieties, with the only exception being 2% pruriens mixture, which did not differ significantly from the control. At 4%, the mixture and stem extracts of utilis were more inhibitory than those of pruriens. A similar trend was observed for maize shoot length. No inhibition was observed at 1% concentration in any plant part, while flower and root extracts of utilis, and mixture and seed extracts of

pruriens showed a stimulatory effect at 1%. Significant inhibition was observed at 4% for all plant parts, with pruriens flower extract being more inhibitory than utilis at 4%,

whereas stem and mixture extracts of utilis were more inhibitory than those of pruriens at the same concentration (Fig. 3D).

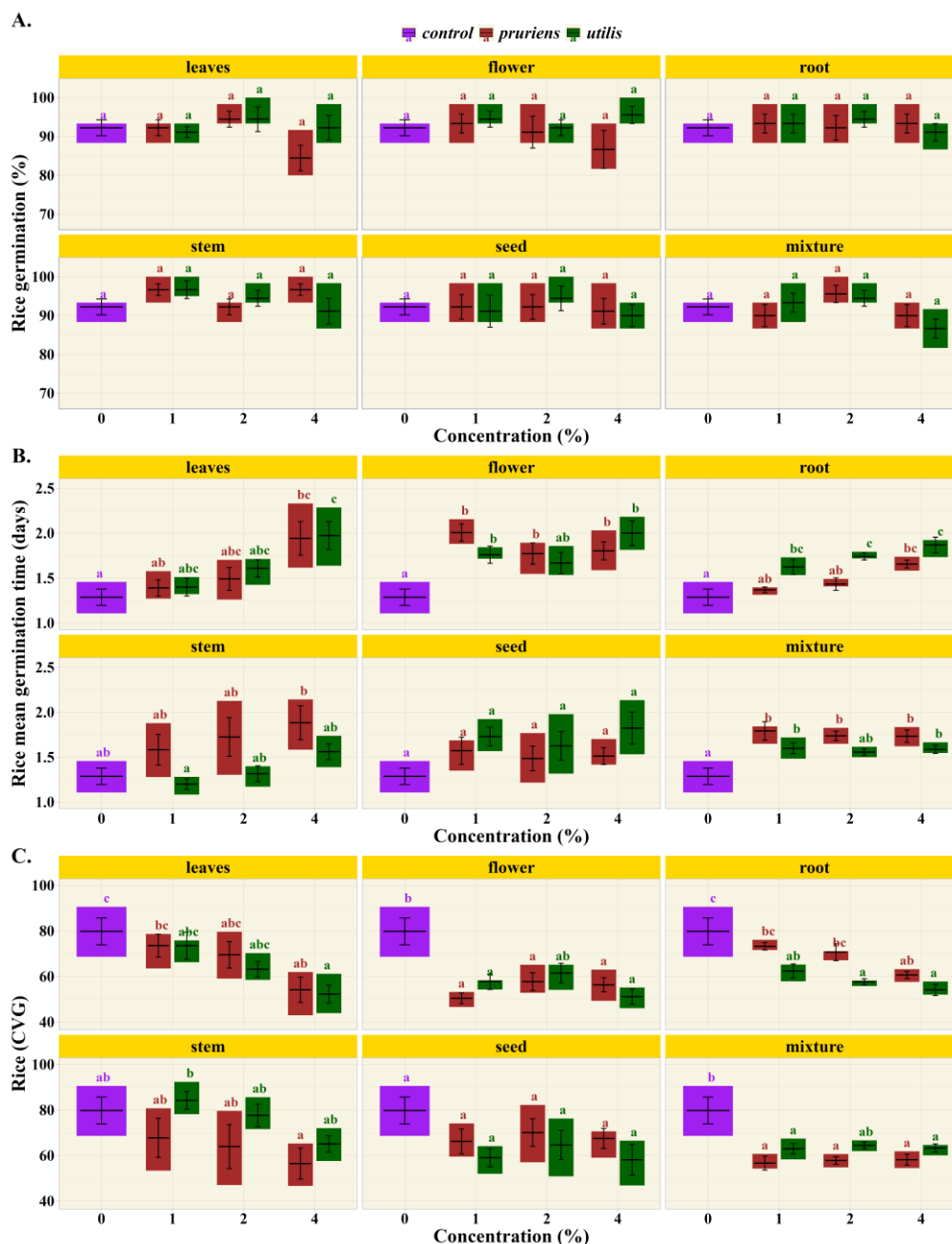


Figure 1 Influence of *Mucuna pruriens* extracts on germination percentage, mean germination time and coefficient of velocity of germination of rice. Data are presented as mean $\pm$ SD of six replicates. Different letters above the bars within each panel indicate significant differences among treatments, whereas bars sharing at least one common letter are not significantly different at $p < 0.05$.

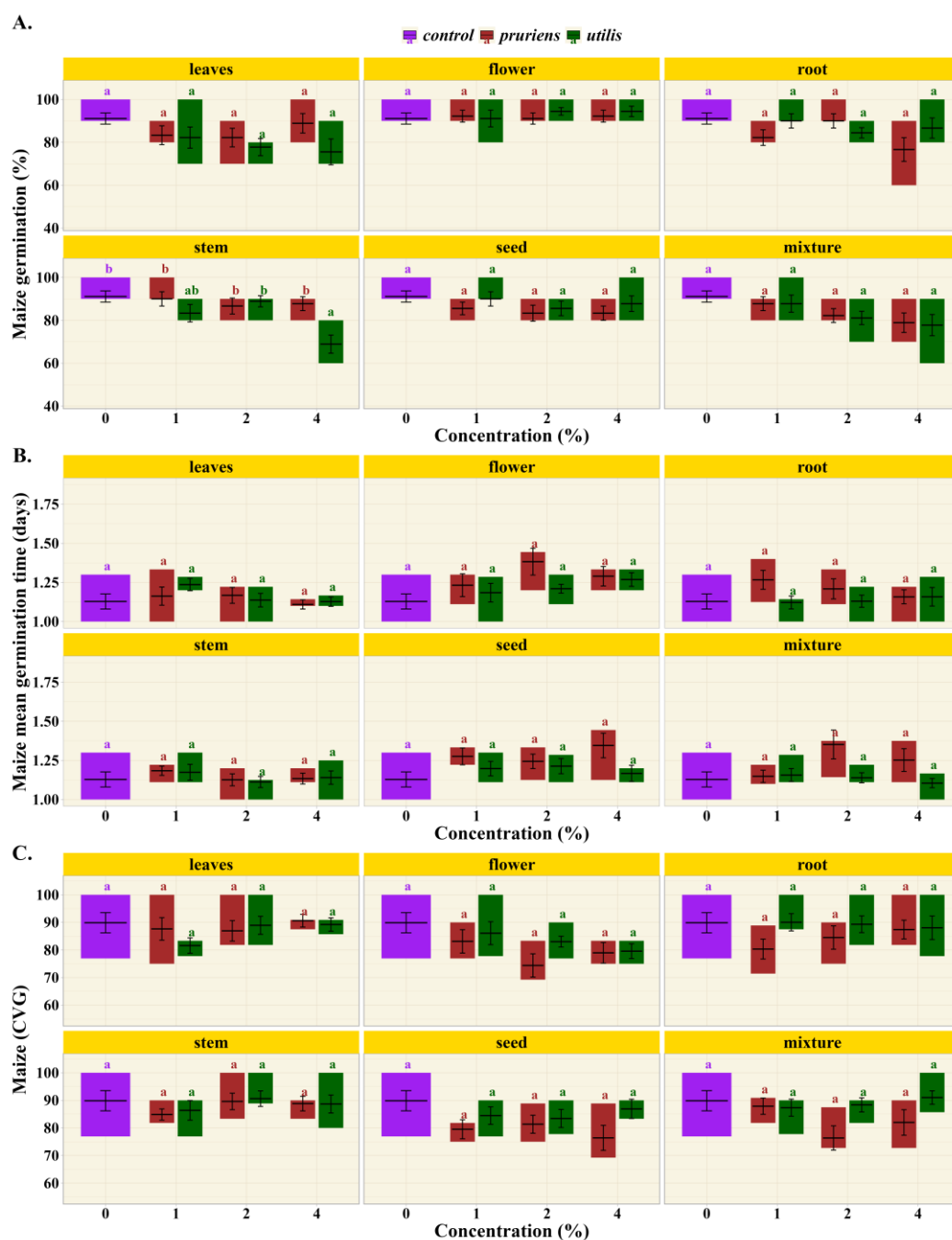


Figure 2 Influence of *Mucuna pruriens* extracts on germination percentage, mean germination time and coefficient of velocity of germination of maize. Data are presented as mean $\pm$ SD of nine replicates. Different letters above the bars within each panel indicate significant differences among treatments, whereas bars sharing at least one common letter are not significantly different at $p < 0.05$.

3. Effect on seedling fresh weight

The inhibitory effects of both varieties on the shoot fresh weight of rice and maize were

significant, except at certain concentrations and plant parts. In rice, at 1% concentration, none of the plant parts differed significantly from the

control except for leaves and flower extracts of both varieties, which showed significant inhibition. Both varieties showed concentration-dependent inhibition at 2% and 4%. Within each plant part, at all other concentrations, both varieties showed similar effects, except for the 1% utilis root and 4% utilis mixture extracts, which were significantly different from the corresponding pruriens extracts (Fig. 4A). In maize, 1% utilis root extract and 1% stem extracts of both varieties showed significant stimulation in shoot fresh weight, whereas all other plant parts at 1% did not differ significantly from the control. The utilis mixture extract at 4% and utilis stem extracts at 2% and 4% were more inhibitory than those of pruriens. However, pruriens showed a higher inhibitory effect at 2% flower extract and 2% and 4% seed extract than utilis (Fig. 4C).

A plant part-specific inhibitory effect of both varieties was observed on the root fresh weight of

both rice and maize. For rice, at 1% concentration, root and mixture extracts from both varieties, and stem and seed extracts of utilis, did not differ significantly from the control. The utilis mixture extract was more inhibitory than the pruriens extract across all concentrations. The utilis extracts at 4% stem, 2% leaves, and 1% flower were more inhibitory than the corresponding pruriens extracts. In contrast, pruriens was more inhibitory than utilis at 4% flower and 2% seed extracts (Fig. 4B). In maize, at 1% concentration, flower and mixture extracts from both varieties and utilis root extract did not differ significantly from the control. In addition, the utilis mixture extract was more inhibitory than the corresponding pruriens mixture extract at all concentrations. At 1% and 2%, pruriens root extracts were more inhibitory than those of utilis; however, at 4%, utilis stem extract was more inhibitory than that of pruriens (Fig. 4D).

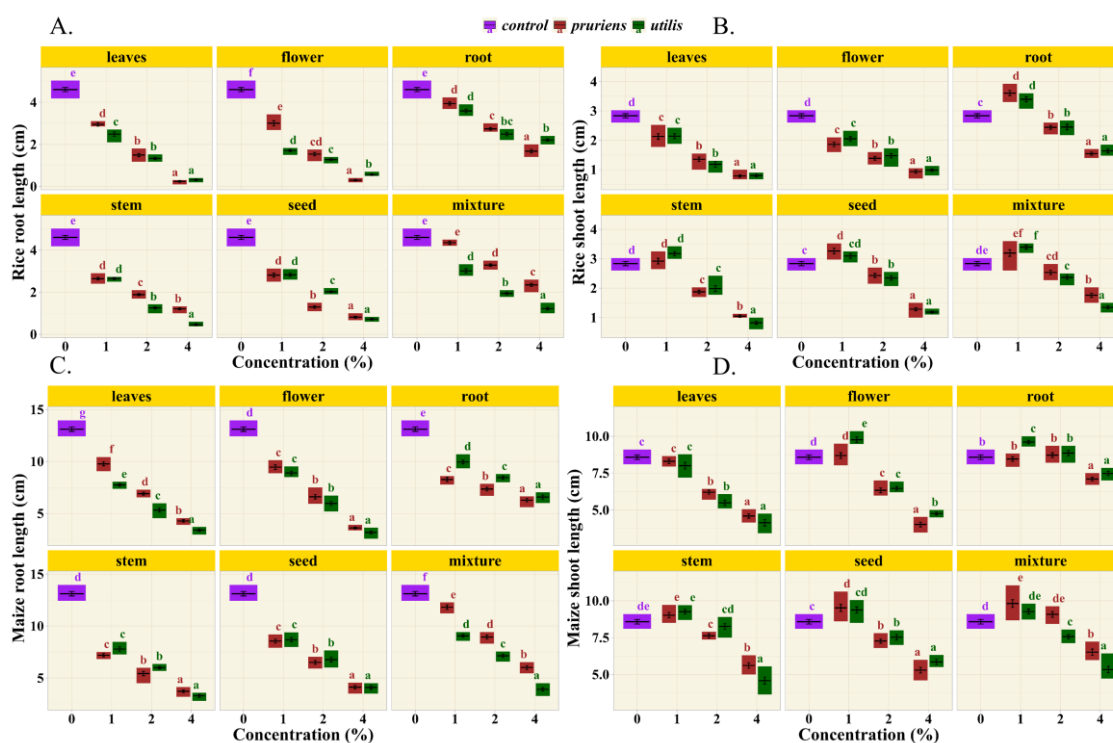


Figure 3 Influence of *Mucuna pruriens* extracts on seedling length. Rice: (A) root length, (B) shoot length; maize: (C) root length, (D) shoot length. Data are shown as mean $\pm$ SD of twenty seedlings from each concentration. Different letters above the bars within each panel indicate significant differences among treatments, whereas bars sharing at least one common letter are not significantly different at $p < 0.05$.

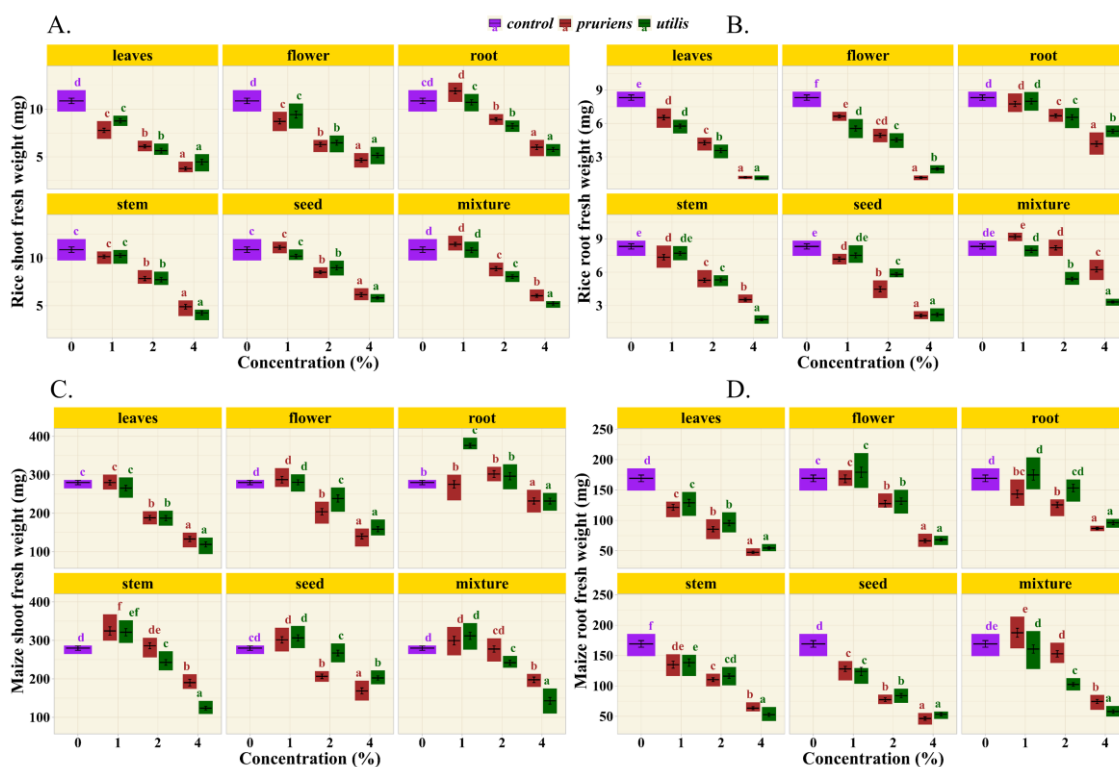


Figure 4 Influence of *Mucuna pruriens* on seedling fresh weight. Rice: (A) shoot fresh weight, (B) root fresh weight; maize: (C) shoot fresh weight, (D) root fresh weight. Data are shown as mean $\pm$ SD of twenty seedlings from each concentration. Different letters above the bars within each panel indicate significant differences among treatments, whereas bars sharing at least one common letter are not significantly different at $p < 0.05$.

4. Effect on seedling dry weight

All plant parts significantly inhibited rice shoot dry weight, except the stem and mixture extracts of utilis and the seed extract of pruriens at 1%, which did not differ significantly from the control. The pruriens flower extracts at 1% and 2% and the pruriens root extract at 4% showed greater inhibitory effects than the corresponding utilis extracts. In contrast, the utilis seed extract at 1% and the mixture extract at 4% produced greater inhibition than the corresponding pruriens extracts (Fig. 5A). For maize, at 1% concentration, flower and seed extracts from both varieties, the utilis root extract, and the pruriens stem and mixture extracts exhibited a stimulatory effect. At 4%, the utilis leaf, stem, and mixture extracts exerted greater inhibitory effects than the corresponding pruriens extracts, whereas the pruriens root extract produced greater inhibition than the corresponding utilis root extract (Fig. 5C).

All plant parts and concentrations showed significant inhibition of rice root dry weight, except the 1% utilis root and 1% pruriens mixture extracts, which did not differ significantly from the control. At 2% and 4%, the utilis mixture extract was more inhibitory than the corresponding pruriens extract. Additionally, the 4% utilis stem extract was more inhibitory, whereas the 4% pruriens root extract produced greater inhibition (Fig. 5B). For maize, all extracts showed inhibitory effects except the 1% flower and root extracts of both varieties, and the 1% pruriens mixture extract, which did not differ significantly from the control. The 4% utilis leaf extract was more inhibitory than the corresponding pruriens extract, while the utilis mixture and pruriens root extracts consistently showed greater inhibition than their corresponding extracts across all concentrations (Fig. 5D).

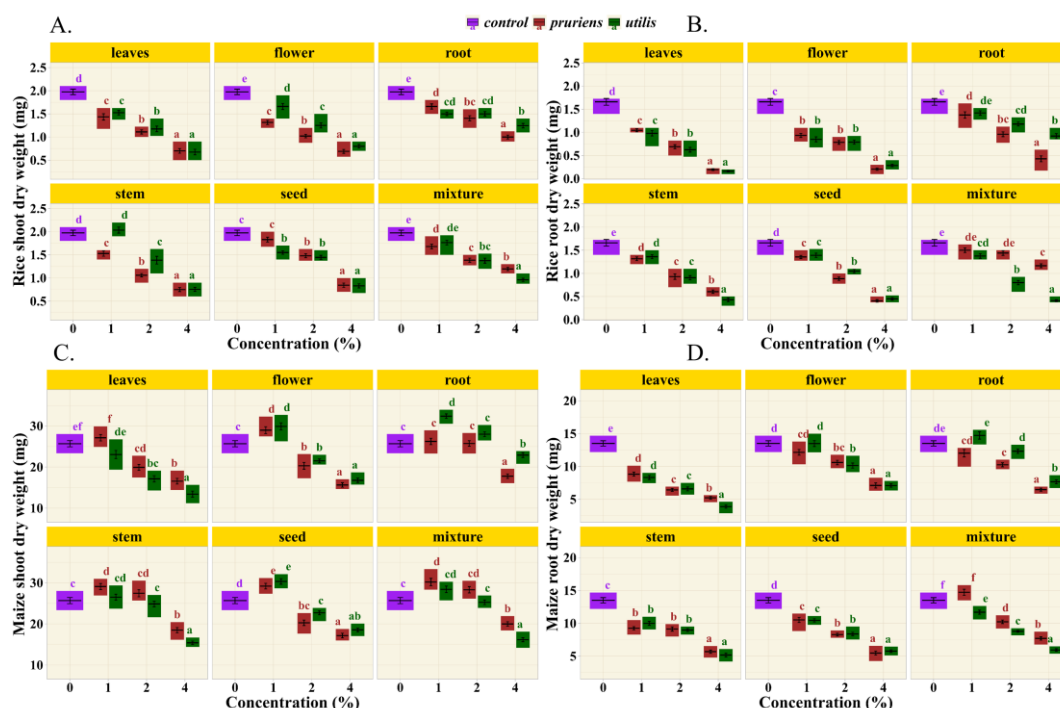


Figure 5 Influence of *Mucuna pruriens* on seedling dry weight. Rice: (A) shoot dry weight, (B) root dry weight; maize: (C) shoot dry weight, (D) root dry weight. Data are shown as mean $\pm$ SD of twenty seedlings from each concentration. Different letters above the bars within each panel indicate significant differences among treatments, whereas bars sharing at least one common letter are not significantly different at $p < 0.05$.

5. Interaction effects of plant part, concentration and variety

Three-way ANOVA and aligned rank transform (ART) analyses were performed to evaluate the combined effects of plant part, concentration and variety on germination and seedling growth parameters of both rice and maize. In rice, mean germination time and the coefficient of velocity of germination indicated that concentration and variety differed among plant parts; in maize, germination percentage showed a tissue-specific varietal difference. However, the combined effect of plant part, variety and concentration was not significant for any germination parameter in either rice or maize ($p > 0.05$) (Table S6). On the contrary, a significant three-way interaction was observed for all seedling growth parameters in rice, indicating that the concentration effect differed among varieties by plant part ($p < 0.05$) (Table S6). Similar results were obtained for all maize seedling growth parameters, except for

shoot dry weight, for which the three-way interaction was not significant. However, significant plant part*concentration and plant part*variety interactions in maize shoot dry weight indicated that concentration and variety effects differed among plant parts (Table S6).

6. L-DOPA content

Both varieties showed significant differences in L-DOPA content across plant parts. Flowers and seeds from both varieties had the highest L-DOPA, while leaves had the lowest. A significant difference in L-DOPA content was observed between the two varieties as well for flower, seed, stem, and root, with pruriens having much higher levels compared to utilis (Fig. 6A). In contrast, for leaf tissues, no significant difference was detected between the varieties. L-DOPA content in pruriens followed the pattern: flower = seed > root = stem > leaves, whereas in utilis the trend was: flower > seed > stem > root > leaves (Table 1).

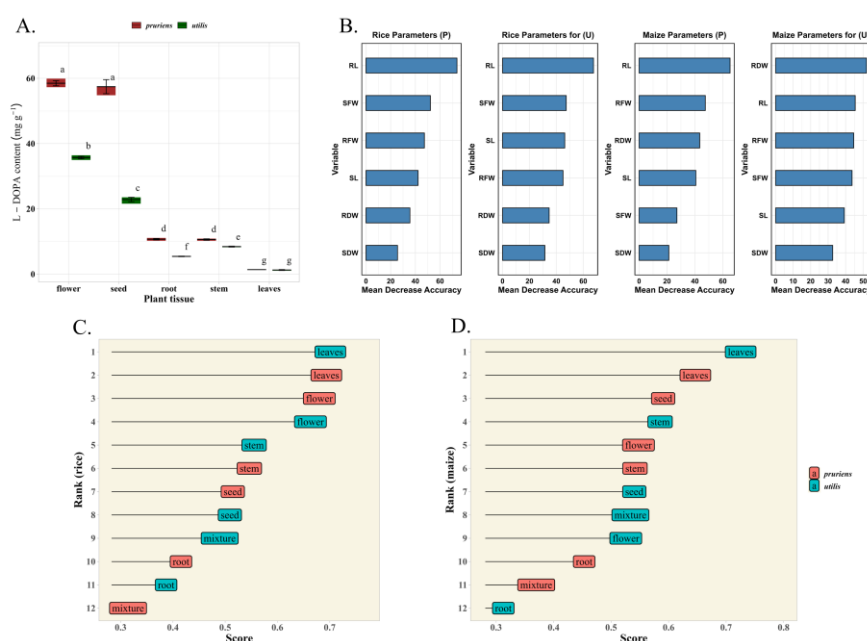


Figure 6 (A) L-DOPA content across different plant parts of *Mucuna pruriens*, data are shown as mean $\pm$ SD of six replicates (B): important variables in *M. pruriens* allelopathy. Here P and U represent pruriens and utilis allelopathy respectively, (C) and (D): comprehensive topsis score. A lower rank and high topsis score indicate more inhibitory activity.

Table 1 L-DOPA content in *Mucuna pruriens* across different plant parts.

Sample	Variety	LDOPA (mg.g ⁻¹)
Flower	Pruriens	58.49 $\pm$ 0.79
	Utilis	35.74 $\pm$ 0.37
Seed	Pruriens	57.43 $\pm$ 2.16
	Utilis	22.88 $\pm$ 0.67
Root	Pruriens	10.72 $\pm$ 0.22
	Utilis	5.45 $\pm$ 0.09
Stem	Pruriens	10.62 $\pm$ 0.22
	Utilis	8.46 $\pm$ 0.13
Leaves	Pruriens	1.41 $\pm$ 0.02
	Utilis	1.29 $\pm$ 0.14

Data are expressed in dry weight.

7. Variable importance and TOPSIS

To identify which parameters were most affected by allelopathy, we ran a random forest analysis with 500 trees and an mtry value of 2. Only seedling growth parameters were included, as inhibitory effects were more consistently reflected in seedling growth. Among all the

parameters, root length had the highest mean decrease in accuracy (MDA) in both rice and maize under pruriens allelopathy, and in rice under utilis allelopathy. However, in maize under utilis allelopathy, root dry weight had the highest MDA, whereas shoot dry weight showed the lowest MDA across all samples (Fig. 6B). According to the TOPSIS ranking, both varieties showed strong allelopathic activity. The comprehensive TOPSIS score for both rice and maize showed that leaves from both varieties had the highest allelopathic activity, while utilis roots and the pruriens mixture showed the lowest (Fig. 6C and 6D).

Discussion

Both varieties of *M. pruriens* significantly affected rice and maize seedling growth; however, their effects on seed germination were comparatively limited. The combined influence of plant part, variety, and concentration modulated the inhibitory effects on seedling growth, indicating that allelopathic potential

varied with extract type and concentration. Radicle growth was significantly more inhibited than hypocotyl growth. Among all measured parameters, root length was the most affected, while shoot dry weight was the least affected. Appiah *et al.* (2015) previously reported that *M. pruriens* strongly inhibits radicle growth but has no significant effect on seed germination. Similarly, Rugare *et al.* (2020) observed that aqueous extracts of velvet bean had no impact on maize germination or plumule length but significantly inhibited radicle length. In the current study, although the allelopathic effects largely matched earlier findings, certain germination parameters were also affected. In rice, final germination was unaffected, although certain plant parts and extract concentrations delayed germination. In maize, only the highest concentration of utilis stem extract inhibited final germination. Our results suggest that *M. pruriens* can inhibit seed germination, particularly at higher extract concentrations and depending on the phytotoxicity of the plant part. Most previous studies suggest that L-DOPA is the primary allelochemical responsible for allelopathy. This is mainly because L-DOPA also shows inhibition similarly. L-DOPA is known to affect radicle growth without influencing the hypocotyl. It disrupts the TCA cycle in roots, inhibiting amino acid transport from roots to shoots and suppressing root growth (Nishihara *et al.*, 2004). In maize, L-DOPA leads to the accumulation of phenylalanine and tyrosine, which contribute to increased lignin deposition and a consequent reduction in root growth. Additionally, root length, fresh weight, and dry weight of maize decrease with increasing L-DOPA concentration (Siqueira-Soares *et al.*, 2013). Similarly, Mushtaq *et al.* (2013) reported that L-DOPA inhibited cucumber root growth by inducing quinoprotein and melanin formation in root cells. In another study, both aqueous extracts of velvet bean seeds and pure L-DOPA significantly inhibited the root and stem length, as well as the fresh and dry weight of soybeans, in a concentration-dependent manner (Marchiosi *et al.*, 2016).

The present study found that L-DOPA is present in all plant parts of *Mucuna*, with significant variation in concentration across tissues. Our findings are consistent with Singh *et al.* (2018), which reported that leaves contain the lowest L-DOPA levels, whereas reproductive parts exhibit higher L-DOPA content than vegetative parts. Despite having different L-DOPA content, the allelopathic potential of both varieties was closely aligned. In fact, the utilis stem and mixture showed a greater inhibitory effect than pruriens although they had significantly lower L-DOPA levels. The aqueous leaf extract from both varieties showed the highest inhibitory effect; interestingly, the leaves had the lowest L-DOPA levels among all plant parts. The stem contains much lower L-DOPA than seeds, but in utilis, the stem showed higher allelopathic potential than seed extracts. The utilis root and pruriens mixture had the least contribution to allelopathic activity. This is consistent with Rugare *et al.* (2020), who state that velvet bean allelopathy is concentration-dependent, with leaf extract showing the strongest inhibition and root extract being less inhibitory. These results suggest that although L-DOPA exhibits strong allelopathic effects, its full potential is achieved through the combined action of multiple chemicals that interact synergistically, additively, or antagonistically in natural conditions.

In conclusion, our findings align with existing theories proposing that *M. pruriens* is highly allelopathic. However, plants can show intraspecific variation in the concentration of allelochemicals they produce, which significantly affects their allelopathic potential. Therefore, we further explored the varietal effect. We observed that, although both varieties were significantly allelopathic, their activity was mainly dose-dependent and plant-part-specific. Our study also revealed that the allelopathic activity of *M. pruriens* is not solely due to L-DOPA, the only known major allelochemical from this plant; rather, other unidentified compounds also play a substantial role in its allelopathic effects. This opens a new avenue for exploring the plant's allelopathy,

particularly by understanding the differential production of allelochemicals. Future work should focus on identifying novel compounds and understanding how chemicals act together in natural environments, which can ultimately contribute to more sustainable agricultural practices.

Conflict of interest

The authors declare no competing interests.

Author contributions

UK: Experimental analysis, data curation and writing; AC: Review and editing; NS: Review and editing

Acknowledgements

The author would like to thank Mr. Bendangyanger and Ms. Priyanka Kumari for their assistance with garden setup and sample collection. The author also extends sincere thanks to Mr Anit Baidya for support with statistical analysis. The author is grateful to ICAR–Sikkim for providing rice and maize seeds from their germplasm collection. The author also thanks CSIR-UGC for the Junior Research Fellowship and Sikkim University for providing laboratory facilities.

Funding

This work received no funding.

References

- Appiah, K., Amoatey, C. and Fujii, Y. 2015. Allelopathic activities of selected *Mucuna pruriens* on the germination and initial growth of lettuce. *International Journal of Basic and Applied Sciences*, 4: 475-481. <https://doi.org/10.14419/ijbas.v4i4.5148>.
- Bido, G. D. S., Silva, H. A. D., Bortolo, T. D. S. C., Maldonado, M. R., Marchiosi, R., Dos Santos, W. D. and Ferrarese-Filho, O. 2018. Comparative effects of L-DOPA and velvet bean seed extract on soybean lignification. *Plant Signalling & Behavior*, 13(4): e1451705.
- Cheng, F. and Cheng, Z. 2015. Research progress on the use of plant allelopathy in agriculture and the physiological and ecological mechanisms of allelopathy. *Frontiers in Plant Science*, 6: 1020.
- de Albuquerque, M. B., dos Santos, R. C., Lima, L. M., Melo Filho, P. D. A., Nogueira, R. J. M. C., Da Câmara, C. A. G. and de Rezende Ramos, A. 2011. Allelopathy, an alternative tool to improve cropping systems. A review. *Agronomy for Sustainable Development*, 31(2): 379-395.
- Fujii, Y., Shibuya, T. and Yasuda, T. 1992. Allelopathy of velvetbean [*Mucuna pruriens*]: Its discrimination and identification of L-DOPA as a candidate of allelopathic substances. *JARQ (Japan)*.
- Guragain, R. P., Baniya, H. B., Pradhan, S. P., Pandey, B. P., Shrestha, B., Fronczak, M., Kierzkowska-Pawlak, H. and Subedi, D. P. 2023. Growth enhancement of radish seed induced by low-temperature argon plasma. *Plasma Chemistry and Plasma Processing*, 43: 111-137. <https://doi.org/10.1007/s11090-022-10291-x>.
- Inderjit, Weston, L. A. and Duke, S. O. 2005. Challenges, achievements and opportunities in allelopathy research. *Journal of Plant Interactions*, 1(2): 69-81.
- ICH. 2005, ICH Harmonised Tripartite Guideline: Validation of Analytical Procedures: Text and Methodology Q2(R1), Current Step 4 Version. International Conference on Harmonisation (ICH), Available from: https://database.ich.org/sites/default/files/Q2_R1_Guideline.pdf [Accessed 12 October 2024].
- Jandová, K., Dostál, P., Cajthaml, T. and Kameník, Z. 2015. Intraspecific variability in allelopathy of *Heracleum mantegazzianum* is linked to the metabolic profile of root exudates. *Annals of Botany*, 115(5): 821-831.
- Kalinova, J. 2008. Varietal differences in allelopathic potential of common buckwheat (*Fagopyrum esculentum* Moench). *Cereal Research Communications*, 36(3): 397-408.
- Kaur, A., Kaur, S., Singh, H. P. and Batish, D. R. 2022. Alterations in phytotoxicity and

- allelochemistry in response to intraspecific variation in *Parthenium hysterophorus*. Ecological Complexity, 50: 100999.
- Lydon, J., Teasdale, J. R. and Chen, P. K. 1997. Allelopathic activity of annual wormwood (*Artemisia annua*) and the role of artemisinin. Weed Science, 45(6): 807-811.
- Marchiosi, R., de Souza Bido, G., Böhm, P. A. F., Soares, A. R., da Silva, H. A., Ferro, A. P. and Ferrarese-Filho, O. 2016. Photosynthetic response of soybean to L-DOPA and aqueous extracts of velvet bean. Plant Growth Regulation, 80(2): 171-182.
- Meiners, S. J., Kong, C. H., Ladwig, L. M., Pisula, N. L. and Lang, K. A. 2012. Developing an ecological context for allelopathy. Plant Ecology, 213(8): 1221-1227.
- Mushtaq, M. N., Sunohara, Y. and Matsumoto, H. 2013. Allelochemical L-DOPA induces quinoprotein adducts and inhibits NADH dehydrogenase activity and root growth of cucumber. Plant Physiology and Biochemistry, 70: 374-378.
- Nishihara, E., Parvez, M. M., Araya, H. and Fujii, Y. 2004. Germination growth response of different plant species to the allelochemical L-3, 4-dihydroxyphenylalanine (L-DOPA). Plant Growth Regulation, 42(2), 181-189.
- Nishihara, E., Parvez, M. M., Araya, H., Kawashima, S. and Fujii, Y. 2005. L-3-(3, 4-Dihydroxyphenyl) alanine (L-DOPA), an allelochemical exuded from velvetbean (*Mucuna pruriens*) roots. Plant Growth Regulation, 45(2): 113-120.
- Ceballos, A. I. O., Rivera, J. R. A., Arce, M. M. O. and Valdivia, C. P. 2012. Velvet bean (*Mucuna pruriens* var. utilis) a cover crop as bioherbicide to preserve the environmental services of soil. Herbicides-Environmental Impact Studies and Management Approaches, Intech Open Press, pp.167-184.
- Rugare, J. T., Pieterse, P. J. and Mabasa, S. 2020. Effects of green manure cover crops (*Canavalia ensiformis* L. and *Mucuna pruriens* L.) on seed germination and seedling growth of maize and *Eleusine indica* L. and *Bidens pilosa* L. weeds. Allelopathy Journal, 50(1): 121-139.
- Sathyanarayana, N., Mahesh, S., Leelambika, M., Jaheer, M., Chopra, R. and Rashmi, K. V. 2016. Role of genetic resources and molecular markers in *Mucuna pruriens* (L.) DC improvement. Plant Genetic Resources, 14(4): 270-282.
- Singh, S. K., Dhawan, S. S., Lal, R. K., Shanker, K. and Singh, M. 2018. Biochemical characterization and spatio-temporal analysis of the putative L-DOPA pathway in *Mucuna pruriens*. Planta, 248(5): 1277-1287.
- Siqueira-Soares, R. D. C., Soares, A. R., Parizotto, A. V., Ferrarese, M. D. L. L. and Ferrarese-Filho, O. 2013. Root Growth and Enzymes Related to the Lignification of Maize Seedlings Exposed to the Allelochemical L-DOPA. The Scientific World Journal, 2013(1): 134237.
- Wardle, D. A., Karban, R. and Callaway, R. M. 2011. The ecosystem and evolutionary contexts of allelopathy. Trends in Ecology & Evolution, 26(12): 655-662.
- Xie, M. and Wang, X. 2024. Allelopathic effects of *Thuidium kanedae* on four urban spontaneous plants. Scientific Reports, 14(1): 14794.

بررسی تفاوت‌های ارقامی در پتانسیل آلوپاتیک گیاه باقلا *Mucuna pruriens* (L.) DC.

اوپاما کالیتا^۱، آرون چتری^۱ و ان. ساتیانارایانا^{۲*}

۱- گروه گیاه‌شناسی، دانشگاه سیکیم، گانگتوک، سیکیم، هند.

۲- گروه علوم زیستی، دانشگاه مرکزی کارناتاکا، کادگانچی، کارناتاکا، هند.

پست الکترونیکی نویسنده مسئول مکاتبه: sathyan@cuk.ac.in

دریافت: ۱۸ دی ۱۴۰۴؛ پذیرش: ۲۹ تیر ۱۴۰۵

چکیده: فعالیت آلوپاتیک ارقام مختلف گیاه باقلا *Mucuna pruriens* (L.) DC. پتانسیل قابل‌توجهی برای توسعه گیاهان پوششی با خاصیت زیست‌علف‌کشی دارد. این مطالعه تفاوت‌های ارقامی در پتانسیل آلوپاتیک دو رقم از باقلا را روی برنج *Oryza sativa* L. و ذرت *Zea mays* L. ارزیابی می‌نماید. آزمون زیستی در ظروف پتری با استفاده از عصاره‌های آبی حاصل از بافت‌های خشک هر رقم انجام شد و میزان L-DOPA در بخش‌های مختلف گیاه با روش HPLC تعیین گردید. اگرچه جوانه‌زنی بذر حساسیت کمتری نسبت به اثرات آلوپاتیک نشان داد، اما رشد گیاهچه دچار مهار و بسته به دوز شد؛ به‌طوری‌که رشد ریشه بیش از رشد اندام هوایی تحت تأثیر قرار گرفت. تفاوت معنی‌داری در میزان L-DOPA بین ارقام مشاهده شد و هر دو رقم اثرات آلوپاتیک قوی از خود نشان دادند. نکته قابل‌توجه این‌که عصاره‌های برگ با وجود داشتن کمترین میزان L-DOPA بیش‌ترین فعالیت بازدارندگی را بروز دادند. این یافته‌ها نشان می‌دهد که اثرات آلوپاتیک باقلا صرفاً ناشی از L-DOPA نیست و فرضیه پیشین را رد می‌کند؛ بلکه عوامل دیگری همچون نوع اندام گیاهی و غلظت عصاره نیز تأثیر بسزایی بر این اثرات دارند.

واژگان کلیدی: *Mucuna pruriens*، آلوپاتی، گیاه پوششی، تنوع درون‌گونه‌ای، L-DOPA