



Seed Invigoration Approaches for Improving Germinability and Productivity in Wheat (*Triticum aestivum* L.)

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ABSTRACT

The study was conducted during *kharif* for laboratory experiment from the month of May, 2022 to September, 2022 followed by *rabi* for field experiment from the month of October, 2022 to April, 2023 and repeated for second year 2023–24 at the District Seed Farm of BCKV, Kalyani, using completely randomized block design with three replications for each treatment, to create a straight forward and affordable seed invigoration treatment approach that would allow our farmers to enhance the vigor, viability, and field performance of pre-storage wheat seeds. The germinability, field performance, and productivity of high medium vigor wheat (*Triticum aestivum* L. cv. PBW 343) seeds enhanced by pre-storage dry and wet physiological seed invigoration treatments using crude plant materials, such as neem leaf powder, chemical treatment bleaching powder, red chilli powder, aspirin, and soaking-drying and moist-sand -conditioning- drying of seeds. Aspirin had the greatest vigor index (21976) and germination (67%) among all the treatments and produced less volatile aldehyde, a sign of lipid peroxidation, and less lipid peroxide. In terms of yield-attributing characters, aspirin, soaking-drying, and neem leaf powder treatments outperform over the control. Among the treatments, aspirin produced the best results in terms of wheat productivity, field performance, and storability.

KEYWORDS: Wheat, seed invigoration, germinability, yield, storage

Citation (VANCOUVER): Patra et al., Seed Invigoration Approaches for Improving Germinability and Productivity in Wheat (*Triticum aestivum* L.). *International Journal of Bio-resource and Stress Management*, 2026; 17(10), 01-09. [HTTPS://DOI.ORG/10.23910/1.2026.7184](https://doi.org/10.23910/1.2026.7184).

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, author have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The author has declared that no conflict of interest exists.

1. INTRODUCTION

Pre sowing seed invigoration for improving germinability and productivity is quite important and sustainable agriculture depends on high-quality seeds, particularly those with high vigor and viability (Zaman and Hedayetullah, 2019). Crop types lose their uniqueness and health when they are not properly cared and agronomic management strategies are crucial (Zaman and Hedayetullah, 2025; Zaman and Hedayetullah, 2025a, 2025c). Diseases spread by seeds, genetic drift, outcrossing, volunteer plants, mutation, and environmental pressures are the primary drivers of contamination and degradation (Zaman and Hedayetullah, 2021, 2025d, 2025e). This deterioration can be avoided with careful seed management during seed multiplication (Patra, 2023b, 2025a). According to Patra (2023a), traditional rice varieties are also protected when seed multiplication procedures are followed correctly. Seed germination, vigor, viability, and eventually seed yield are significantly impacted by temperature, humidity, draught, soil salinity, soil acidity, and other variables, according to numerous research (Patra, 2022; Zaman and Hedayetullah, 2025b). A large number of field crops have been impacted by the different seed hardening treatments in terms of germination, crop growth, and yield metrics (Patra, 2025b, Hedayetullah et al., 2025). Research on the critical elements influencing quality seeds and some crucial management techniques for prolonging longevity during storage (Patra, 2025c). Seed priming breaks dormancy, prevents deterioration, and boosts tolerance to biotic and abiotic stressors by triggering metabolic pathways (Garai, and Patra, 2024). The application of macro and micronutrients, integrated nutrient management (Hedayetullah et al., 2026): (Hedayetullah et al., 2026a) and the proper use of farming techniques and processing steps on the nutritional quality of crops (Patra et al., 2026b) are all crucial for producing high-quality seeds. However, in the warm, humid climate of Eastern India, the loss of vigor and viability of stored wheat seed is a significant problem, which is the primary motivation for this work. The wheat belts in North India, where the seed grows well in the relatively dry climate, provide the majority of West Bengal's high-quality seed imports. The situation is particularly problematic for *rabi* crops in West Bengal because the seeds were collected between March and May and then kept in containers with a lot of atmospheric moisture as well as soil moisture under ambient temperatures (Zaman and Hedayetullah, 2019, 2025, 2025a, 2025b, 2025e; Hussain et al., 2024). It receives a lot of moisture from the humid atmosphere during the monsoon season (June to August), which, when combined with high temperatures, significantly accelerates the ageing process of the seed, resulting in a loss of vigor, viability, and crop production potential. The loss of seed viability would

be significantly decreased if seeds were sun-dried to safe moisture content limits after harvest and then stored in moisture-impermeable containers like metal tins (Zaman and Hedayetullah, 2025c, 2025f). However, there is a noticeable loss in seed vigor even in enclosed storage. The seed's storability would be significantly decreased in such storage if it was not adequately dried to its safe moisture level after harvest. Even in short-term storage, the seeds from the rain-soaked crop may exhibit a considerable loss of vigor and viability if sufficient care is not taken. Occasional showers prior to harvesting are also detrimental to good storability. Fungal invasion and insect attack would worsen seed deterioration during the harvesting, threshing, and storing of such seeds (Hedayetullah and Zaman, 2018a and 2018b; Meenambigai et al., 2023). The objectives of the study were to improve vigor, viability, and biochemical study as well as field performance of wheat seed by employing pre-storage seed invigoration treatments.

2. MATERIALS AND METHODS

2.1. Experimental site and methodology

The study was conducted during *kharif* for laboratory experiment from the month of May, 2022 to September, 2022 followed by *rabi* for field experiment from the month of October, 2022 to April, 2023 and repeated for second year 2023–24 at the District Seed Farm of BCKV, Kalyani, using completely randomized block design with three replications for each treatment. Freshly harvested wheat seeds were used in this study. Seeds of wheat (cv. PBW 343) were collected from the District Seed Farm of BCKV, Kalyani and then cleaned and dried to a moisture content of 9.3% and stored in rubber stoppered 2.5 l capacity glass bottles till they were used for treatments. Dry-dressing of seeds were done with finely powdered, neem leaf powder (2 g kg⁻¹ of seed), red chilli powder (1 g kg⁻¹ of seed), bleaching powder (2 g kg⁻¹ of seed) aspirin (50 mg kg⁻¹ of seed), in the rubber-stoppered glass bottles at room temperature (28±1°C). After treatment, bottles were shaken twice in a day up to 7 days for mixing of chemicals, pharmaceutical products and crude plant materials thoroughly with the seeds. Soaking-drying of seeds were done with soaked in double volume of water for 2 h at room temperature (29±1°C) with occasional stirring. After decanting off water, seeds were first surface dried under electric fan and then dried in a drying cabinet for two to three days in a current of hot air at 35±1°C and dried back to its original weight. After drying, seeds were stored in a desiccator over fused calcium chloride for 7 days to stabilize the moisture content to a low and uniform level. After stabilization, seeds were restored in the rubber stoppered glass bottle under ambient conditions for laboratory as well as field studies. Moist sand conditioning-drying (MSC-D) of seeds were done with 1 kg

of seed, 3 kg of dry sand. At first the sand was thoroughly washed with clean water and then dried in the sun and make it air dry. One hundred fifty milliliters of water were added to 3 kg of sand (5% of sand) and then thoroughly mixed. The pre-moistened sand was then mixed with 1 kg of seed and kept covered for 24 h. The process of seed hydration was slow and soaking injury to the seed was less. After conditioning, seeds were sieved to let the sand passed and then seeds were dried back to its original weight. After treatment, 20 g of wheat seeds from each treatment were taken separately in perforated paper packets (each packet consisted of equal number of hole) and kept at 98% relative humidity and $40\pm 1^\circ\text{C}$ temperature for 10 days to evaluate the treatment effects on germinability. For this purpose, the relative humidity was maintained at 98% by storing the seeds in a desiccator with an air-tight glass lid containing 380 ml of water with 20 ml of concentrated H_2SO_4 and keeping it in a B.O.D. incubator at 40°C temperature. Germination tests were performed immediately after treatment and after accelerated ageing at 98% relative humidity and $40\pm 10^\circ\text{C}$ for 10 days, using over 400 seeds per treatment.

2.2. Experimental soil type

Experimental soil type is presented in table 1. The experimental site was characterized by Gangetic alluvial soil, classified under the Inceptisol order. The soil exhibited a clay loam texture and moderate fertility, with sufficient internal drainage. To assess the initial fertility status of the field (Table 1).

Soil samples were collected prior to the commencement of the experiment. Using a screw auger, samples were randomly taken from five different locations at a depth of 0–30 cm, ensuring adherence to standard soil sampling protocols. These prepared samples were then analyzed for various physical and chemical properties. The results of these analyses are summarized in Table 1.

2.3. Field experiment

The experiment was conducted during the *rabi* season of 2022–23 and 2023–24 at the District Seed Farm of BCKV, Kalyani, using completely randomized block design with three replications for each treatment. Treated and untreated seeds of wheat (cv PBW 343) were sown in the field to evaluate the treatment effects on field performance and productivity. After land preparation, the plot was divided into 21 subplots (7 treatments $\times$ 3 replications); each measuring 10 sq.m. ($4\times 2.5\text{ m}^2$). The fertilized with basal as well as top dressing application of N: P_2O_5 : K_2O at the rate of 120: 60: 40 kg per hectare was added. During final land preparation, 50% of the total nitrogen and the whole amount of phosphate and potassium were added. The rest of the nitrogen was supplied in two split doses, one at peak tillering stage and other at panicle initiation stage. Wheat seeds were

Table 1: Different physical and chemical properties of experimental soil

Soil parameters	Value	Analytical procedure employed
Physical properties		
Sand (%)	46.75	Particle size analysis using hydrometer method
Silt (%)	32.16	
Clay (%)	21.09	
Chemical properties		
Soil pH	6.7	1:2.5 Soil water (w/v) suspension method
Soil EC (dS m^{-1})	0.6	Electrical conductivity meter
Organic carbon (%)	0.9	Walkley and Black's rapid titration method
Available nitrogen (N) (kg ha^{-1})	248	Alkaline KMnO_4 Method
Available phosphorus (P_2O_5) (kg ha^{-1})	34	Olsen's method
Available potassium (K_2O) (kg ha^{-1})	167	Neutral normal ammonium acetate method

sown at 100 kg ha^{-1} giving a spacing of 25 cm between the rows. A post-sowing irrigation was made on the same day. Besides the post-sowing irrigation, four more irrigations were given to the crop, one at crown root initiation (C.R.I) stage, at tillering stage, at flowering stage and at dough stage. The other cultural practices, viz., weeding, application of pesticides, etc., were made following the recommended methodology. Data on plant population (field emergence) were taken after 14 days of sowing. The number of tillers was counted replication-wise at the flowering stage. The height of the plant was measured one week before harvesting. After harvest, grain yield (g m^{-2}), length of panicle, numbers of seeds per panicle and 1000-grain weight were recorded replication-wise for each treatment.

3. RESULTS AND DISCUSSION

Treated seeds significantly improve germinability (Table 2) accelerated ageing at 98% RH and 40°C for 10 days Before ageing or membrane permeability, enzyme activity, or volatile aldehyde production of high medium vigor wheat (cv. PBW 343) compared to untreated control in a germination test carried out right after pre-storage treatment (Table 3). However, following 10 days of accelerated ageing at 98% relative humidity and 400 degrees Celsius, the majority of the treated seeds demonstrated notable improvements in germination percentage, seedling length as determined by root and shoot length compared to

Table 2: Effect of pre-storage seed invigoration treatments on the germinability of wheat seed immediately after treatment and accelerated ageing at 98% RH and 40°C for 10 days Before ageing

Treatment	Germination		Mean root length (mm)	Mean shoot length (mm)	Vigour index	Germination		Mean root length (mm)	Mean shoot length (mm)	Vigour index
	%	Arc-sin value				%	Arc-sin value			
Control	80	63.4	290	56	27680	53	46.7	155	56	11183
NLP	85	67.2	320	60	32300	63	52.6	250	60	19530
RCP	84	66.5	295	63	30072	65	53.7	253	60	20345
Bleaching powder	85	97.2	318	64	32470	62	52	265	58	20026
Aspirin	88	69.6	325	65	34320	67	55.2	268	60	21976
MSC-D	85	67.2	315	63	32130	68	55.8	263	58	21828
S-D	84	66.5	298	65	30492	69	56.4	260	50	21390
LSD ($p=0.05$)	--	NS	NS	NS	--	--	19.8	2.5	20.5	--
LSD ($p=0.01$)	--	NS	NS	NS	--	--	28.7	3.4	29.8	--

Note: i. Seed treatment with powdered materials, bleaching powder, S-D and MSC-D treatments were given to 2-month-old wheat (cv. PBW 343) seed which were stored in rubber-stoppered glass bottles under ambient conditions at laboratory (temperature, $29\pm1^\circ\text{C}$). ii. Data on germination percentage and length of all the seminal roots and length of shoots were measured after 120 hrs at $25\pm1^\circ\text{C}$. iii. Germination percentage values were transformed to respective arc-sin values for statistical analysis. iv. Vigour index was calculated by multiplying seedling length $\times$ germination percentage. NS: Not significant; MSC-D: Moist sand conditioning -drying; NLP: Neem leaf powder; RCP: Red chilli powder; S-D: Soaking-drying

Table 3: Effect of pre-storage seed treatments on membrane permeability and enzyme activity and volatile aldehyde production of medium vigour wheat (cv. PBW 343) immediately after treatment i.e. before ageing

Treatments	Germination		Electrical conductance ($\mu\text{ mho}$)	Leakage of sugar (O.D at 580 nm)	Dehydrogenase activity (O.D at 470 nm)	Volatile aldehyde production (O.D at 635 nm)
	(%)	Arc-sin value				
Control	83	65.7	150	0.07	0.349	0.25
NLP	88	69.6	140	0.05	0.355	0.20
RCP	86	68	147	0.05	0.353	0.22
Bleaching powder	87	68.8	148	0.07	0.358	0.22
Aspirin	90	71.8	145	0.06	0.350	0.20
MSC-D	87	68.8	146	0.07	0.353	0.24
S-D	85	67.2	149	0.08	0.351	0.23
CD ($p=0.05$)	-	NS	NS	NS	NS	NS

the untreated control (Table 2), membrane permeability, enzyme activity, and volatile aldehyde production (Table 4). Aspirin showed the greatest vigor index (21976) and higher germination (67%) of all the treatments, with MSC-D and soaking-drying (S-D) treatments coming in second and third, respectively (Table 2). Better membrane integrity was demonstrated by treated seeds, especially aspirin and NLP, which showed decreased electrical conductivity and decreased sugar leakage in comparison to the control (Table 3). Particularly in seeds treated with bleaching powder, dehydrogenase activity, a measure of metabolic activity, was marginally higher (Table 4). Similarly, aspirin and

NLP treatments showed comparatively decreased levels of volatile aldehyde generation, which is indicative of lipid peroxidation (Table 4). When the crop was grown from both treated and untreated seeds, the majority of the treated seeds significantly outperformed the untreated control in terms of yield per unit area and other characteristics (Table 5 and Figure 1 and 2). Aspirin, soaking-drying, and neem leaf powder are the treatments that have improved wheat (cv. PBW 343) field performance and productivity the most (Table 5 and Figure 1 and 2).

In terms of how seed invigoration treatments work, when seeds were fully imbibed, essential bio-organelles would be

Table 4: Effect of pre-storage seed treatments on membrane permeability and enzyme activity and volatile aldehyde production of high medium vigour wheat after accelerated ageing at 98% RH and 40°C for 10 days

Treatments	Germination		Electrical conductance (μ mho)	Leakage of sugar (O.D at 580 nm)	Dehydrogenase activity (O.D at 470 nm)	Volatile aldehyde production (O.D. at 635 nm)
	(%)	Arc-sin value				
Control	50	45	255	0.23	0.18	0.62
NLP	67	54.96	160	0.16	0.21	0.57
RCP	65	53.68	170	0.14	0.22	0.55
Bleaching powder	66	54.33	245	0.12	0.21	0.60
Aspirin	72	58.08	180	0.10	0.24	0.50
MSC-D	68	55.60	168	0.14	0.22	0.52
S-D	65	53.68	165	0.16	0.19	0.56
CD ($p=0.05$)	-	4.2	3.5	0.08	0.10	0.05

Table 5: Effect of pre-storage seed invigoration treatments on field performance and productivity of wheat

Treatments	Plant population m^{-2}	Plant height (cm)	No. of grains Panicle ⁻¹	Grain yield m^{-2} (g)
Control	145	70	32.2	195
NLP	165	73	35.1	217
RCP	159	75	35	212
Bleaching powder	168	75	36	216.9
Aspirin	179	77	36	225.4
MSC-D	165.8	75	34.9	216
S-D	160	74	35	220
LSD ($p=0.05$)	6.5	NS	1.8	4.7
LSD ($p=0.01$)	9.0	NS	NS	6.6

repaired, extending the seed's storage life. Without a repair process, molecular damage would build up in dry-stored seeds. Protein synthesis, which was dependent on pre-existing enzyme proteins, was necessary for any healing of biochemical damages (Patra et al., 2026a; 2026b; 2026c). Many harvest fresh non-leguminous crop seeds have been successfully kept from deteriorating by dry dressing them with halogenated compounds, such as bleaching powder (main ingredient calcium hypochlorite) or iodinated calcium carbonate. The proposed iodine's role in the stabilization of double bonds of unsaturated fatty acid moieties of lipoprotein bio membranes as a potential cause of viability extension (Hedayetullah et al., 2026, 2026a & 2026b). It was yet unclear how crude plant preparations and pharmaceutical formulations contributed to the maintenance of viability. Lipid peroxidation was known to be inhibited by capsaicin, an active component of chillies (*Capsicum frutescens* L.) (Brand et al., 1990). Similar results from this laboratory

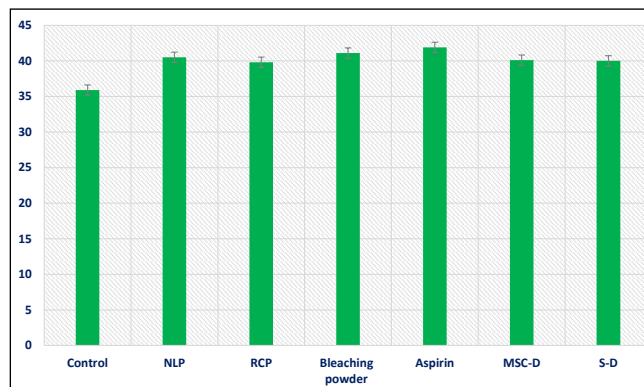


Figure 1: Performance of invigoration treatments on test weight of wheat

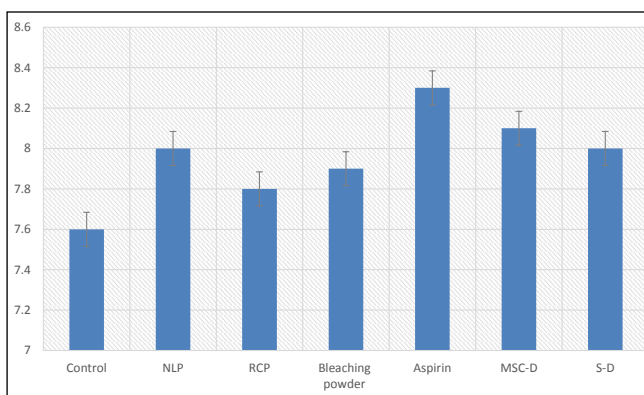


Figure 2: Performance of invigoration treatments on length of panicle (cm) of wheat

have been confirmed by Sung and Chiu (2001), who strongly supported the idea that free radical-induced lipid peroxidation was a cause of seed degeneration in sweet maize (*Zea mays* L.). However, a crucial issue that needs more clarification was how dry active chemicals enter the dry-stored seed. Exogenously applied chemicals might be able to enter the seed through the fissures and crevices in

the seed coat, potentially revitalizing the seed. Salicylic acid was a member of the remarkably diverse class of plant phenolics, which were generally described as compounds with an aromatic ring that contains a hydroxyl group or its functional derivative. Numerous phenolic chemicals were crucial for controlling how plants grow, develop, and interact with other living things. The formation of lignin, a crucial structural element of plant cell walls, depends on phenolics. A number of phenolics have allelopathic properties that affect the germination and growth of nearby plants (Einhellig, 1986). Salicylic acid increased the total RNA content, phosphatases, and some unknown proteins in the vegetative organs of treated plants, and it had a synergistic effect on the timing of flower bud initiation and the overall number of flower buds. The results aligned with previous findings regarding the effectiveness of dry treatments in preserving the vigor, viability, and productivity of various other horticultural and agricultural crop seeds

(Mandal et al., 2011; Patra., 2013; and 2017b; 2018; Patra and Burman, 2017; Patra, 2025b and 2025c; Patra et al., 2026a). Pre-storage dry dressing treatments with aspirin at 50 mg kg⁻¹ of seed, neem leaf powder at 2 g kg⁻¹ of seed, and a wet treatment (soaking-drying) in high-medium vigor wheat (cv. PBW-343) seeds might be recommended to improve germinability, field performance, and productivity of the resulting crop, regardless of the precise mechanism involved in the viability maintenance.

Grain yield showed (Table 6) strong positive correlation with number of grains panicle⁻¹ (r=0.943), 1000-grain weight (r=0.960), Plant population (r=0.909) and the highest correlation was observed between the number of grains panicle⁻¹ and 1000-grain weight (r=0.988). This indicates that grain yield in wheat was largely influenced by grain number and grain weight under seed invigoration treatments.

Table 6: Pearson correlation coefficients (r) among field performance and productivity traits of wheat

Parameters	Plant population m ⁻²	Plant height (cm)	Length of panicle (cm)	No. of grains panicle ⁻¹	Grain yield m ⁻² (g)	1000-grain weight (g)
Plant population m ⁻²	1.000	0.894	0.913	0.902	0.909	0.944
Plant height (cm)	0.894	1.000	0.923	0.936	0.926	0.904
Length of panicle (cm)	0.913	0.923	1.000	0.850	0.916	0.832
No. of grains panicle ⁻¹	0.902	0.936	0.850	1.000	0.943	0.988
Grain yield m ⁻² (g)	0.909	0.926	0.916	0.943	1.000	0.960
1000-grain weight (g)	0.944	0.904	0.832	0.988	0.960	1.000

4. CONCLUSION

Pre-storage physiological seed invigoration treatments significantly improved germination, vigor, storability, membrane stability, and field performance of wheat seeds cv. PBW 343. Among all treatments, aspirin proved most effective, followed by moist-sand conditioning-drying and soaking-drying treatments. Treated seeds showed reduced electrolyte leakage, lipid peroxidation, and volatile aldehyde production, along with enhanced dehydrogenase activity and yield attributes. Overall, seed invigoration treatments, particularly aspirin application, effectively enhanced wheat productivity, seed quality, and storage potential under field conditions.

5. ACKNOWLEDGEMENT

Authors are thankful to Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India and Param Nath Bhaduri Crop Research & Seed multiplication Farm, Department of Botany, The University of Burdwan, Burdwan-713104, West Bengal for extending support for carrying out in field as well as laboratory work.

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