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RESEARCH ARTICLE

Enhancing rice seedling growth and vigour through liquid organic manure-based seed priming

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Abstract

Seed invigoration is a post-harvest treatment aimed at enhancing seed germination and seedling growth, with seed priming being one of the most important techniques in this category. A pot culture experiment was conducted in the net house of the Department of Agronomy, College of Agriculture, Vellayani, during September 2023. The objective of the study was to evaluate the effect of seed priming with liquid organic manures (LOMs) on the germination and seedling vigour of rice (*Oryza sativa* L.). The LOMs employed in the study included beejamrit, jeevamrit, panchagavya and vermiwash, each tested at four concentrations: 2.5 %, 3 %, 5 % and 6 %. Compared to control treatments (hydropriming and unprimed seeds), LOMs priming significantly enhanced germination parameters and seedling vigour. Among the treatments, vermiwash at 5 % concentration recorded higher values for germination index (125.3), germination speed (2.68) and mean daily germination (2.1). Panchagavya at 5 % concentration showed the highest germination rate index, whereas the coefficient of velocity of germination was greatest with vermiwash at 3 %. Beejamrit at 6 % resulted in the highest germination percentage, while seedling vigour index II was highest in vermiwash 6 %. Both treatments performed comparably to vermiwash 5 %. Although several treatments excelled in specific parameters, vermiwash 5 % consistently outperformed others across multiple germination metrics, indicating its strong potential as an effective seed priming agent for rice. Additionally, beejamrit and jeevamrit demonstrated specific advantages, suggesting their suitability for tailored applications based on crop-specific requirements or desired outcomes.

Keywords: beejamrit; jeevamrit; panchagavya; seedling vigour; seed priming; vermiwash

Introduction

Rice is a major staple food in Asia, the Caribbean and Latin America, where it forms the foundation of daily diets and in recent years, its popularity has also been rapidly increasing across Africa (1). The world per capita consumption of rice was approximately 54 kg per person (2) making it the single most important food item in terms of calorie intake globally, providing on average over 20 % of the total dietary energy for the human population (3). However, poor germination, rising labour costs, water scarcity and global population growth pose significant challenges to rice productivity. To tackle these issues and support global food security, there is a need to adopt solutions that are simple, efficient and sustainable (4).

Among the various approaches, seed invigoration techniques have been shown to be effective in enhancing seed performance. These methods are known to reduce emergence time, synchronize germination and improve seedling establishment (5). Among seed invigouration methods, seed priming stands out as the most common, eco-friendly and sustainable technique. It improves seed vigour, accelerates germination, promotes seedling growth and ultimately increases crop yield across various plant species (6).

Seed priming works by initiating pre-germinative metabolic processes during the early phase of imbibition, seeds absorb water, triggering a cascade of pre-germinative physiological and biochemical activities. This includes the activation of DNA repair mechanisms and antioxidant pathways, which help maintain genome integrity and support better germination and seedling development (7).

Liquid organic manures (LOMs) are prepared through the fermentation of animal by-products such as cow dung, cow urine and other organic residues over a specific period. These inputs play a vital role in enhancing the physical, chemical and biological properties of the soil, ultimately leading to improved soil fertility. Commonly used LOMs include beejamrit, jeevamrit, panchagavya and vermiwash. These inputs are not only sustainable and environmentally friendly but also promote microbial activity and nutrient availability in the soil, contributing to better crop health and productivity. Several authors reported that seed priming with liquid organics significantly enhanced the seedling parameters in various crops (8-11). LOMs can be effectively utilized for seed priming, as they are rich in macro and micronutrients, vitamins, plant hormones, essential amino acids and beneficial microorganisms (12).

Panchagavya is a traditional organic formulation comprising nine ingredients, viz., cow dung, cow's urine, cow's milk, curd, jaggery, ghee, banana, tender coconut and water, widely recommended for promoting sustainable and organic agriculture (13). Its application has been shown to enhance various plant growth parameters, including increased development of side shoots, improved root growth and higher germination rates (14). As a result, panchagavya contributes significantly to improved germination, seedling vigour, root and shoot development and overall yield.

Similarly, beejamrit has demonstrated notable benefits in seed invigoration. Treatment with undiluted beejamrit (100 %) has resulted in higher germination percentages, greater seedling growth and an improved seed vigour index (15).

Jeevamrit also plays a vital role in organic farming systems. Studies have shown that jeevamrit is a rich microbial consortium that supports nitrogen fixation and phosphorus solubilization (16, 17). In addition to being a valuable source of beneficial microbes, it supplies essential macro and micronutrients such as carbon (C), nitrogen (N), phosphorus (P), potassium (K) and trace elements, thereby enhancing soil fertility and crop productivity. Chickpea seeds primed at 9 % concentration of jeevamrit resulted in higher seed yield (18).

Vermiwash is a liquid extract derived from vermicompost, rich in essential macro and micronutrients, enzymes, vitamins, humic acids and plant growth hormones such as indole-3-acetic acid (IAA) and cytokinins. It also contains earthworm mucous and beneficial microorganisms (19, 20). The P, Ca, Mg and Na contents in vermiwash were 84 %, 89 %, 97 % and 98 % higher respectively, than those in vermicompost (21). The nutrient composition of vermiwash is largely influenced by the organic substrates used during vermicomposting (22). Acting as a natural tonic, vermiwash has been reported to reduce the incidence of fungal diseases, enhance photosynthetic activity, promote plant growth and increase both nutrient availability and uptake (23). Seeds primed in vermiwash at 6 % concentration for 12 hr resulted in higher seedling length (37.2 cm), seedling fresh weight (8.6 g) and seedling dry weight (2.04 g) in chickpea (24). With this background the present study aims to assess the seed invigouration potential of different concentrations of LOMs, beejamrit, jeevamrit, vermiwash and panchagavya on germination parameters and seedling vigour of rice (*Oryza sativa* L.).

Materials and Methods

The experiments were conducted during September 2023 in the net house of the Department of Agronomy, College of Agriculture, Vellayani, located at 8°25′43′′ N latitude, 76°59′98′′ E longitude and 29 m above mean sea level (MSL). The method adopted for the study was pot culture.

Experimental design

The experiment was laid out in a Completely Randomized Design (CRD) with 18 treatments and three replications. The treatments included panachagavya, beejamrit, jeevamrit and vermiwash at four different concentrations (2.5 %, 3 %, 5 % and 6 %) along with hydropriming and no priming treatment (unprimed). The experiment was repeated to confirm the results.

Preparation of LOMs

Panchagavya and vermiwash were prepared as per the methods described in Package of Practices Recommendations (Organic) Crops of Kerala (25). Jeevamrit and beejamrit were prepared based on the methodology given in the Training Module of NCONF (26). Characterization of LOMs were done and is presented in Table 1 and 2.

Seed priming and sowing

Seeds of the Prathyasa variety were primed in the respective concentrations of LOMs for 16 hr, then dried back to their original moisture content. In the hydropriming control, seeds were soaked in tap water for the same duration and similarly dried.

Twenty-five seeds were sown per pot (6-inch plastic pots) filled with pure sand. The crop was maintained under uniform conditions for 14 days.

Observations recorded

Daily germination counts were recorded up to 14 days after sowing (DAS). On the 14th DAS, seedlings were carefully uprooted and the following parameters were measured: root length and shoot length (cm), fresh weight of shoots and roots (g). Dry weight of root and shoot were determined after drying in a hot air oven at 60 °C for three days till a constant weight was obtained and expressed in g. The following germination parameters, seedling vigour index I and II were determined using the formulas below:

Table 1. Chemical parameters of liquid organic manures

Parameters	Method adopted	Panchagavya	Beejamrit	Jeevamrit	Vermiwash
pH	pH meter (27)	3.56	7.83	6.01	3.56
EC, dS m^{-1}	Conductivity meter (27)	3.2	0.9	0.8	3.1
OC (%)	Titration method (28)	8.35	0.81	0.69	1.86
Total N (%)	Microkjeldahl digestion and distillation (27)	3.64	1.57	2.07	1.85
Total P (%)	Vanadomolybdate phosphoric yellow colour method (27)	0.64	0.19	0.154	0.89
Total K (%)	Diacid digestion (HNO_3 and $HClO_4$ in ratio 9:4) and estimation using flame photometer (27)	0.15	0.36	0.09	0.63
Total Ca (%)	Diacid (HNO_3:$HC1O_4$ in the ratio 9:4) digestion and estimation using AAS (27)	0.1	0.06	0.04	0.04
Total Mg (%)	Diacid (HNO_3:$HC1O_4$ in the ratio 9:4) digestion and estimation using AAS (27)	0.06	0.048	0.084	0.168
S (%)	Diacid (HNO_3:$HC1O_4$ in the ratio 9:4) digestion and turbidimetry (29)	0.305	0.308	0.165	0.187
Fe (mg L^{-1})	Diacid (HNO_3 and $HClO_4$ in ratio 9:4) digestion and estimation using AAS (27)	2.26	0.27	0.38	0.40
Zn (mg L^{-1})	Diacid (HNO_3 and $HClO_4$ in ratio 9:4) digestion and estimation using AAS (27)	0.31	0.07	0.08	0.08
Cu (mg L^{-1})	Diacid (HNO_3 and $HClO_4$ in ratio 9:4) digestion and estimation using AAS (27)	0.06	0.03	0.08	0.06

Table 2. Biological parameters of liquid organic manures

Parameters	Method	Panchagavya	Beejamrit	Jeevamarit	Vermiwash
Urease enzyme activity (µg urea hydrolysed mL^{-1} 4 hr^{-1})	Spectrophotometric method (30)	8.33	6.91	7.58	8.99
Dehydrogenase enzyme activity (µg TPF hydrolysed g^{-1})	Modified TTC dehydrogenase technique (31)	9.35	7.17	8.70	10.44
Bacteria ($10^{-4} \times$ CFU mL^{-1})	Nutrient Agar medium (32)	76	46	55	49
Fungi ($10^{-4} \times$ CFU mL^{-1})	Martin's Rose Bengal Agar (33)	37	33	23	22
Actinomycetes ($10^{-4} \times$ CFU mL^{-1})	Ken Knight's Agar medium (34)	7	9	8	5

1. Germination Percentage (GP) (35)

GP = (Total number of seeds germinated/Total number of seeds sown) × 100

2. Germination Index (GI) (36)

$GI = (14 \times n_1) + (14 \times n_2) + \ldots\ldots.. + (1 \times n_{14})$

Where, n_1, n_2,…n_{14} are the numbers of seedlings emerged on the first, second and subsequent days until the 14th day; 14, 13, … and 1 are weightage assigned to the number of seedlings emerged on the 1st, 2nd and 14th day respectively.

3. Germination Rate Index (GRI) (37)

$GRI = (G_1 \times 100)/1 + (G_2 \times 100)/2 + \ldots + (G_n \times 100)/n$

Where, G_1 and G_2 are the germination percentage on the 1st and 2nd day after sowing and G_n is the emergence percentage on the nth day after sowing.

4. Co-efficient of Velocity of Germination (CVG) (38)

$CVG = (\sum N_i)/(\sum N_i \times T_i) \times 100$

Where, N_i is the number of seeds germinated in each time interval, T_i is the time from the start of the experiment to the end of each time interval and ∑ represents the sum of all values within the time intervals.

5. Speed of Germination (SG) (39)

$SG = n_1/d_1 + n_2/d_2 + \ldots + n_{14}/d_{14}$

Where, n_1 is the number of seedlings emerged on the 1st day, n_2 is the number of seedlings emerged on the 2nd day and n_{14} is the number of seedlings emerged on the xth day, d_1 is the 1st day, d_2 the 2nd day and d_{14} the 14th day.

6. Mean Germination Time (MGT) (40)

$MGT = n_1 \times d_1 + n_2 \times d2 + n_3 \times d_3 + \text{--------}/\sum n$

Where, n = number of seeds germinated on each day

7. Mean Daily Germination (MDG) (36)

MDG = Total number of seeds germinated till 14 DAS/Σn

8. Time to 50 % germination (T_{50}) (41)

$T_{50} = t_i + [(N/2 - n_i)(t_j - t_i)]/(n_j - n_i)$

Where, N is the number of final germination count and n_i, n_j cumulative number of seeds germinated at adjacent days t_i and t_j when $n_i < n_j$

9. Seedling Vigour Index I (SVI I) (42)

SVI I = Seedling length (cm) × Germination percentage

10. Seedling Vigour Index II (SVI II) (42)

SVI II = Seedling dry weight (g) × Germination percentage.

Statistical analysis

Data from the trials were pooled for statistical analysis, as no significant interaction effects were observed between treatments and trials. The experimental data were analysed using analysis of variance (ANOVA) (43). Statistical significance was assessed using the F-test and the least significant difference (LSD) was calculated at $P < 0.05$ to determine significant differences among treatments (43). All statistical analyses were conducted using Grapes Agri 1 software (44).

Results

Characterization of LOMs

The chemical properties of LOMs are summarized in Table 1. The pH ranged from 3.56 to 7.83. Panchagavya was strongly acidic, jeevamrit slightly acidic, whereas vermiwash and beejamrit were slightly alkaline. The electrical conductivity (EC) varied from 0.8-3.2 dS m^{-1}. The EC of panchagavya and vermiwash exceeded 3 dS m^{-1}, while beejamrit and jeevamrit recorded values below1 dS m^{-1}.

The N content of the liquid manures varied from 1.57-3.64 %. The highest N content was observed in panchagavya (3.64 %) and the lowest in beejamrit (1.57 %). Phosphorus content varied from 0.154-0.894 %. Vermiwash had the highest P content (0.894 %) and jeevamrit had the lowest P content (0.154 %). Potassium content of the LOMs varied from 0.09-0.63%. Vermiwash had the highest K content (0.63 %) and the lowest K content was observed in jeevamrit (0.09 %).

The Ca content was the highest in panchagavya (0.1 %) and the lowest in vermiwash (0.04 %). However, Mg content was the highest in vermiwash (0.17 %) and the lowest in panchagavya (0.06 %). Sulphur content was highest in beejamrit (0.308 %) and the lowest in jeevamrit (0.165 %).

Among the LOMs, panchagavya contained the highest concentrations of iron (2.26 %) and zinc (0.31 %), whereas the highest copper content (0.08 %) was observed in jeevamrit.

Among the different LOMs tested, panchagavya had the highest organic carbon content (8.35 %) and it was followed by vermiwash (1.86 %). The lowest organic carbon content was noted in jeevamrit (0.69 %). Vermiwash resulted in the highest urease enzyme and dehydrogenase activities (8.99 µL urea hydrolyzed mL^{-1} 4 hr^{-1} and 10.44 µL TPF $mL^{-1}d^{-1}$), whereas beejamrit recorded the lowest value for both the enzymes.

The bacterial and fungal population was higher in panchagavya (76.0 × 10^{-4} CFU mL^{-1}). The bacterial population was the lowest in beejaamrit (55 ×10^{-4} CFU mL^{-1}), whereas fungal population was lower in vermiwash (22 × 10^{-4}CFU mL^{-1}). However, the actinomycetes population was higher in beejamrit (9 × 10^{-4}CFU) and lower in vermiwash (5 × 10^{-4} CFU).

Effect of seed priming with LOMs on germination parameters of rice

Germination percentage

Germination percentage was significantly influenced by seed priming with LOMs in different concentrations (Table 3). Beejamrit at 6 % concentration resulted in the highest germination percentage (90.0 %) and was on par with vermiwash at 5 % (82.2 %) and jeevamrit at 3 % (80.0%). In contrast, jeevamrit at 5 % recorded the lowest germination percentage (53.3 %).

Germination index

Germination index was significantly influenced by seed priming treatments (Table 3). Vermiwash at 5 % recorded the highest germination index (125.3), followed by jeevamrit at 3 % (115.7), which was statistically on par with vermiwash at 3 % and 6 % (112.7). Jeevamrit at 5 % resulted in the lowest germination index (53.3).

Germination rate index

Germination rate index was also influenced by the seed priming treatments (Table 3). Among the treatments, beejamrit at 5 % resulted in the highest germination rate index (21.6), which was on par with vermiwash at 5 %, vermiwash at 2.5 %, panchagavya at 5 % and jeevamrit at 6 %. In contrast, panchagavya at 3 % and unprimed seeds recorded the lowest germination rate index (16.6).

Co-efficient of velocity of germination

Co-efficient of velocity of germination was also significantly influenced by seed priming with LOMs (Table 4). Vermiwash at 3 % resulted in highest CVG (21.4), which was on par with vermiwash at 2.5 %, 5 % and 6 %, beejamrit at 5 %, 3 % and 2.5 %, jeevamrit at 6 % and 3 %. Panchagavya at 3 % resulted in lowest CVG among the treatments (15.8).

Speed of germination

Seed priming with LOMs had significant effect on speed of germination (Table 4). Among the treatments, vermiwash at 5 % resulted in highest speed of germination (2.68), which was on par with vermiwash at 3 % (2.38) and jeevamrit at 3 %. Among the treatments, lower speed of germination was observed in panchagavya at 3 % (1.43).

Mean germination time

Mean germination time was also significantly influenced by seed priming with LOMs (Table 4). Among the treatments, panchagavya at 3 % resulted in the lowest mean germination time (5.2), which was on par with jeevamrit at 5 % (5.6) and 6 % (5.8) and panchagavya at 2.5 % (5.8). The highest mean germination time was noted in vermiwash at 5 % (9.2).

Mean daily germination

Mean daily germination time was also influenced by seed priming with LOMs (Table 4). Vermiwash at 5 % resulted in higher mean daily germination (2.1), which was on par with vermiwash at 2.5 % and 6 %. Panchagavya at 3 % recorded the shortest mean daily germination among the treatments (0.9).

Time to 50 % germination

T_{50} was also significantly influenced by seed priming with LOMs (Table 4). Among the treatments, vermiwash at 2.5 %, 3 % and 6 %, beejamrit at 5 %, jeevamrit at 6 % and hydro primed seeds took lesser time to achieve 50 % germination (4.7 days), which was on par with vermiwash at 6 %, beejamrit at 6 % and jeevamrit at 3 % and 5 %. Seeds primed in panchagavya at 2.5 % took the longest time to achieve 50 % germination among the treatments (6.3 days).

Effect of seed priming with LOMs on seedling growth parameters and vigour index

Seedling shoot length

Seed invigouration had significant effect on shoot length of rice seedlings (Table 5). Panchagavya at 5 % resulted in the maximum shoot length (25.1 cm), followed by vermiwash at 2.5 % (23.3 cm), which was statistically on par with vermiwash at 3 %, 5 % and 6 %. The minimum shoot length was recorded in unprimed seeds (control).

Table 3. Effect of seed invigouration with LOMs at different concentrations on germination percent, germination index, germination rate index and co-efficient of velocity of germination

Treatments	GP	GI	GRI	CVG
T_1: Panchagavya 2.5 %	66.7	89.3	16.9	16.2
T_2: Panchagavya 3 %	55.5	76.3	16.6	15.9
T_3: Panchagavya 5 %	68.9	86.0	20.8	15.8
T_4: Panchagavya 6 %	74.4	105.0	18.6	16.9
T_5: Beejamrit 2.5 %	68.9	89.7	19.0	19.5
T_6: Beejamarit 3 %	64.5	93.0	19.4	20.4
T_7: Beejamrit 5 %	66.7	99.7	21.6	20.5
T_8: Beejamrit 6 %	90.0	106.3	19.4	18.2
T_9: Jeevamrit 2.5 %	71.1	95.7	17.6	16.3
T_{10}: Jeevamrit 3 %	80.0	115.7	19.8	18.8
T_{11}: Jeevamrit 5 %	53.3	90.3	18.0	16.9
T_{12}: Jeevamritham 6 %	60.0	88.3	20.2	19.3
T_{13}: Vermiwash 2.5 %	62.2	96.3	21.4	21.2
T_{14}: Vermiwash 3 %	75.6	112.7	20.5	22.4
T_{15}: Vermiwash 5 %	82.2	125.3	21.5	20.6
T_{16}: Vermiwash 6 %	75.5	112.7	20.0	19.9
T_{17}: Hydropriming	77.8	108.0	19.1	18.0
T_{18}: No priming	66.7	87.7	16.6	16.0
SEm (±)	3.8	2.0	0.5	1.0
CD (p = 0.05)	11.25	6.09	1.43	2.86

GP: germination percentage; GI: germination index; GRI: germination rate index; CVG: co-efficient of velocity of germination.

Table 4. Effect of seed invigouration with different LOMs at different concentrations on speed of germination, mean germination time, mean daily germination and time to 50 % germination

Treatments	SG	MGT (d)	MDG (no.)	T_{50} (no.)
T_1: Panchagavya 2.5 %	1.67	5.8	1.0	6.3
T_2: Panchagavya 3 %	1.43	5,2	0.9	5.7
T_3: Panchagavya 5 %	1.79	6.6	1.1	5.7
T_4: Panchagavya 6 %	1.91	7.9	1.4	5.7
T_5: Beejamrit 2.5 %	1.99	6.0	1.5	4.7
T_6: Beejamarit 3 %	1.91	7.5	1.5	5.0
T_7: Beejamrit 5 %	1.78	6.8	1.4	4.7
T_8: Beejamrit 6 %	2.22	7.6	1.6	5.3
T_9: Jeevamrit 2.5 %	1.91	6.3	1.1	5.0
T_{10}: Jeevamrit 3 %	2.36	8.1	1.5	5.3
T_{11}: Jeevamrit 5 %	1.45	5.6	1.1	5.3
T_{12}: Jeevamritham 6 %	1.79	5.8	1.1	4.7
T_{13}: Vermiwash 2.5 %	2.09	8.3	2.0	4.7
T_{14}: Vermiwash 3 %	2.38	8.1	1.7	4.7
T_{15}: Vermiwash 5 %	2.68	9.2	2.1	4.7
T_{16}: Vermiwash 6 %	2.33	7.1	1.9	5.0
T_{17}: Hydropriming	2.25	7.5	1.5	4.7
T_{18}: No priming	1.75	6.3	0.9	5.7
SEm (±)	0.11	0.3	0.1	0.3
CD (p = 0.05)	0.331	0.77	0.20	0.87

SG: speed of germination; MGT: mean germination time; MDG: mean daily germination; T50: time to 50 % germination.

Seedling root length

Root length of rice seedlings was also significantly influenced by seed invigouration treatments (Table 5). Among the treatments, vermiwash at 3 % resulted in the highest root length (18.5 cm) and it was followed by vermiwash at 2.5 %. Hydropriming treatment recorded the shortest root length among the treatments.

Seedling shoot fresh weight

Among the treatments, panchagavya at 5 % resulted in highest shoot fresh weight (0.129 g), which was on par with vermiwash at 6 %. Unprimed seeds resulted in lower shoot fresh weight (Table 5).

Seedling shoot dry weight

Among the treatments, vermiwash at 6 % resulted in highest shoot dry weight (0.057g), which was on par with vermiwash at 5 % (0.053g). Unprimed seeds resulted in the lowest seedling shoot dry weight (Table 5).

Seedling root fresh weight

Seed invigouration with LOMs had significant effect on root fresh weight of rice seedlings (Table 5). Among the treatments, panchagavya at 5 % resulted in higher root fresh weight (0.259 g), which was on par with vermiwash at 6 % (0.246 g). Unprimed seeds had the lowest seedling root fresh weight (0.092 g).

Seedling root dry weight

Vermiwash at 6 % resulted in the highest root dry weight (0.088g), followed by vermiwash at 5 % (0.079g). The lowest root dry weight was observed in unprimed seeds (0.027 g).

Seedling vigour index I

Seed priming with LOMs had significant effect on seedling vigour index I (Fig. 1). Among the treatments, beejamrit at 6 % resulted in higher seedling vigour index I (3123), which was on par with vermiwash at 3 % and 5 %, jeevamrit at 3 %, panchagavya at 5 % and vermiwash at 6 %. Panchagavya at 3 % resulted in the lowest seedling vigour index I (1771).

Seedling vigour index II

Seedling vigour index II was also significantly influenced by the seed invigouration treatments (Fig. 2). Among the treatments, vermiwash at 6 % resulted in the highest seedling vigour index II (10.95), which was on par with vermiwash at 5 % (10.85). The lowest seedling vigour index II was observed in unprimed seeds (2.68).

Discussion

Effect of seed priming on germination parameters

Co-efficient of velocity of germination focuses on the rate of germination, considering both the number of seeds germinated and the time taken for germination, higher CVG means, faster germination. In contrast, speed of germination indicates the speed with which the seed germinates and it considers only the number of seeds germinating in a period. Mean germination time is the measures of the average time taken for a seed to germinate under specific conditions and it relates to the speed and uniformity of germination. Mean daily germination, indicates the average number of seeds germinating per day. Time to 50 % germination refers to the duration required for 50 % of the seeds to germinate.

In this study, LOMs, particularly vermiwash at 5 % showed overall superior performance across most germination parameters, indicating its potential as a promising seed priming agent. It recorded higher values for germination index (125.3), speed of germination (2.68) and mean daily germination (2.1). However, the germination rate index was highest with panchagavya at 5 %, while the CVG was highest in vermiwash at 3 % and the germination percentage was highest with beejamrit at 6 %.

Seed priming is a seed invigoration technique that enhances the rate of germination, accelerates seed emergence, improves seedling vigour, boosts stress tolerance and ultimately increases the growth and yield potential of rice. This is achieved by partially hydrating the seeds and activating early metabolic processes that occur during Phase I and II of germination, prior to sowing. The use of LOMs as natural priming agents aligns with sustainable agriculture practices, offering an eco-friendly alternative to synthetic treatments.

Table 5. Effect of seed invigouration with LOMs at different concentrations on seedling growth parameters of rice

Treatments	Shoot length (cm)	Root length (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)
T_1: Panchagavya 2.5 %	20.7	14.9	0.068	0.023	0.136	0.047
T_2: Panchagavya 3 %	17.3	14.6	0.057	0.019	0.114	0.031
T_3: Panchagavya 5 %	25.1	14.7	0.129	0.037	0.259	0.070
T_4: Panchagavya 6 %	21.2	11.9	0.094	0.024	0.187	0.050
T_5: Beejamrit 2.5 %	21.6	15.5	0.068	0.020	0.135	0.043
T_6: Beejamarit 3 %	21.2	15.0	0.093	0.023	0.186	0.045
T_7: Beejamrit 5 %	21.1	14.0	0.122	0.022	0.244	0.042
T_8: Beejamrit 6 %	21.5	13.2	0.097	0.023	0.194	0.047
T_9: Jeevamrit 2.5 %	18.0	12.3	0.062	0.023	0.123	0.043
T_{10}: Jeevamrit 3 %	21.5	12.9	0.058	0.026	0.115	0.052
T_{11}: Jeevamrit 5 %	20.4	13.0	0.057	0.031	0.115	0.059
T_{12}: Jeevamrith 6 %	20.0	14.8	0.050	0.034	0.099	0.061
T_{13}: Vermiwash 2.5 %	23.3	16.3	0.106	0.035	0.211	0.063
T_{14}: Vermiwash 3 %	22.5	18.5	0.098	0.033	0.197	0.058
T_{15}: Vermiwash 5 %	22.2	14.8	0.112	0.053	0.225	0.079
T_{16}: Vermiwash 6 %	22.1	13.8	0.123	0.057	0.246	0.088
T_{17}: Hydropriming	20.4	10.4	0.048	0.024	0.095	0.047
T_{18}: No priming	14.9	12.2	0.046	0.013	0.092	0.027
SEm (±)	0.6	0.5	0.002	0.001	0.005	0.002
CD (p = 0.05)	1.68	1.44	0.0070	0.0040	0.014	0.005

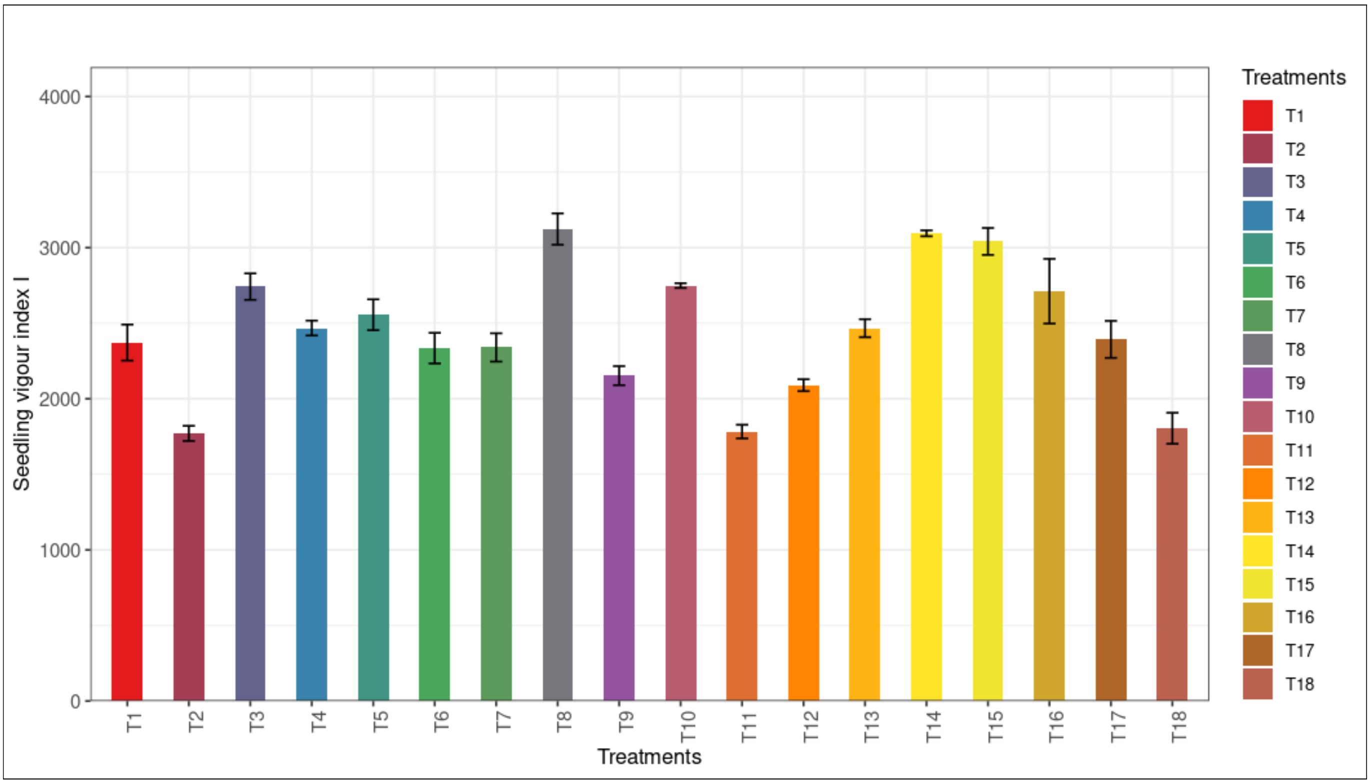

Fig. 1. Effect of liquid organic manures at different concentrations on seedling vigour index I.

T1: Panchagavya 2.5 %; T2: Panchagavya 3 %, T3: Panchagavya 5 %; T4: Panchagavya 6 %; T5: Beejamrit 2.5 %; T6: Beejamrit 3 %; T7: Beejamrit 5 %; T8: Beejamrit 6 %; T9: Jeevamrit 2.5 %; T10: Jeevamrit 3 %; T11: Jeevamrit 5 %; T12: Jeevamrit 6 %; T13: Vermiwash 2.5 %; T14: vermiwash 3 %; T15: vermiwash 5 %; T16: vermiwash 6 %; T_{17}: Hydropriming; T_{18}: No priming.

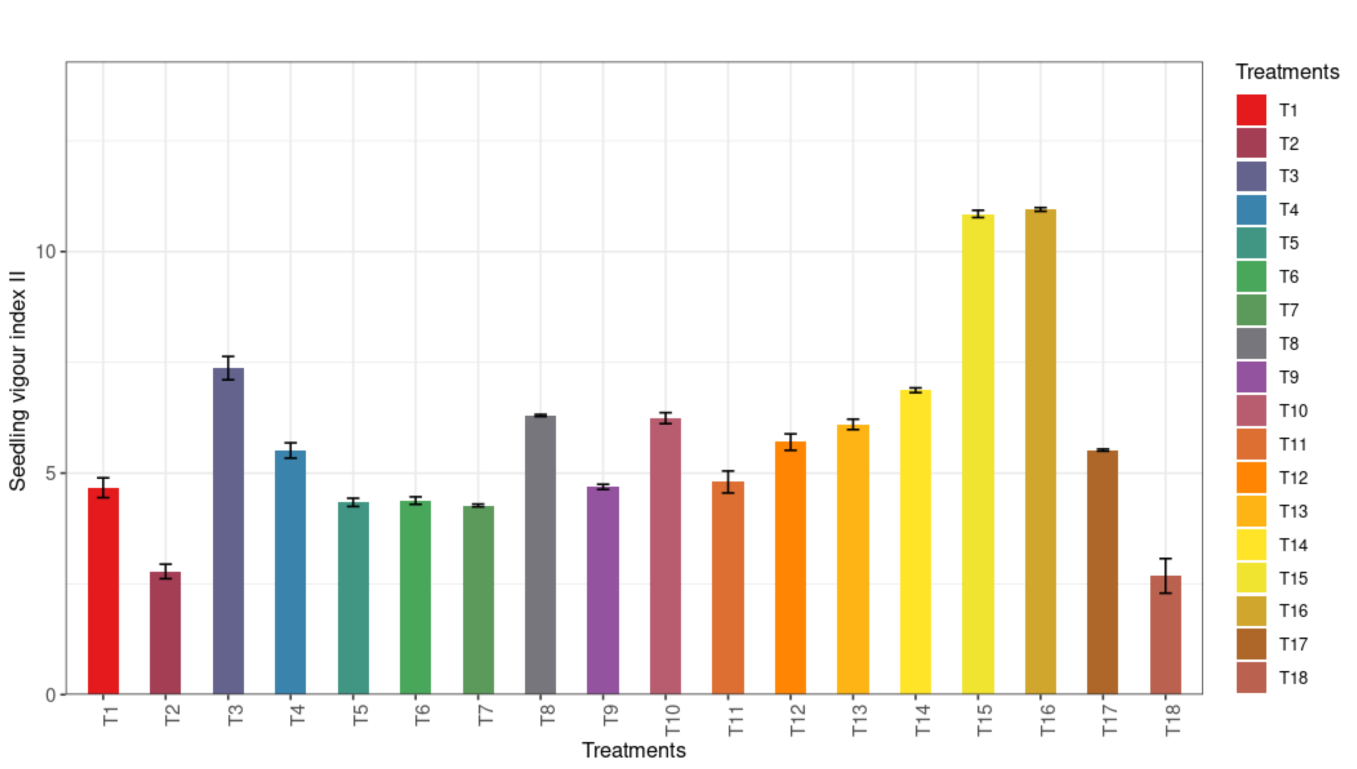

Fig. 2. Effect of liquid organic manures at different concentrations on seedling vigour index II.

T1: Panchagavya 2.5 % T2: Panchagavya 3 %; T3: Panchagavya 5 %; T4: Panchagavya 6 %; T5: Beejamrit 2.5 %; T6: Beejamrit 3 %; T7: Beejamrit 5 %; T8: Beejamrit 6 %; T9: Jeevamrit 2.5 %; T10: Jeevamrit 3 %; T11: Jeevamrit 5 %; T12: Jeevamrit 6 %; T13: Vermiwash 2.5 %; T14: Vermiwash 3 %; T15: Vermiwash 5 %; T16: Vermiwash 6 %; T_{17}: Hydropriming; T_{18}: No priming.

Seed priming initiates essential metabolic processes without triggering radicle protrusion, leading to faster and more uniform germination, improved seedling establishment and enhanced performance under abiotic stress conditions. Seed priming significantly contributes to early and vigorous seedling emergence, which is crucial for achieving optimal plant population and productivity in rice cultivation (45). The results clearly indicated that all priming treatments resulted in higher values for germination parameters. This improvement can be attributed to the physiological alterations induced by priming, which enhances seed quality by activating key metabolic enzymes such as amylases, proteases and lipases (46). These enzymes play a vital role in mobilizing stored reserves, thereby supporting early seedling development.

Priming also enhances the hydration of colloids and increases the viscosity of the plasma and cell membranes, thereby facilitating more rapid water uptake by the seed (47). This accelerated water absorption activates starch metabolism, promotes metabolite synthesis and boosts antioxidant activity, all of which contributes to improved germination rate, uniformity and seedling vigour in primed seeds compared to unprimed ones (48, 49).

Compared to hydropriming and unprimed seeds, seed priming with LOMs consistently resulted in higher values across all germination parameters (Table 3). This enhancement can be attributed to the beneficial effects of growth-promoting substances present in these organic inputs, such as vitamins, plant hormones and a diverse array of macro and micronutrients. The characterization of these organic manures confirmed the presence of significant quantities of these nutrients as well as beneficial microorganisms (Table 1). Additionally, enhanced dehydrogenase and urease activities in LOMs (Table 1 and 2) further indicate increased microbial activity and nutrient transformation, supporting better seed germination and seedling development which were further validated through dehydrogenase and urease enzyme activity assays (Table 2).

Several researchers have previously reported improvements in germination resulting from seed priming with organic liquid formulations such as vermiwash, panchagavya, jeevamrit and beejamrit across various crops (11, 18, 19, 50, 51). In the present study, among the treatments tested, vermiwash at 5 % concentration emerged as the most effective, showing significantly higher values for GI, CVG, SG and MDG.

The superior performance of vermiwash can be attributed to its diverse biochemical composition, including amino acids, enzymes, earthworm-derived mucous, vitamins, proteins and both macro and micronutrients. It also contains plant growth regulators such as indole acetic acid (IAA), cytokinins and gibberellins (52, 53). The presence of bioactive compounds, nutrients and beneficial microbes in vermiwash enhances metabolic activity, promotes osmotic regulation and supports metabolic repair during seed imbibition, which collectively contribute to improved germination outcomes (54). However, variations in germination parameters across different vermiwash concentrations may be due to differences in the levels of bioactive compounds and nutrient content, as well as fluctuations in pH and EC.

Notably, vermiwash at 6 % concentration resulted in lower germination values, likely due to osmotic inhibition of water uptake. Higher solute concentrations in the priming solution can reduce its water potential, thereby limiting water absorption by the seeds. Elevated salt levels may induce osmotic stress, creating a lower external water potential relative to the seed's internal environment, which hinders effective imbibition (55).

Effect of seed priming on growth attributes and seedling vigour

Seed priming treatments had a positive impact on growth parameters like shoot length, root length, fresh weight of shoots and roots, dry weight of shoots and roots and also seedling vigour index I and II. Among the treatments, panchagavya at 5 % resulted in higher shoot length and fresh weight of shoots and roots. However, vermiwash at 3 % resulted in higher root length and vermiwash at 6 % recorded higher shoot dry weight. Beejamrit at 6 % resulted in higher seedling vigour index I (3123), which was on par with vermiwash at 3 % and 5 %, jeevamrit at 3 %, panchagavya at 5 % and vermiwash at 6 %. Seedling vigour index II was higher in vermiwash at 6 % and it was on par with vermiwash at 5 %.

The enhanced growth parameters observed with treatments such as 6 % beejamrit, 3-6 % vermiwash, 3 % jeevamrit and 5 % panchagavya can be attributed to the activation of key pre-germination physiological processes. These processes include membrane repair, synthesis and repair of DNA and RNA, early embryo development, modification of the endosperm tissue surrounding the embryo and mobilization of stored reserves, all of which were favourably stimulated during the priming phase in these treatments.

Beejamrit, panchagavya, jeevamrit and vermiwash are known to contain plant growth-promoting hormones such as IAA, indole butyric acid (IBA), cytokinins and gibberellins, along with trace elements, vitamins, amino acids, antibiotics and both macro and micronutrients (20, 21, 56). Additionally, these formulations harbour beneficial microbial populations, including lactic acid bacteria, nitrogen fixers, phosphorus-solubilizing bacteria, actinomycetes and fungi. The combined action of bioactive compounds, nutrients (Table 1), microbial consortia (Table 2) and enzymatic activities such as urease and dehydrogenase (Table 2), plays a crucial role in enhancing seed germination and seedling growth, ultimately leading to improved growth attributes and seedling vigour (57).

Vermiwash, a coelomic fluid extract from earthworms, contains hydrolytic enzymes such as protease, amylase and phosphatase, which contribute to enhanced growth performance and a higher vigour index. In a previous study, rice seeds primed with 4 % Panchagavya for 16 hr exhibited a significantly higher seedling vigour index (3773) compared to seeds primed with 50 % vermiwash (58). Similarly, priming rice seeds (variety ADT 43) with 50 % vermiwash and 3 % panchagavya for 16 hr significantly improved germination and vigour indices (59).

Conclusion

The findings clearly demonstrate that seed priming with LOMs significantly enhances germination, seedling growth and vigour in rice compared to both hydropriming and unprimed seeds. Among the LOMs evaluated, 5 % vermiwash consistently showed superior performance across all measured germination parameters, seedling growth metrics and vigour indices. While other treatments such as panchagavya, beejamrit and jeevamrit also showed positive effects, 5 % vermiwash emerged as the most effective seed priming treatment for enhancing early seedling performance and overall seed quality in rice.

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Authors' contributions

SKR conceptualized and designed the review topic. AM drafted the manuscript. SKR, JD and SPP provided proper guidance. AS, MRP, ARD and VDVS involved in drafting, reference collection, editing and revision of the manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflicts of interest.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT to improve the language. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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