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Influence of Seed Treatment on Seed Quality of Rice CMS Line Pusa 6A During Storage

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ABSTRACT: The present investigation was conducted to study the effect of seed treatments on storability of rice CMS line Pusa 6A. The seeds were coated with polymers: Disco Agro SP Blue (hydrophobic) and Disco Metal Red (hydrophilic) at different concentrations *viz.*, one coat, two coats with and without thiram @ 2.5 g/kg seeds, thiram @ 2.5 g/kg seeds + thiamethoxam @ 2.5g/kg seed and neem oil @ 6ml/kg seed. The treated seeds were stored in three storage environments and evaluated for physiological quality attributes at three month intervals for a period of nine months. The seed quality declined with advancement in storage period, irrespective of storage environments and treatments. All the treatments showed significantly higher seed quality parameters compared to control, except neem oil and thiram + thiamethoxam. However, among the treatments, seed coated with polymer (hydrophobic and hydrophilic) @ 6 ml + thiram @ 2.5 g/kg seed revealed higher germination, vigour index, seedling length and dry weight, regardless of storage environments, until nine months of storage. Among the polymers, the hydrophobic polymer was more effective in maintaining the physiological quality of seed during the storage. The seeds stored in controlled environment at 15±2°C/35±5% RH showed better quality traits as compared to ambient environments, throughout the storage period. Therefore, hydrophobic polymer coupled with thiram can be used as treatment for storage of seeds of rice CMS line Pusa 6A, to maintain seed viability and vigour during 9 months of storage.

Keywords: Rice, CMS line, Seed quality, Seed enhancement, Storability, Storage environment

INTRODUCTION

The availability of quality seed of rice hybrids and their parental lines, at an affordable price, is one of the primary determinants of the success of hybrid rice technology. The main challenge in hybrid rice is a lack of availability of quality seed to the farming community. The seeds of hybrid rice and CMS (A) line have a specific problem of split husk due to incomplete closure of glumes after pollination [1] which results in poor storability [2, 3]. In hybrid rice, storage of carryover seeds is unavoidable due to fluctuating preferences in the seed market. Hence, seed storage till the next sowing season is an integral part of seed supply chain.

Seed being a living entity loses its physiological quality over a period of storage, which manifests in poor crop establishment in the field. However, the rate of seed deterioration can be slowed down by seed enhancement treatments with fungicides, insecticides, polymers, botanicals *etc.* The post-harvest seed treatment with polymer coating alone or in combination with fungicides would bring qualitative improvement in the seed, particularly germinability, storability and field performance, as compared to the corresponding untreated control seeds. In polymer coating, a precise amount of active ingredient along with a polymer material is applied directly on to the seed

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surface without obscuring its shape [4]. The seed coated with polymer adheres and protects the fungicide on the seed surface and prevents dusting off and loss of fungicide, thus enhancing the efficiency of fungicide till the end of storage. It also ensures dust-free handling, making treated seed both user and environment-friendly.

The polymer film formed around the seed act as a physical barrier, which has been reported to reduce leaching of inhibitors from the seed coverings and may restrict oxygen diffusion to the embryo and thus reduce the respiration rate of embryo, thereby reducing the ageing effect on seeds [5]. The polymer coating also prevents fluctuation of seed moisture content under varying relative humidity and temperature during the storage [6, 7]. Seed coated with polymer either singly or in combination with fungicides may be a potent tool for improving the planting value and storability of rice seeds. Hence, an attempt was made to enhance storage life of the seeds with the use of polymer, chemicals and bio-protectant under different storage conditions.

MATERIALS AND METHODS

The rice CMS (A) line seeds of Pusa 6A obtained from the Seed Production Unit, IARI, New Delhi was used to study the effect of enhancement treatments on quality parameters of stored seeds. The details of seed enhancement treatments applied on seeds are as follows; T_1: control (untreated), T_2: hydrophobic polymer (one coat) @ 6ml/kg seed, T_3: hydrophobic polymer (two coats) @ 6ml/kg seed, T_4: hydrophobic polymer @ 6ml/kg seed + thiram @ 2.5g/kg seed, T_5: hydrophilic polymer (one coat) @ 6ml/kg seed, T_6: hydrophilic polymer (two coats) @ 6ml/kg seed, T_7: hydrophilic polymer @ 6ml/kg seed + thiram @ 2.5g/kg seed, T_8: neem oil @ 6ml/kg seed and T_9: thiram @ 2.5 gm/kg + thiamethoxam @ 2.5 gm/kg. The seeds, after treatment, were dried back to original moisture content (<13%) and stored in cloth bags under three different environmental conditions *viz.*, controlled condition at DSST, IARI (New Delhi) (15±2°C and 35±5% RH), ambient conditions at DSST, IARI (New Delhi) (average 24.9°C and 68.3% RH) and ambient condition at IIMR, Hyderabad (Telangana) (average 25.8°C and 66.5% RH) for nine months. The effect of seed enhancement treatments was assessed by evaluating the seed quality attributes *viz.*, germination, vigour indices, seedling length and dry weight before storage and at three months intervals, until the end of storage period.

The germination test was conducted with 100 seeds by adopting the between paper method, as described by ISTA [8]. Ten normal seedlings per replication were selected at random for measuring shoot and root length and their mean value was expressed as the seedling length in centimeter. Ten normal seedlings which were picked up for observing total seedling length were dried in a hot air oven maintained at 80 ± 1°C for 24 hrs and then cooled in desiccators for one hr. The mean seedling dry weight was recorded and expressed in milligram per seedling. The vigour indices of the seedling were computed using the formula suggested by Abdul-Baki and Anderson [9] and expressed in number. The experiment was conducted under completely randomized block design with three replications. The generalized linear model (GLM) procedure of Statistical Analysis System (version 9.3) was used for comparing means by Fisher's least significant difference test.

RESULTS AND DISCUSSION

Significantly higher seed quality attributes were observed in the seeds treated with fungicides coupled with polymer coating, throughout the storage period. In the rice CMS line Pusa 6A, irrespective of the seed treatments and storage environments, all the seed quality parameters declined gradually with the advancement of storage period. Among the treatments, significantly higher germination (93.3%) over control (86.1%) was observed in seeds treated with T_7 (hydrophilic polymer + thiram), though it was found at par with T_4 (hydrophobic polymer + thiram) treatment (Table 1). The germination of 93.6 per cent observed initially was reduced to 83.4 per cent after ninth month of storage. The rate of reduction in germination percentage was slower in seeds treated with the polymer (hydrophobic and hydrophilic) plus fungicide, compared to untreated control seed and other treatments from the initial storage, till the end of storage. The decrease in germination with progress in storage period may be attributed to the ageing process, leading to depletion of seed reserves and decline in synthetic activity of embryo. The results are in agreement with findings of Rettinassababady *et al.* [10] in rice hybrid KRH-2, who reported that polymer coated seeds along with fungicide (Thiram and Vitavax) deteriorates at a slower rate during storage, as manifested by higher germination and less or no seed infection, in comparison to control.

The enhancement treatments showed significantly higher seed quality parameters *viz.*, vigour index, seedling dry weight, root and shoot length, at initial storage and a gradual decline in these parameters was observed with the progress in storage period. A significant difference in seedling dry weight was noticed among different treatments; the seed treated with T_4 (hydrophobic polymer + thiram) recorded higher seedling dry weight of 12.37 mg, followed by T_2 (hydrophobic polymer + one coat) (12.11mg) over the storage period, whereas the lowest seedling dry weight (11.21 mg) was observed in T_1 (control), though it was on par with T_8 (neem oil) and T_9 (thiram + thiamethoxam) (Table 2). The seedling length is a good indicator of seed vigour and it decreased with the increase in storage period. Initially, the seedling length of 33.42 cm was recorded in fresh seeds which reduced to 27.29 cm after ninth month of storage. The seeds coated with T_4 (hydrophobic polymer + thiram) and T_6 (hydrophilic polymer + two coats) recorded a minimal decrease in seedling length (31.41 cm and 31.65 cm, respectively) as compared to untreated T_1 (control seed) (28.87 cm) during storage (Table 3). The decline in seedling length may be attributed to age-induced decline in germination [11]. The green gram and red gram seeds coated with polymer, recorded higher germination per cent and seedling growth [12]. Further, maize seed treated with pink polykote + fungicide + insecticide showed higher germination and vigour index as compared to control [13].

The vigour index, which is the totality of performance, has been regarded as a good index to measure the seed quality [9]. In the present investigation, the enhancement treatments differed significantly in the maintenance of seed vigour over a period of storage. Initially the vigour index I of 3126.4 was recorded which reduced to 2284.8 at the end of storage (Table 4). The seeds coated with T_4 (hydrophobic polymer + thiram) showed a minimal decrease in vigour index I with 19.2 per cent increase over untreated control seed at ninth month of storage. Similarly, significantly higher vigour index II was discerned in the seeds coated with T_4 (hydrophobic polymer + thiram) (1150.0) as compared to T_1 (control seed) (969.9) and other treatments during entire storage (Table 5). The T_8 (neem oil) treatment did not reveal any significant difference for seed quality parameters with respect to control. The seeds of hybrid rice KRH-2 coated with little polykote yellow + captan + thiram + gouch + super red recorded higher germination (85.7%), seedling dry weight (9.63 mg) and vigour index (806) as against the control (66.0%, 4.50 mg and 297, respectively) at the end of the storage [7].

The enhanced germination and vigour of stored seeds coated with fungicide coupled with the polymer may be due to the compatibility and synergetic effect which reduced the growth of pathogen and improved seed quality attributes [14, 15]. The polymer in combination with fungicide (captan) was more effective in enhancing seed vigour rather than polymer coating alone [16]. The seed of rice hybrid CORH-3 coated with Quick Root polymer recorded higher germination, root length, shoot length and vigour index, as compared to control [11]. The polymer film that formed around the seed, act as a physical barrier that may restrict oxygen diffusion to the embryo, thereby reducing the respiration rate of embryo and the ageing effect on seeds [5]. The seeds coated with hydrophobic and hydrophilic polymer singly or in combination with fungicide recorded minimal decrease in physiological quality of seed over untreated control seed after nine months of storage. The fungicide (thiram) acts as a protective agent against seed deterioration due to the invasion of storage fungi and physiological ageing, as a result of which the seed viability and vigour are maintained for a comparatively longer period of time during storage [17, 18]. The results of present study stipulate the efficacy of different polymer coating along with thiram on slowing

Table 1: Effect of seed quality enhancement treatments on germination of Pusa 6A genotype in different storage environments

Storage periods	SP1				SP2				SP3				SP4				
Trt	Germination %			Mean	Germination %			Mean	Germination %			Mean	Germination %			Mean	Mean
Env.	E_1	E_2	E_3	SP×T	E_1	E_2	E_3	SP×T	E_1	E_2	E_3	SP×T	E_1	E_2	E_3	SP×T	
T_1	93.0 (74.3)*	93.0 (74.3)	93.0 (74.3)	93.0 (74.3)	87.3 (69.0)	91.7 (71.9)	85.3 (66.9)	88.1 (69.3)	82.0 (65.0)	87.7 (69.5)	81.3 (64.4)	83.7 (66.3)	76.7 (60.8)	84.3 (66.5)	77.3 (61.7)	79.4 (63.0)	**86.1 (68.2)^{de}**
T_2	93.3 (75.1)	93.3 (75.1)	93.3 (75.1)	93.3 (75.1)	90.7 (72.9)	93.0 (74.9)	89.3 (71.4)	91.0 (73.1)	87.3 (69.5)	91.3 (73.4)	87.0 (69.3)	88.5 (70.7)	84.0 (66.5)	90.3 (72.0)	82.3 (65.5)	85.5 (68.0)	**89.6 (71.7)^{b}**
T_3	91.0 (72.6)	91.0 (72.6)	91.0 (72.6)	91.0 (72.6)	88.0 (69.9)	91.3 (73.5)	87.0 (68.9)	88.8 (70.8)	85.3 (67.9)	88.3 (70.4)	86.0 (68.1)	86.5 (68.8)	80.3 (63.8)	85.3 (67.6)	83.3 (66.1)	83.0 (65.8)	**87.3 (69.5)^{cd}**
T_4	95.3 (77.7)	95.3 (77.7)	95.3 (77.7)	95.3 (77.7)	95.0 (77.8)	95.0 (77.4)	93.3 (75.4)	94.4 (76.9)	91.3 (72.9)	93.3 (75.3)	92.3 (74.2)	92.3 (74.1)	87.0 (69.0)	92.3 (74.0)	87.0 (69.1)	88.8 (70.7)	**92.7 (74.9)^{a}**
T_5	94.0 (76.0)	94.0 (76.0)	94.0 (76.0)	94.0 (76.0)	90.3 (72.5)	92.3 (74.4)	87.3 (69.4)	90.0 (72.1)	85.3 (67.6)	90.0 (71.9)	85.7 (67.8)	87.0 (69.1)	82.0 (64.9)	87.3 (69.7)	79.0 (62.8)	82.8 (65.8)	**88.4 (70.8)^{bc}**
T_6	92.3 (74.0)	92.3 (74.0)	92.3 (74.0)	92.3 (74.0)	89.3 (71.2)	90.0 (72.0)	90.3 (72.2)	89.9 (71.8)	85.3 (67.7)	87.3 (69.4)	84.0 (66.8)	85.5 (68.0)	81.7 (64.9)	84.3 (66.8)	78.0 (62.0)	81.3 (64.6)	**87.3 (69.6)^{cd}**
T_7	95.3 (77.9)	95.3 (77.9)	95.3 (77.9)	95.3 (77.9)	94.3 (76.7)	95.0 (77.1)	94.3 (76.7)	94.5 (76.8)	91.0 (72.7)	96.0 (78.9)	92.0 (73.7)	93.0 (75.1)	87.3 (70.0)	94.0 (76.0)	89.3 (71.5)	90.2 (72.5)	**93.3 (75.6)^{a}**
T_8	92.7 (74.6)	92.7 (74.6)	92.7 (74.6)	92.7 (74.6)	87.3 (69.3)	91.0 (72.7)	85.3 (67.8)	87.9 (69.9)	75.7 (60.5)	86.7 (68.9)	81.0 (64.2)	81.1 (64.5)	71.0 (57.4)	84.3 (66.9)	73.0 (58.7)	76.1 (61.0)	**84.5 (67.5)^{e}**
T_9	95.0 (77.5)	95.0 (77.5)	95.0 (77.5)	95.0 (77.5)	91.0 (72.9)	91.7 (73.4)	86.7 (68.7)	89.8 (71.7)	87.0 (68.9)	91.7 (73.6)	85.0 (67.6)	87.9 (70.0)	82.0 (65.3)	88.0 (69.8)	79.0 (62.8)	83.0 (66.0)	**88.9 (71.3)^{bc}**
Mean (SP×E)	93.6 (75.5)	93.6 (75.5)	93.6 (75.5)		90.4 (72.5)	92.3 (74.1)	88.8 (70.8)		85.6 (68.1)	90.3 (72.4)	86.0 (68.5)		81.3 (64.7)	87.8 (69.9)	80.9 (64.5)		**88.7 (71.0)**
Mean (SP)	**93.6(75.5)^{a}**				**90.5(72.5)^{b}**				**87.3(69.7)^{c}**				**83.3(66.4)^{d}**				
Mean (E)	**87.7^{b}**	**91.0^{a}**	**87.3^{b}**														

LSD (p= 0.05%) T= 1.80, E= 1.04, SP= 1.20, T×SP= NS, E×T= NS, SP×E= NS, SP×E×T= NS

*Figures within parentheses are arcsine transformed values; Means with the same superscript are statistically non-significant; NS = Non-significant.

Seed Treatment (T): T1- Control, T2- Hydrophobic Polymer + One Coat, T3- Hydrophobic Polymer + Two Coats, T4- Hydrophobic Polymer + Thiram, T5- Hydrophilic Polymer + One Coat, T6- Hydrophilic Polymer + Two Coats, T7- Hydrophilic Polymer + Thiram, T8- Neem Oil, T9-Thiram + Thiamethoxam; **Storage Period (SP):** SP1- Before storage, SP2- 3 months storage, SP3- 6 months storage, SP4- 9 months storage; **Storage Environment (E):** E1- Ambient Environment at Delhi, E2- Controlled Environment at Delhi, E3- Ambient Environment at Hyderabad.

Table 2: Effect of seed quality enhancement treatments on seedling dry weight of Pusa 6A genotype in different storage environments

Storage periods	SP1				SP2				SP3				SP4				
Trt	Seedling dry weight (mg)			Mean SP×T	Seedling dry weight (mg)			Mean SP×T	Seedling dry weight (mg)			Mean SP×T	Seedling dry weight (mg)			Mean SP×T	Mean
Env.	E_1	E_2	E_3		E_1	E_2	E_3		E_1	E_2	E_3		E_1	E_2	E_3		
T_1	11.92	11.92	11.92	11.92	11.14	11.86	11.67	11.56	10.61	11.83	11.57	11.34	9.85	11.53	8.75	10.04	**11.21^{e}**
T_2	12.53	12.53	12.53	12.53	11.31	12.25	11.81	11.79	10.68	12.15	11.54	11.46	10.54	11.69	10.92	11.05	**11.71^{cd}**
T_3	13.35	13.35	13.35	13.35	11.54	12.85	12.14	12.18	11.12	12.07	11.99	11.73	11.07	12.06	10.50	11.21	**12.11^{ab}**
T_4	13.39	13.39	13.39	13.39	11.52	13.37	12.71	12.53	11.33	13.17	12.62	12.37	10.47	12.99	10.15	11.20	**12.38^{a}**
T_5	12.75	12.75	12.75	12.75	10.78	12.61	12.24	11.88	10.65	12.49	12.05	11.73	10.11	12.43	10.37	10.97	**11.83^{bc}**
T_6	12.77	12.77	12.77	12.77	11.48	12.68	12.64	12.27	10.73	12.50	12.21	11.81	10.61	12.28	10.07	10.99	**11.96^{bc}**
T_7	12.73	12.73	12.73	12.73	10.94	12.14	12.01	11.70	10.75	11.97	11.71	11.48	10.63	11.87	10.26	10.92	**11.71^{cd}**
T_8	12.12	12.12	12.12	12.12	10.78	11.99	11.97	11.58	10.80	11.93	11.39	11.37	9.53	11.67	9.91	10.37	**11.36^{e}**
T_9	12.37	12.37	12.37	12.37	10.95	12.35	11.56	11.62	10.69	12.26	11.18	11.38	9.93	12.04	9.71	10.56	**11.48^{de}**
Mean (SPxE)	12.66	12.66	12.66		11.16	12.45	12.08		10.82	12.26	11.81		10.30	12.06	10.07		**11.75**
Mean (SP)	**12.66^{a}**				**11.90^{b}**				**11.63^{c}**				**10.81^{d}**				
Mean (E)	**11.2^{c}**	**12.4^{a}**	**11.7^{b}**														
LSD (p= 0.05%) T= 0.33, E= 0.19, SP= 0.22, T×SP= NS, E×T= NS, SP×E= 0.38, SP×E×T= NS																	

Means with the same superscript are statistically non-significant; NS = Non-significant; **Seed Treatment (T):** T1- Control, T2- Hydrophobic Polymer + One Coat, T3- Hydrophobic Polymer + Two Coats, T4- Hydrophobic Polymer + Thiram, T5- Hydrophilic Polymer + One Coat, T6- Hydrophilic Polymer + Two Coats, T7- Hydrophilic Polymer + Thiram, T8- Neem Oil, T9--Thiram + Thiamethoxam; **Storage Period (SP):** SP1- Before storage, SP2- 3 months storage, SP3- 6 months storage, SP4- 9 months storage; **Storage Environment (E):** E1- Ambient Environment at Delhi, E2- Controlled Environment at Delhi, E3- Ambient Environment at Hyderabad.

Table 3: Effect of seed quality enhancement treatments on seedling length of Pusa 6A genotype in different storage

Storage periods	SP1				SP2				SP3				SP4				
Trt Env.	Seedling length (cm)			Mean SP×T	Seedling length (cm)			Mean SP×T	Seedling length (cm)			Mean SP×T	Seedling length (cm)			Mean SP×T	Mean
	E_1	E_2	E_3		E_1	E_2	E_3		E_1	E_2	E_3		E_1	E_2	E_3		
T_1	31.71	31.71	31.71	31.71	29.96	30.76	28.41	29.71	27.00	29.88	27.03	27.97	25.48	27.94	24.85	26.09	**28.87[d]**
T_2	35.03	35.03	35.03	35.03	29.59	33.23	30.81	31.21	28.28	31.87	29.02	29.72	25.48	29.93	26.88	27.43	**30.85[b]**
T_3	33.14	33.14	33.14	33.14	30.62	32.35	31.09	31.35	28.87	31.80	28.27	29.65	25.17	30.13	27.45	27.58	**30.43[b]**
T_4	34.30	34.30	34.30	34.30	30.85	32.96	31.15	31.65	29.84	32.20	30.23	30.76	25.91	31.22	29.66	28.93	**31.41[a]**
T_5	33.02	33.02	33.02	33.02	31.28	31.92	30.03	31.08	27.65	30.95	29.25	29.28	23.53	29.27	25.81	26.20	**29.89[c]**
T_6	35.26	35.26	35.26	35.26	31.36	33.85	32.05	32.42	28.84	33.49	29.28	30.54	26.73	30.95	27.45	28.38	**31.65[a]**
T_7	33.28	33.28	33.28	33.28	31.04	32.66	29.69	31.13	28.39	31.82	28.73	29.65	26.51	30.96	25.34	27.60	**30.42[b]**
T_8	31.54	31.54	31.54	31.54	28.21	31.60	29.09	29.63	27.33	30.90	28.34	28.86	23.91	29.77	25.94	26.54	**29.14[d]**
T_9	33.47	33.47	33.47	33.47	29.57	31.30	28.95	29.94	28.67	30.65	28.60	29.31	25.31	29.05	26.21	26.86	**29.89[c]**
Mean (SPxE)	33.42	33.42	33.42		30.28	32.29	30.14		28.32	31.51	28.75		25.34	29.91	26.62		**30.28**
Mean (SP)	**33.42[a]**				**30.90[b]**				**29.53[c]**				**27.29[d]**				
Mean (E)	**29.3[b]**	**31.8[a]**	**29.7[b]**														
LSD (p= 0.05%) T= 0.46, E= 0.27, SP= 0.31, T×SP= NS, E×T= NS, SP×E= 0.54, SP×E×T= NS																	

Means with the same superscript are statistically non-significant; NS = Non-significant; **Seed Treatment (T):** T1- Control, T2- Hydrophobic Polymer + One Coat, T3- Hydrophobic Polymer + Two Coats, T4- Hydrophobic Polymer + Thiram, T5- Hydrophilic Polymer + One Coat, T6- Hydrophilic Polymer + Two Coats, T7- Hydrophilic Polymer + Thiram, T8- Neem Oil, T9- Thiram + Thiamethoxam; **Storage Period (SP):** SP1- Before storage, SP2- 3 months storage, SP3- 6 months storage, SP4- 9 months storage; **Storage Environment (E):** E1- Ambient Environment at Delhi, E2- Controlled Environment at Delhi, E3- Ambient Environment at Hyderabad.

Table 4: Effect of seed quality enhancement treatments on vigour index I of Pusa 6A genotype in different storage environments

Storage periods	SP1				SP2				SP3				SP4				
Trt	Vigour index I			Mean SP×T	Vigour index I			Mean SP×T	Vigour index I			Mean SP×T	Vigour index I			Mean SP×T	Mean
Env.	E_1	E_2	E_3		E_1	E_2	E_3		E_1	E_2	E_3		E_1	E_2	E_3		
T_1	2948.8	2948.8	2948.8	2948.8	2616.9	2821.0	2420.8	2619.6	2214.4	2621.1	2198.5	2344.7	1950.9	2362.8	1923.3	2079.0	**2498.0[d]**
T_2	3270.1	3270.1	3270.1	3270.1	2681.2	3091.5	2753.2	2842.0	2471.4	2910.6	2525.9	2636.0	2140.8	2705.8	2225.7	2357.4	**2776.4[b]**
T_3	3016.5	3016.5	3016.5	3016.5	2694.9	2954.4	2704.9	2784.7	2465.6	2808.2	2430.4	2568.1	2026.7	2572.6	2294.9	2298.1	**2666.8[c]**
T_4	3270.7	3270.7	3270.7	3270.7	2930.9	3132.0	2907.7	2990.2	2726.5	3005.5	2790.9	2841.0	2255.9	2884.3	2580.3	2573.5	**2918.8[a]**
T_5	3102.9	3102.9	3102.9	3102.9	2820.8	2947.7	2623.1	2797.2	2360.0	2786.8	2505.9	2550.9	1929.6	2561.4	2039.4	2176.8	**2656.9[c]**
T_6	3253.8	3253.8	3253.8	3253.8	2801.9	3047.2	2896.6	2915.2	2461.3	2923.7	2460.3	2615.1	2183.7	2612.0	2142.8	2312.8	**2774.2[b]**
T_7	3172.7	3172.7	3172.7	3172.7	2927.7	3102.7	2800.9	2943.8	2583.0	3054.1	2642.2	2759.8	2314.9	2910.9	2264.8	2496.9	**2843.3[b]**
T_8	2922.9	2922.9	2922.9	2922.9	2465.3	2875.1	2483.0	2607.8	2069.3	2676.3	2292.8	2346.1	1697.9	2515.5	1889.5	2034.3	**2477.8[d]**
T_9	3179.3	3179.3	3179.3	3179.3	2687.5	2868.5	2508.9	2688.3	2495.2	2810.5	2429.3	2578.3	2074.5	2557.9	2071.0	2234.5	**2670.1[c]**
Mean (SPxE)	3126.4	3126.4	3126.4		2736.3	2982.2	2677.7		2427.4	2844.1	2475.1		2063.9	2631.4	2159.1		**2698.0**
Mean (SP)	**3126.4[a]**				**2798.7[b]**				**2582.2[c]**				**2284.8[d]**				
Mean (E)	**2588.5[b]**	**2896.0[a]**	**2609.6[b]**														
LSD (p= 0.05%) T= 74.11, E= 42.79, SP= 49.31, T×SP= NS, E×T= NS, SP×E= 85.58, SP×E×T= NS																	

Means with the same superscript are statistically non-significant; NS = Non-significant; **Seed Treatment (T):** T1- Control, T2- Hydrophobic Polymer + One Coat, T3- Hydrophobic Polymer + Two Coats, T4- Hydrophobic Polymer + Thiram, T5- Hydrophilic Polymer + One Coat, T6- Hydrophilic Polymer + Two Coats, T7- Hydrophilic Polymer + Thiram, T8- Neem Oil, T9- Thiram + Thiamethoxam; **Storage Period (SP):** SP1- Before storage, SP2- 3 months storage, SP3- 6 months storage, SP4- 9 months storage; **Storage Environment (E):** E1- Ambient Environment at Delhi, E2- Controlled Environment at Delhi, E3- Ambient Environment at Hyderabad.

Table 5: Effect of seed quality enhancement treatments on vigour index II of Pusa 6A genotype in different storage environments

Storage periods	SP1				SP2				SP3				SP4				
Trt	Vigour index II			Mean SP×T	Vigour index II			Mean SP×T	Vigour index II			Mean SP×T	Vigour index II			Mean SP×T	Mean
Env.	E_1	E_2	E_3		E_1	E_2	E_3		E_1	E_2	E_3		E_1	E_2	E_3		
T_1	1108.5	1108.5	1108.5	1108.5	973.6	1087.8	996.3	1019.2	867.7	1036.2	941.5	948.5	755.6	974.8	680.2	803.5	**969.9^{d}**
T_2	1169.2	1169.2	1169.2	1169.2	1029.7	1139.7	1055.3	1074.9	934.3	1109.3	1007.8	1017.1	885.7	1055.3	900.0	947.0	**1052.1^{c}**
T_3	1215.0	1215.0	1215.0	1215.0	1015.5	1173.9	1056.3	1081.9	950.0	1068.5	1031.5	1016.7	889.6	1030.6	874.7	931.6	**1061.3^{bc}**
T_4	1276.7	1276.7	1276.7	1276.7	1092.5	1269.5	1187.0	1183.0	1034.4	1228.3	1165.7	1142.8	910.3	1198.9	883.5	997.6	**1150.0^{a}**
T_5	1198.2	1198.2	1198.2	1198.2	975.7	1163.9	1072.8	1070.8	907.6	1123.0	1032.1	1020.9	828.8	1086.3	819.0	911.4	**1050.3^{c}**
T_6	1178.7	1178.7	1178.7	1178.7	1028.3	1140.7	1142.3	1103.8	918.0	1090.5	1025.2	1011.2	864.8	1037.3	785.6	895.9	**1047.4^{c}**
T_7	1213.7	1213.7	1213.7	1213.7	1030.4	1153.4	1133.0	1105.6	977.4	1152.3	1076.9	1068.9	927.7	1117.5	915.7	987.0	**1093.8^{b}**
T_8	1123.3	1123.3	1123.3	1123.3	942.0	1091.5	1022.0	1018.5	819.2	1029.1	924.5	924.3	677.0	987.8	722.7	795.8	**965.5^{d}**
T_9	1175.3	1175.3	1175.3	1175.3	997.6	1129.7	998.9	1042.1	930.1	1119.5	947.0	998.9	815.0	1060.3	767.8	881.0	**1024.3^{c}**
Mean (SP×E)	1184.3	1184.3	1184.3		1009.5	1150.0	1073.8		926.5	1106.3	1016.9		839.4	1061.0	816.6		**1046.1**
Mean (SP)	**1184.3^{a}**				**1077.8^{b}**				**1016.6^{c}**				**905.7^{d}**				
Mean (E)	**989.9^{c}**	**1125.4^{a}**	**1022.9^{b}**														

LSD (p= 0.05%) T= 38.52, E= 22.24, SP= 25.68, T×SP= NS, E×T= NS, SP×E= 44.48, SP×E×T= NS

Means with the same superscript are statistically non-significant; NS = Non-significant; **Seed Treatment (T):** T1- Control, T2- Hydrophobic Polymer + One Coat, T3- Hydrophobic Polymer + Two Coats, T4- Hydrophobic Polymer + Thiram, T5- Hydrophilic Polymer + One Coat, T6- Hydrophilic Polymer + Two Coats, T7- Hydrophilic Polymer + Thiram, T8- Neem Oil, T9- Thiram + Thiamethoxam; **Storage Period (SP):** SP1- Before storage, SP2- 3 months storage, SP3- 6 months storage, SP4- 9 months storage; **Storage Environment (E):** E1- Ambient Environment at Delhi, E2- Controlled Environment at Delhi, E3- Ambient Environment at Hyderabad.

down the rate of seed deterioration. Thus, our study corroborates the finding of Basavaraj *et al.* [18] who reported that onion seed coated with polymer + thiram recorded higher germination, vigour index, dry weight of seedlings and lower seed infection as compared to control during storage.

Storage environments also caused significant variations in seed quality parameters of treated seeds of rice CMS line Pusa 6A. The present study revealed that, with the progress in the storage period, irrespective of storage environments, all the seed quality parameters *viz.*, germination, seedling length, dry weight and vigour index gradually declined. This might be due to the ageing phenomenon that resulted in depletion of food reserves and reduced activity of enzymes and weakening of membrane integrity [19]. However, the decline in seed quality attributes was lowest in controlled storage environment in comparison to ambient environments of Delhi and Hyderabad during storage. In controlled storage environments, both temperature and the relative humidity are maintained at a lower level in comparison to the ambient environment, which might have helped in controlling respiration rate and metabolic activity of stored seed, thereby resulting in maintenance of high vigour and viability for longer periods [20]. Our results are in conformation with findings reported in soybean [21] and cucumber hybrid [22]. Among different enhancement treatments, thiram-based polymer treatment showed their superiority in maintaining seed quality traits of Pusa 6A, irrespective of storage environments, in comparison to untreated control seed, throughout the storage. Generally, seed moisture content did not fluctuate much over the storage period, particularly in polymer-coated seeds stored in either controlled or ambient environment mainly due to the protection offered by these polymers, which prevented the absorption of moisture from the surrounding environment [6, 7]. The results of the study indicated the influence of the polymer seed coating in lowering the rate of seed ageing.

It is inferred from the present study that seed coating with thiram @ 2.5 g per kg of seed coupled with polymer @ 6 ml per kg of seeds is more effective in maintaining seed viability and longevity of rice CMS line Pusa 6A during storage. Among the polymers, the hydrophobic polymer (Disco Agro SP Blue) was superior to hydrophilic polymer (Disco Metal Red) in maintaining the seed quality during storage.

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