



RESEARCH ARTICLE

Eco biological adaptability of blood grass (*Isachne miliacea*) proliferation in wetland rice ecosystems

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Received: 30 December 2025; Accepted: 10 February 2026; Available online: Version 1.0: 16 April 2026

Cite this article: Renjan B, Bindu B, Gayathri K, Ameena M. Eco biological adaptability of blood grass (*Isachne miliacea*) proliferation in wetland rice ecosystems. Plant Science Today. 2025; 13(sp3): 1-7. <https://doi.org/10.14719/pst.13447>

Abstract

Blood grass (*Isachne miliacea* Roth ex Roem. & Schult.), locally known as valari, changalipullu, naringa or vanchi, is a major constraint in the wetland rice ecosystems of Kerala. It occurs across cultivated fields, fallows, bunds and irrigation channels, although its vigour diminishes under continuous flooding. Weed biology assessments revealed it as a perennial, prostrate grass with year-round growth and flowering, with peak activity during the monsoon. Propagation occurs via seeds and rooted stem fragments, which establish within 2–6 and 3–8 days, respectively, in puddled soils. Seedlings initiated branching at 11–24 days, coinciding with early crop growth and intensifying competition. Flowering commenced within 28–42 days and seeds matured and shattered by 60–75 days, resulting in steady replenishment of the soil seedbank. Mechanical land preparation accelerated vegetative spread, with plants forming around 8 rooted nodes capable of establishing independently. Dense mat formation within 3 weeks impeded identification of individual plants and rendered manual or mechanical weeding highly difficult. Freshly shed seeds germinated readily; viability declined to 79.7 % by 6 months and reached zero by 10 months. The requirement for direct sunlight during germination enhances establishment under high-temperature environments, while tolerance to elevated iron concentrations and prolonged soil moisture contributes to its persistence and widespread occurrence. Heavy-metal uptake followed the order Fe > Mn > Zn > Cu > Cr > Cd > Pb, with maximum iron uptake (0.65 kg ha⁻¹), highlighting the capacity of the weed to thrive in acidic lateritic and iron-toxic wetland environments.

Keywords: germination ecology; heavy metal uptake; iron toxic wetland; seed dormancy; weed biology

Introduction

Blood grass (*Isachne miliacea* Roth ex Roem. & Schult.), locally known as valari, changalipullu, naringa or vanchi, is a highly troublesome wetland species belonging to the Poaceae family that has infested extensive tracts of rice fields in Kerala. Its native range is Eastern Asia (1) and the genus name *Isachne* derives from the Greek 'isos' (equal/similar) and achene (chaff/glume/scale), referring to its lemma, glumes and 2 equal florets (2). This perennial, prostrate grass grows and flowers throughout the year, with peak vigour during the rainy season. It has been identified as the most dominant species in the rice fields of Thiruvananthapuram district across both crop seasons and under cultivated and fallow conditions, with a relative density reaching 65 % (3, 4).

The species propagates both by seeds and rooted stem fragments, making it highly persistent even under well-managed conditions. Its resistance to ploughing and hand-pulling, combined with dense mat-forming roots that obstruct the movement of mechanical weeding tools, further complicates management. Increased use of power tillers has exacerbated the problem by breaking stem fragments, thereby accelerating vegetative spread. Understanding weed behavior, population dynamics, seed bank characteristics and the influence of biotic and abiotic factors is

essential for designing effective management strategies (5). High seed production is a key survival mechanism in many rice-field weeds, enabling them to withstand control interventions (6, 7). Seedbank size and composition vary with climate, topography, soil moisture, sampling depth, field history and management practices (8). The soil seedbank comprises both newly shed and long-persistent seeds (9), representing the pool of viable seeds and vegetative propagules that drive future weed pressure (10).

In blood grass, significant reductions in soil seedbank were achieved through intensive tillage, sustained water impounding and post-emergence application of azimsulfuron (35 g ha⁻¹) or fenoxaprop-p-ethyl (35 g ha⁻¹) (11). However, the effectiveness of these interventions is closely linked to its germination ecology, vegetative regeneration and tolerance to prolonged soil moisture highlighting the need for knowing the ecological requirements to formulate site-specific management. Weeds generally grow faster than crop plants and absorb applied nutrients more rapidly and in greater quantities, thereby depriving the crop of essential nutrients (12). This competitive advantage is especially evident in direct-seeded rice, where nutrient removal by weeds has been reported to be up to 8 times higher than in puddled transplanted systems (13, 14). In transplanted rice, weed nutrient uptake has been quantified at 30 kg N, 10 kg P and 17 kg K ha⁻¹ in clay loam soils of

Coimbatore (15). Supporting these observations, unweeded control plots in direct-seeded rice showed the greatest nutrient loss due to unchecked weed growth (16).

The biological traits of weeds make them paradigm examples of rapid adaptation to changing climates, frequently exhibiting aggressive growth and invasive tendencies beyond their native range (17). Traits such as high genetic variation, flexible phenology, prolific seed production and persistent seedbanks and diverse physiological pathways allow weed populations to shift distribution, phenology and competitive interactions under climate change condition (18). In this backdrop, the present study aimed to understand the biology of blood grass, with specific emphasis on seed germination, seed viability and its capacity for nutrient uptake and heavy metal absorption, which collectively facilitate its adaptation to wetland rice ecosystems.

Materials and Methods

The experiment field was selected at State Seed Farm, Kottarakkara, Kerala. The soil type was sandy clay characterised by acidic pH (4.52) and high content of organic carbon (1.69 %). The available nitrogen, phosphorus and potassium were 303.34, 13.52 and 153.42 kg ha⁻¹, respectively. The biology of blood grass was studied by observing 25 sample plants marked in the experimental field for a period of 1 year. For this the weed infested paddy field was tilled and puddled and allowed the weeds to proliferate. The growth and development parameters of the newly emerging blood grass seedlings were observed, recorded and the values were averaged.

Five hundred mature seeds of blood grass were collected from the sample plants, air dried and packed in airtight polythene bags and germination studies were undertaken at intervals using the same set of seeds. Initially it was observed that the seeds failed to germinate under laboratory conditions of light and temperature. But when the petri plates were kept in the open sunlight, the seeds germinated readily and hence the trials were continued accordingly at 15 days intervals till the seeds registered total failure of germination.

Twenty seeds were kept in petri plates replicated 5 times and placed under direct sunlight and the number of germinated

seeds on the 7th day of sowing was counted and the germination % was calculated by the following formula.

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds}} \times 100 \quad (\text{Eqn. 1})$$

For estimating the nutrient concentration and removal of blood grass vs rice crop growing in the same field was studied by analysing composite plant samples collected at 60 days after transplanting (DAT) of the rice crop. The content of major (N, P and K) and minor (Ca, Mg and S) nutrients were analysed and the uptake was calculated as the product of respective plant nutrient content and the average dry matter produced by the weed and the crop and expressed as kg ha⁻¹. Average biomass production of blood grass and rice were taken as 36 and 12.73 t ha⁻¹, respectively.

Heavy metal uptake by blood grass and rice grown in the same field was evaluated using composite plant samples collected at 60 DAT of the rice crop. The oven dried samples were ground to a fine powder and subjected to heavy metal analysis using atomic absorption spectrophotometer. The heavy metal uptake was calculated as the product of the respective heavy metal content and the average dry matter produced by the weed and the crop and expressed as kg ha⁻¹.

Results and Discussion

General description and biology

Observations from blood grass infested wetlands of Kerala showed that the weed was present in cultivated rice fields, rice fallows, bunds and irrigation channels but the growth was poor under flooded condition. The perennial prostrate grass is found growing and flowering all throughout the year but prolific growth was observed during rainy seasons. The culms are slender with pubescent nodes, branching and rooting at their lower nodes and is reddish purple in colour. The inflorescence is characterised by paired spikelets, unequally stalked and reddish purple in colour (Fig. 1). When in flower, the inflorescence in group on field bunds and rice fields impart a distinct reddish purple colour to the field, likely giving rise to the common name 'blood grass'. The habit and biology of blood grass was studied and depicted in Table 1.



Fig. 1. Different growth stages of blood grass.

Table 1. Habit, habitat, season and general description of blood grass (*Isachne miliacea*)

Characteristics	Description
Habit	Perennial prostrate grass
Habitat	Cultivated rice fields, rice fallows, bunds, irrigation channels. Poor growth under flooded conditions
Season	Found growing throughout the year. Prolific growth observed during the rainy seasons.
Shoot	Slender culm, branching and rooting at the lower nodes, nodes pubescent, reddish/purple in colour.
Leaves	Leaf lamina lanceolate, acuminate, softly hairy with numerous nerves, hardly distinguishable midribs.
Inflorescence	Paired spikelet, unequally stalked and purple in colour. The inflorescence in groups in field bunds or rice fields provide a characteristic purple colour to the field at its flowering time.
Seeds	Minute seeds, black in colour.
Propagation	Through seeds and rooted stem bits.

Phenology of blood grass

In the well prepared puddled field, blood grass was found to germinate within 2–6 days while the stem bits rooted and established within 3–8 days (Table 2.) The emerged seedlings started producing branches within 11–24 days and spread out which evidently coincided with the early stages of crop growth in the rice field which explains the severe crop - weed competition in the heavily infested fields. The emerged seedlings started flowering within 28–42 days and flowering was found in all seasons. The seed production was within a few days of flowering which matured and shattered by 60–75 days. While the flowering branches shed seeds and withered out, the growth was found to continue vegetative which accounts for the perennial nature of the wetland weed and also its ability to resist weed control practices and flourish throughout the year. Phenotypic plasticity is the property of a given genotype to produce different physiological or morphological phenotypes in response to different environmental conditions (19, 20). The phenophases of blood grass observed in the present study differed from earlier reports, who conducted similar investigations on this species (21). Such variations can be attributed to the phenotypic plasticity of the aggressive weed species which helped it to infest wetlands of varying soil and climatic conditions as is seen in Kerala state.

Table 2. Phenology of blood grass under humid tropical situation

Phenophases	Range	Average	SEm (+/-)
Days to seed germination in the puddled field	2–6	3.5	0.25
Days to rooting of stem bits in the puddled field	3–8	5.8	0.32
Days to produce branches in the emerged plants	11–24	18.4	0.27
Days to flowering	28–42	34.7	0.94
Days to seed formation	32–52	44.7	1.09
Days to seed shedding	60–74	67.8	0.80

Vegetative characteristics

The observations on vegetative characteristics of blood grass showed that on an average, single plant produced 38–56 leaves of 20.9 mm length and 4.8 mm width on an average and the number of branches ranged from 4–13 (Table 3). The average internodal length was 6.4 cm and the shoot and root lengths were 22.4 and 14.6 cm respectively. The average plant dry weight was 362 g m⁻² and the biomass production was worked out as 3.62 t ha⁻¹. The observed growth characteristics were not consistent with earlier reports (21). The growth characteristics of this serious rice weed were significantly influenced by nutrient management and crop density in the rice fields (3). In the current study, the sample plants

for the study were collected from a field where there was no crop weed competition. Hence, the variations in the growth parameters and biomass production in different reports can be attributed to the differences in resources available for the weed growth in different infestation sites.

Table 3. Vegetative characteristics of blood grass

Characteristics	Range	Average	SEm (+/-)
Leaf number	38–56	45.6	0.88
Leaf length (mm)	16–25	20.9	0.52
Leaf width (mm)	4.3–5.2	4.8	0.05
Number of branches per plant	4–13	7	0.47
Internode length (cm)	4.9–7.9	6.4	0.15
Root length of seedlings (cm)	12.2–19.6	14.6	0.36
Root length of stem bits (cm)	10.5–18.3	13.8	0.24
Plant dry weight (g m ⁻²)	215–489	362	0.03
Biomass production (t ha ⁻¹)	2.15–4.89	3.62	2.09

Propagation characteristics

In our study, the seedlings which emerged out from the prepared rice field was found to branch and spread out fast and characters are depicted in Table 4. On an average each plant produced 7.1 panicles which produced 62.9 seeds. The character of prolific seed production relieves the weeds to survive and establish under wetland rice ecosystems of tropical region (22). Vegetative propagation was also found fast and aggressive. On an average eight rooted nodes were produced by each plant which again were capable of developing as individual plants. After about 3 weeks, it was found difficult to distinguish the individual plants because of its mat forming growth pattern above and below ground. Blood grass is a perennial weed which is capable of spreading through seeds as well as rooted stem bits making it one of the most troublesome weeds even under better managed situations. In an earlier report it was observed that blood grass which infested vast tracts of rice fields in Kerala was resistant to the prevalent farmers' practice of hand pulling and its mat forming roots interfered with the movement of wheels of small implements like rotary weeder restricting their efficient use (23). In wet-seeded rice, perennial weed species pose a major challenge because their underground propagules allow them to survive and persist through unfavourable climatic conditions (20). The ability to produce a large number of seeds is one of the main features developed by weeds that occur in rice fields to escape the stress imposed by the control methods and ensure the species survival (7, 24, 25).

Table 4. Propagation characteristics of blood grass

Characteristics	Range	Average	SEm(+/-)
Number of inflorescences per plant	4–9	7.1	0.31
Length of panicle (mm)	54–72	62.9	0.83
Number of seeds per panicle	58–78	69.6	1.00
Total seeds per plant	232–702	614	0.47
Number of rooted nodes per plant	6–13	8	0.35

Dormancy, germination and viability of blood grass seeds

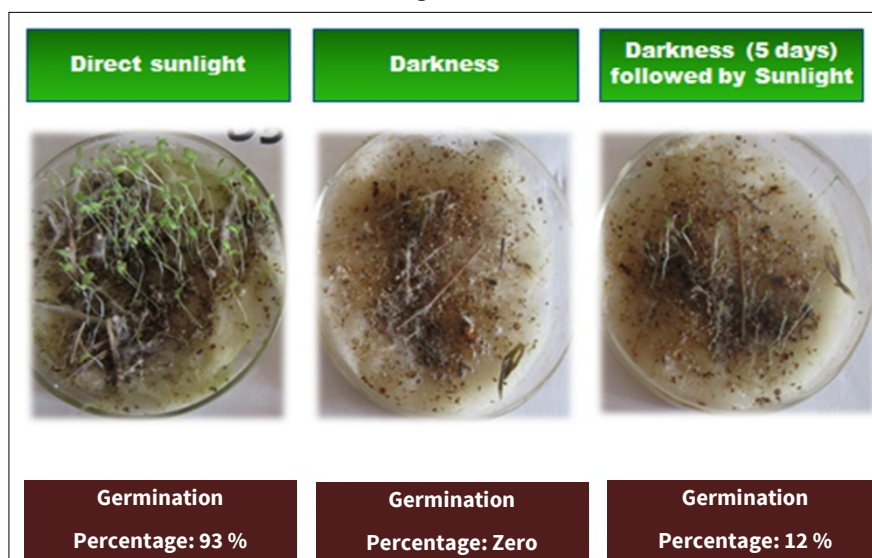
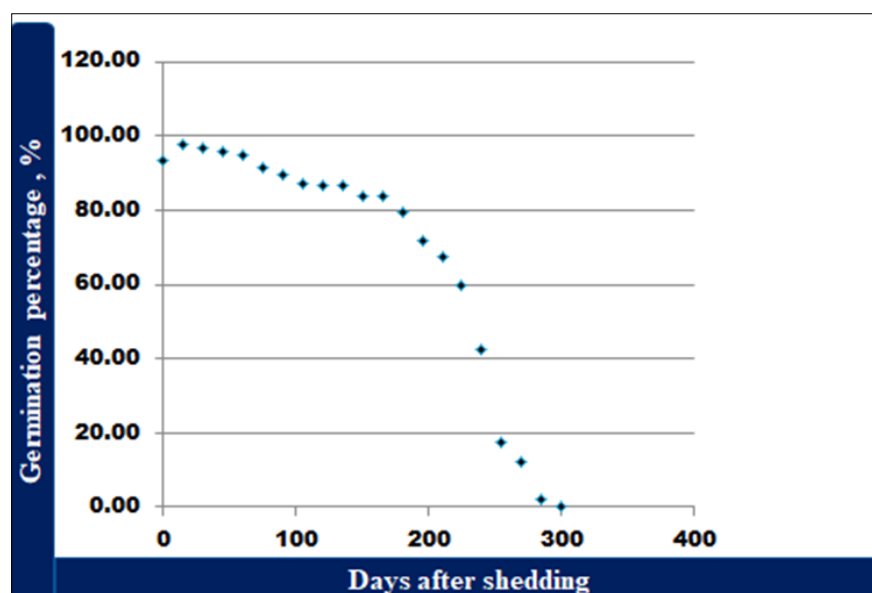
Initially it was observed that the seeds failed to germinate under the lab conditions of light and temperature but germinated readily when the petri plates were transferred and maintained under direct sunlight (Fig. 2). It was clear that direct sunlight available in open rice fields was essential for the seed germination. This is an adaptation for the survival and proliferation of blood grass under wetland rice ecosystem, especially when heat stress climate vagaries increases.

The results of the germination studies revealed that the seeds had no dormancy and could germinate soon after shedding and retained >80 % germination up to 6 months. After that there was a sharp decline in germination and at 10 months after shedding

there was no further seed germination indicating total loss of seed viability (Fig. 3). Evidently such extended viability of the seeds, must be the major reason for the difficulty in suppressing the weed in the infested wetlands which are likely to be very rich in the soil seed bank (20). Low initial dormancy of seeds accumulated in surface soil layers ensures a persistent seed bank (26). The result also explains why blood grass has become such a persistent weed in the wetlands of Kerala. It is also in agreement when the moist seeds were placed on the soil surface > 95 % of the seeds germinated and declined their germination and vigour index on increasing the soil depth. In a variable soil and water column study all the seeds of blood grass failed to germinate at 10 cm soil depth under water column of 7.5 and 10 cm (11).

Content and uptake of nutrients -blood grass vs rice

The results revealed that the content of nitrogen and potassium was higher in rice while phosphorus content was more in blood grass (Table 5). Calcium, magnesium and sulphur concentration in both species was more or less similar. The order of concentration was $N > K > P > Ca > Mg > S$ in blood grass while in rice plant it was $N > K > Ca > P = Mg > S$. The nutrient uptake value in blood grass followed the order $N > K > P > Ca > Mg > S$ whereas in rice plant it was $N > K > Ca > P = Mg > S$. Between the 2 plant species, the uptake

**Fig. 2.** Importance of sunlight for the germination of blood grass.**Fig. 3.** Germination percentage of blood grass over a period of time.

values of all the nutrients were found much higher in rice crop. Weeds accumulate high concentrations of nutrients in their tissues which in many cases are more than those found in common crop plants. This combined with heavy vegetative growth of weeds, enables them to remove large quantities of plant nutrients from the soil (27).

Table 5. Content and uptake of nutrients - blood grass vs rice

Nutrients	Blood grass		Rice plant	
	Content (%)	Uptake* (kg ha ⁻¹)	Content (%)	Uptake* (kg ha ⁻¹)
Nitrogen (N)	1.18	42.7	1.32	168.1
Phosphorus (P)	0.34	12.3	0.23	29.3
Potassium (K)	0.94	34.0	1.21	154.1
Calcium (Ca)	0.25	9.1	0.24	30.6
Magnesium (Mg)	0.24	8.7	0.23	29.3
Sulphur (S)	0.14	5.1	0.16	20.4

*Average biomass of blood grass: 3.62 t ha⁻¹, **Average biomass of rice: 12.73 t ha⁻¹.

Among the 3 nutrients, the quantity of nitrogen removed from the rice field was more than that of phosphorus and potassium during both seasons. This aligns with earlier observations that weeds are more efficient in nitrogen uptake, whereas the crop absorbs phosphate and potash more effectively (28). In line with this, nutrient removal to the tune of 43.05 kg N, 3.08 kg P and 48.28 kg K ha⁻¹ was reported due to unrestricted weed proliferation in wet seeded direct-seeded rice (29).

Content and uptake of heavy metals - blood grass vs rice

The results showed that heavy metal concentrations were considerably higher in blood grass than in rice (Table 6). In blood grass, concentrations followed the order Fe > Mn > Zn > Cu > Cr > Cd > Pb, whereas in rice the order was Mn > Fe > Zn > Cu > Pb > Cd > Cr. A similar pattern was observed for uptake values, which were consistently higher in rice for all metals except iron. Blood grass recorded the highest uptake for iron (0.65 kg ha⁻¹), while in rice the maximum uptake was for manganese (0.59 kg ha⁻¹) (Fig. 4). The iron content of blood grass was more than 4 times that of rice, indicating its remarkable tolerance to iron-rich conditions. This suggests that blood grass can thrive in iron-toxic wetland rice ecosystems where rice productivity is severely constrained. Its ability to withstand high iron levels, especially under conditions of prolonged soil moisture resulting from erratic rainfall in tropical climates, contributes to its persistent and widespread occurrence in such environments. Heavy metals are generally defined as metals with relatively high

densities, atomic weights or atomic numbers. Some heavy metals are essential nutrients (typically iron, cobalt and zinc), but heavy metals, such as cadmium, chromium, lead etc. are highly poisonous and the potential sources of heavy metal poisoning include industrial wastes, agricultural runoff, solid wastes etc and wetlands are often sink to such poisonous wastes (30).

Aquatic plant species are widely recognised for their capacity to accumulate and remove substantial quantities of heavy metals from contaminated environments (31, 32). In the present study, comparative analysis of heavy metal content and uptake in blood grass and rice grown in the same wetland ecosystem was undertaken to evaluate the metal-accumulation potential of this dominant species and its role in altering metal dynamics within rice fields. The elevated accumulation is consistent with earlier explanations that certain plant species possess robust detoxification mechanisms such as vacuolar sequestration of metal ions via complexation with organic acids, peptides and proteins, along with exclusion strategies that enable them to tolerate and store high metal loads (33). The uptake of iron and copper by duckweed (*Lemna minor* L.) and water velvet (*Azolla pinnata* R. Br.) was earlier reported from polluted water (34).

Both blood grass and rice demonstrated the ability to extract significant quantities of heavy metals from wetland soils, which function as major sinks for such contaminants. Notably, the substantially higher concentrations observed in blood grass stressed the need for caution when permitting free grazing in infested fallows. This assessment is particularly relevant because heavily infested fields are frequently left fallow and subsequently used for open grazing, raising concerns about potential metal transfer to livestock and, ultimately, to humans.

Table 6. Content and uptake of heavy metals - blood grass vs rice

Heavy metals	Blood grass		Rice plant	
	Content (mg kg ⁻¹)	Uptake* (kg ha ⁻¹)	Content (mg kg ⁻¹)	Uptake** (kg ha ⁻¹)
Iron (Fe)	178.84	0.65	43.34	0.55
Zinc (Zn)	49.63	0.18	38.17	0.49
Manganese (Mn)	86.37	0.31	46.35	0.59
Copper (Cu)	17.15	0.06	14.32	0.18
Lead (Pb)	1.41	0.01	1.21	0.02
Cadmium (Cd)	1.67	0.01	0.91	0.01
Chromium (Cr)	2.17	0.01	0.73	0.01

*Average biomass of blood grass: 3.62 t ha⁻¹, **Average biomass of rice: 12.73 t ha⁻¹.

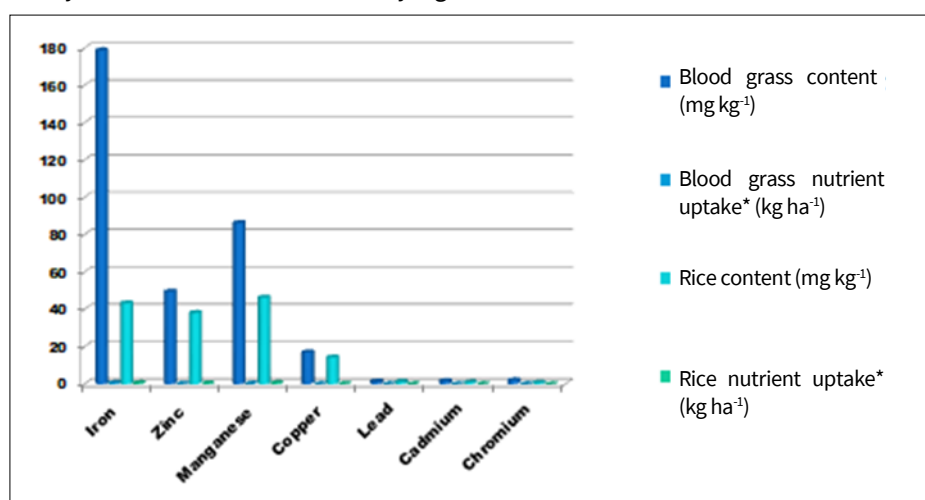


Fig. 4. Heavy metal content and nutrient uptake of blood grass and rice.

Conclusion

Blood grass thrives in wetland rice systems of Kerala due to its rapid, vigorous vegetative spread and continuous seed production. Its ability to form dense mats early in the season and regeneration from multiple rooted nodes makes it highly persistent. Adaptation to thrive under iron-rich acidic soils further strengthens its dominance. These traits highlight the need for integrated, timely and region-specific strategies to effectively limit its spread. Future research should focus on understanding the molecular mechanisms underlying its tolerance to iron toxicity and characterising seedbank dynamics and dormancy behavior across seasons.

Acknowledgements

Authors are thankful to Kerala Agricultural University for providing facilities for the research.

Authors' contributions

RB wrote the manuscript and performed the experiments. BB arranged the resources. GK supervised the study and AM reviewed the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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