Journal of Cereal Research
Volume 13 (Spl - 1): 57-66
Homepage: http://epubs.icar.org.in/ejournal/index.php/JWR

Research Article

Effect of seed coating treatments on Longevity of Wheat (*Triticum aestivum* L.) seeds

Radhika Chaturvedi*, Karam Chand Dhiman, Rajesh Kanwar and Manisha Thakur

CSK Himachal Pradesh Krishi Vishvavidyalaya Palampur, Himachal Pradesh-176 062, India

Article history:
Received: 19 July, 2021
Revised: 07 Aug., 2021
Accepted: 11 Aug., 2021

Citation:
Chaturvedi R, KC Dhiman, R Kanwar and M Thakur. 2021. Effect of seed coating treatments on longevity of wheat (*Triticum aestivum* L.) seeds. *Journal of Cereal Research* ***13 (Spl-1)****: 57-66. http://doi.org/10.25174/2582-2675/2021/114886*

****Corresponding author:***
E-mail: radhikachaturvedi221@gmail.com

Abstract

The experiment was conducted to evaluate the effect of different seed coating treatments on seed longevity and further to identify the effective seed coating treatment for enhancing seed longevity in wheat seeds. The seeds of wheat variety HPW-155 were coated with nine different treatments comprising of polymer, fungicide, insecticide, polymer-fungicide and polymer-insecticide combinations. The treated and untreated seeds were stored in three replications for twenty-four months after packing in HDPE (high density polyethylene) interwoven non-laminated bags. The evaluation of seed quality parameters was made at bi-monthly intervals for twelve months. The experiment revealed that irrespective of seed coating, seed deteriorated and the vigour declined with aging of seeds. Amongst various treatments, seed coated with polymer @ 3 ml per Kg of seed + Vitavax 200 @ 2 g per Kg of seed (T_6) was found superior for quality parameters *viz.*, germination percentage (93.00%), speed of germination (18.45), seedling length (16.06cm), seedling dry weight (0.0116 g), seedling vigour index – I (1494), vigour index -II (1.079) and field emergence (82.00%) at the end of 24 months of storage over untreated control (T_1). Hence, combination of polymer with Vitavax can effectively be utilized to prevent the rapid deterioration of the seed during storage thereby maintaining the quality for a longer period of time.

Keywords: Polymer coating, seed coating, seed quality, storability, wheat

1. Introduction

Wheat (*Triticum aestivum* L.) is an important cereal grain crop of the Gramineae family, widely cultivated and consumed all around the globe with an area and production of 224.49 million hectares and 792.4 million tons respectively (Anonymous 2021). In India, it is the second leading cereal crop after rice, with an area and production of 32.0 million hectares and 108.0 million tons respectively (Anonymous 2021). Storing seeds after harvest till the subsequent cropping season without compromising quality is of prime importance for successful seed production. However, a seed is a living entity that gets impacted by the environment around it which makes the storage of seeds challenging. In storage, vigor and viability of seed are not only persuaded by the genera or the variety but also influenced by different environmental factors (Doijode 1990). Other constraint affecting the storability of the seed include microflora, which is mainly responsible for the degradation of carbohydrates, protein and other food reserves leading to reduced seed germination and vigour. Generally, seeds after attaining their physiological maturity tend to proceed towards aging and thus the process of deterioration begins as soon as seeds are harvested (Abdul – Baki and Anderson, 1973).

Deterioration of seeds during storage is an inevitable process that can be observed by per cent reduction in the germination of seed, seedling vigour, and viability which subsequently lead to seed death or in production of weak seedlings (Tilebeni and Golpayegani, 2011). Deterioration of seeds can lead to various impairments in the metabolic activities, enzymatic activity, compositional changes and phenotypic variations during seed ageing but the pace of seed deterioration can be decelerated either by storing the seeds under the optimum ambient conditions or by encasing the seeds with polymer films along with seed treatment chemicals. Providing optimum conditions for storage involve a huge sum of money, therefore, seed treatment becomes the best feasible approach to maintain the quality of seeds.

Nowadays, various quality enhancing treatments are given to the seed lot before storage as well as during sowing, among them seed coating is the technique wherein external material *viz*., polymer, insecticides, and fungicides are directly applied to the seed without making drastic changes in the size, weight or shape of the seeds. Seed coating is easy to apply, diffuses quickly and is harmless to the seedling during germination. Homogenous film coating with polymer allows better adherence of seed treatment chemicals thus ensuring dust-free handling of seeds. Further, the biodegradable nature of the coating makes it eco-friendly and also helps in providing protection from pathogen attack as well as from the stress imposed due to accelerated ageing (Baig *et al*., 2012). It has been observed that the quality of wheat seeds degrade rapidly mainly when untreated seeds are stored under non- optimum conditions using improper packaging material. So, keeping this in view, the present investigation was formulated to study the effectiveness of treating wheat seeds with polymer alone as well as in various combinations with insecticides and fungicides to understand their influence on the storability and maintaining the quality of seed.

2. Materials and Methods

The current investigation was conducted at the Department of Seed Science and Technology, CSKHPKV Palampur. Seed treatment was done manually during December 2018 on carry-over seeds harvested from *Rabi* season 2017-18. One kg of seeds per treatment was kept in HDPE (high-density polyethylene) interwoven bag. The details of the treatment are depicted in Table 1. After coating the seeds with different treatments, the seeds were kept for shade drying for 72 hours at room temperature and moisture content was brought back to the original i.e., around 10% before packing the seeds for storability. The coated seeds of various treatments were packed in HDPE (high-density polyethylene) interwoven non-laminated bags and stored under ambient conditions for twenty-four months (December 2018 to December 2020) at Department of Seed Science and Technology, CSKHPKV, Palampur. The experiment was laid out in Completely Randomised Design (CRD) with three replications. The evaluation for seed quality parameters was made at bi-monthly interval for twelve months (12^{th} to 24^{th} months) i.e., from January 2020 to December 2020. The seeds were drawn at random from each treatment bag at bimonthly intervals for analysing the seed quality parameters as detailed.

Germination test was conducted using 100 seeds drawn at random from each treatment replication-wise (three replications) by adopting Blotter paper method as described by ISTA procedures (Anonymous 1999). Seeds were incubated in germinator at the temperature of 25±1°C and relative humidity of 90 per cent. Germinated seeds were counted on 8^{th} day and germination percentage was calculated using the following formula:

Germination % =Number of germinated seeds / Total number of seeds × 100

Field emergence count was taken on the 14^{th} day after sowing and the emergence percentage was calculated taking into account the number of seedlings emerged above the soil surface.

10 normal seedlings from the germination test were selected from each replication of the treatment for measuring the seedling length and the average was worked out in centimetres. The same ten normal seedlings were then used for seedling dry weight measurements. The seedlings from each replication of the treatment were put in butter paper pocket and kept in hot air oven at 70°C for 18 hours. The dry weight of the seedlings was recorded and expressed in grams. The seedling vigour index -I was calculated as per the formula (Germination (%) × Seedling length (cm)) and vigour index-II was calculated as per

the formula [Germination (%) × Seedling dry weight (g)] suggested by (Abdul Baki and Anderson, 1973).

Speed of germination was determined on the basis of daily germination count and was calculated by the following formula.

Speed of germination= n1/d1+n2/d2+n3/d3+----------

Where, n = number of germinated seeds, d= number of days.

Moisture of seeds was recorded content in percentage using the moisture meter (Non - Destructive Moisture Meter PM 600). The laboratory data were subjected to statistical analysis using software OPSTAT (Sheoran *et al.* 1998). The data on germination (%), field emergence (%) were transformed into arcsine value, and transformed data were used for statistical analysis.

Table 1. Treatment details

Treatment	Description
T_1	Uncoated seeds - Control
T_2	Polykote @ 3 ml/Kg of seeds, diluted with 5 ml of water
T_3	Flowable Thiram was applied on seeds @ 2.4 ml/Kg of seeds
T_4	Polykote @ 3 ml/Kg of seeds, diluted with 5 ml of water and flowable Thiram @ 2.4 ml/Kg of seeds
T_5	Vitavax 200 @ 2 g/Kg of seeds
T_6	Polykote @ 3 ml/Kg of seeds diluted in 5 ml of water and Vitavax 200 @ 2 g/Kg of seeds
T_7	Imidacloprid @ 4 ml/Kg of seeds
T_8	Polykote @ 3 ml/Kg of seeds and Imidacloprid @ 4 ml/Kg of seeds
T_9	Polykote @ 3 ml/Kg of seeds, diluted with 5 ml of water, followed by flowable Thiram @ 2.4 ml/ Kg of seeds and Imidacloprid @ 4 ml/Kg of seeds
T_{10}	Polykote @ 3ml/Kg of seeds, diluted with 5 ml of water, followed by Vitavax 200 @ 2 g/Kg of seeds and Imidacloprid @ 4 ml/Kg of seeds

3. Result and Discussion

Seed coating produced significant effect in all the seed quality parameters evaluated in the laboratory. After 24 months of storage, a significantly higher germination percentage was recorded for all the treatments over control (86.33%). Irrespective of treatments, average seed germination declined gradually from 91.43 to 89.13 per cent by the end of 24 month of storage (Table 2). After 24 months of storage, seed treated with a combination of polymer @ 3 ml per Kg of seed and Vitavax 200 @ 2 g per Kg of seed (T_6) exhibited significantly highest germination (93.00 %) that was at par with (T_5) Vitavax 200 @ 2 g per kg of seed (92.00%) (Fig. 1). At the end of storage period, higher germination observed in treated seeds may be due to the suppressive nature of chemicals on storage pathogens. Polymer might have acted as a protected shield warding off the deteriorative effects of relative humidity and oxygen on seed. Due to reduced exposure to external deteriorative agents, the seed germinability was maintained for a comparatively longer period of time. The outcomes are consistent with the findings of Roshna *et al.* (2013) in wheat, Rathinavel (2015) in cotton, Patel *et al.* (2017) in soybean, Dixit *et al.* (2018) in wheat and Sharma *et al.* (2017) in corn.

T6 - polymer + Vitavax 200 (after 14 months of storage)

T6 - polymer + Vitavax 200 (after 24 months of storage)

T5 - Vitavax 200 (after 14 months of storage)

T5 - Vitavax 200 (after 24 months of storage)

Fig. 1. Representing the treatment T6 (polymer @ 3ml per Kg of seed + Vitavax 200 @ 2 g per Kg of seed) and T5 (Vitavax 200 @ 2 g per Kg of seed) significantly superior over T1 - control

A similar trend was observed in the case of field emergence which declined progressively with the advancement of storage duration, irrespective of seed coating treatments (Table 2). Significantly higher field emergence (82.00%) was documented in T_6 (polymer @ 3 ml per Kg of seed and Vitavax 200 @ 2 g per Kg of seed) which was at par with T_5 (Vitavax 200 @ 2 g Kg^{-1} of seed)- (78.33%) at the end of 24 months of storage. The polymer and fungicide protected the seed from pathogen and pest thereby keeping all the vital organs and storage metabolites intact which ultimately aid in sustaining field emergence. Similar findings were reported by Sharma *et al.* (2017) in hybrid maize and Padhi *et al.* (2017) in rice.

Table 2. Effect of seed coating treatments on germination (%) and field emergence (%) of seeds of HPW 155 variety of wheat

Treatment	Months after storage											
	Germination (%)						Field emergence (%)					
	14	**16**	**18**	**20**	**22**	**24**	**14**	**16**	**18**	**20**	**22**	**24**
T_1	88.66	88.33	88.00	87.00	86.66	86.33	75.00	73.67	71.00	68.67	67.33	67.00
	(70.32)	(70.03)	(69.72)	(68.85)	(68.56)	(68.28)	(59.99)	(59.11)	(57.40)	(55.94)	(55.12)	(54.92)
T_2	90.33	90.00	89.66	88.66	88.33	88.00	80.33	78.67	77.33	74.00	73.67	71.00
	(71.88)	(71.55)	(71.23)	(70.30)	(70.03)	(69.72)	(63.65)	(62.47)	(61.55)	(59.32)	(59.13)	(57.40)
T_3	91.00	91.00	90.00	89.33	89.00	88.66	78.33	76.33	75.00	73.33	72.00	71.33
	(72.53)	(72.53)	(71.55)	(70.91)	(70.61)	(70.33)	(62.24)	(60.87)	(59.99)	(58.89)	(58.03)	(57.61)
T_4	89.66	89.00	88.33	88.00	87.33	87.00	79.33	77.67	75.00	73.67	72.33	69.67
	(71.23)	(70.60)	(70.03)	(69.74)	(69.13)	(68.84)	(62.94)	(61.77)	(59.98)	(59.10)	(58.25)	(56.58)
T_5	94.33	94.00	93.66	93.00	92.66	92.00	83.67	82.00	81.33	80.00	79.67	78.33
	(76.24)	(75.82)	(75.40)	(74.65)	(74.27)	(73.56)	(66.14)	(64.96)	(64.38)	(63.45)	(63.23)	(62.26)
T_6	95.00	94.66	94.00	93.66	93.33	93.00	88.00	85.33	85.67	85.00	84.33	82.00
	(77.09)	(76.70)	(75.82)	(75.44)	(75.02)	(74.70)	(69.72)	(67.46)	(67.73)	(67.25)	(66.66)	(64.92)
T_7	92.00	91.66	91.66	90.66	90.33	90.00	85.00	83.67	82.00	81.00	79.67	77.33
	(73.56)	(73.20)	(73.22)	(72.19)	(71.86)	(71.55)	(67.31)	(66.14)	(64.88)	(64.15)	(63.22)	(61.57)
T_8	92.33	92.00	91.66	91.00	90.66	90.00	83.33	84.00	83.33	81.00	80.33	77.67
	(73.95)	(73.56)	(73.20)	(72.56)	(72.19)	(71.55)	(65.88)	(66.50)	(65.88)	(64.14)	(63.65)	(61.77)
T_9	89.66	89.33	89.00	88.00	87.66	87.33	81.00	79.67	78.33	76.00	73.33	70.67
	(71.23)	(70.91)	(70.61)	(69.72)	(69.42)	(69.13)	(64.14)	(63.17)	(62.24)	(60.65)	(58.90)	(57.20)
T_{10}	91.33	91.00	90.33	90.00	89.66	89.00	82.00	81.33	79.67	78.00	77.33	75.00
	(72.89)	(72.53)	(71.89)	(71.55)	(71.23)	(70.61)	(64.89)	(64.38)	(63.17)	(62.02)	(61.55)	(60.00)
Mean	91.43	91.10	90.63	89.93	89.56	89.13	81.60	80.23	78.87	77.07	76.00	74.00
	(73.09)	(72.74)	(72.27)	(71.59)	(71.23)	(70.83)	(64.69)	(63.68)	(62.72)	(61.49)	(60.77)	(59.42)
SE(m±)	0.68	0.65	0.59	0.62	0.41	0.59	0.43	0.62	0.32	0.61	0.44	0.92
CD (5%)	2.03	1.85	1.77	1.86	1.24	1.75	1.29	1.85	0.95	1.81	1.31	2.73

Figures in parenthesis indicated arcsine values

T_1 - control (untreated seeds), T_2 - polymer coating (polykote @ 3 ml/Kg of seed, diluted with 5 ml of water), T_3 - flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed , T_4 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed , T_5 - Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed, T_6 - polymer + Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed, T_7 - Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T_8 - polymer + Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T_9 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed + Imidacloprid (Gaucho) @ 4 ml/Kg of seed and T_{10} - polymer + Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed + Imidacloprid (Gaucho) @ 4 ml/Kg of seed.

The mean seedling length observed at the beginning and at the end of storage period was 16.87 and 15.35 cm, respectively. A decline in seedling length was observed irrespective of the coating treatments. The decrease in seedling length over time may be attributed to age induced decline in germination, and damage caused by toxic metabolite accumulation which might have hindered the seedling growth. The seedling length (cm) varied significantly throughout the storage period for different seed coating treatments (Table 3). The treatment T_6 (polymer + Vitavax 200 @ 2 g per Kg of seed) exhibited highest seedling length (16.06 cm) at the end of 24 months of storage, which was at par (16.00 cm) with T_5 (Vitavax 200 @ 2 g per Kg of seed). Coating with polymer and fungicide reduced the rate of deterioration by protecting the seed against environmental moisture and storage fungi. This granted protection might have contributed in safeguarding the metabolites for a longer period of time. These metabolites transformed to vigorous growth, thereby exhibiting higher seedling length. Similar outcomes were reported in maize by Kaushik *et al.* (2014) in maize, Sharma *et al.* (2017) in corn, Padhi *et al.* (2017) in rice, Goswami *et al.* (2017) in soybean, Roopashree *et al.* (2018) in chickpea, Parihar *et al.* (2019) in okra, Kotia *et al.* (2020) in radish.

The effect of several seed treatments on seedling dry weight (g) after 24-month storage period is depicted in Table 3. The data observed the similar trend as witnessed in seedling length. With the advancement of storage period, the dry matter of the seedlings decreased. This reduction in dry matter of seedling could be attributed to natural ageing, resulting in seed decomposition, reduced germination percentage and seedling length. The treatment (T_6) polymer + Vitavax 200 @ 2 g per Kg of seed exhibited significantly highest seedling dry weight (0.0116 g) which was at par with T_5 Vitavax 200 @ 2 g per Kg of seed (0.0115 g) at the end of storage period. This may be due to adequate reserves present in the seed which were transferred to the embryo and utilized in the growth and development of the seedling. Similar outcomes have been confirmed by the study conducted by Thakur and Dhiman (2016) on soybean.

Regardless of seed treatment, the vigour of stored seed deteriorated as the storage period progressed. The mean vigour index-I and vigour index-II was 1543 and 1.127

Table 3. Effect of seed coating treatments on seedling length (cm) and seedling dry weight (g) of seeds of HPW 155 variety of wheat

Treatment	Months after storage											
	Seedling length (cm)						Seedling dry weight (g)					
	14	16	18	20	22	24	14	16	18	20	22	24
T_1	15.03	14.86	14.66	14.53	14.30	13.16	0.0108	0.0106	0.0105	0.0102	0.0098	0.0089
T_2	16.83	16.63	16.36	16.00	15.83	15.50	0.0118	0.0115	0.0113	0.0111	0.0106	0.0101
T_3	16.86	16.70	16.43	16.13	15.86	15.56	0.0121	0.0119	0.0116	0.0113	0.0108	0.0101
T_4	16.80	16.50	16.40	15.40	15.16	14.83	0.0115	0.0112	0.0111	0.0107	0.0101	0.0094
T_5	17.46	17.16	16.83	16.70	16.26	16.00	0.0134	0.0131	0.0127	0.0125	0.0121	0.0115
T_6	17.50	17.20	17.16	16.76	16.46	16.06	0.0135	0.0133	0.0131	0.0128	0.0122	0.0116
T_7	17.13	16.80	16.56	16.33	15.96	15.66	0.0127	0.0125	0.0122	0.0120	0.0114	0.0107
T_8	17.36	16.83	16.66	16.50	15.96	15.70	0.0131	0.0127	0.0125	0.0122	0.0117	0.0108
T_9	16.80	16.60	16.23	15.93	15.73	15.46	0.0117	0.0113	0.0111	0.0108	0.0103	0.0096
T_{10}	16.90	16.76	16.53	16.30	15.90	15.60	0.0125	0.0121	0.0119	0.0117	0.0112	0.0106
Mean	16.87	16.60	16.38	16.05	15.74	15.35	0.0123	0.0120	0.0118	0.0115	0.0110	0.0103
SE(m±)	0.201	0.246	0.229	0.191	0.236	0.244	0.0003	0.0002	0.0004	0.0003	0.0004	0.0003
CD (5%)	0.597	0.731	0.680	0.568	0.702	0.726	0.001	0.001	0.001	0.001	0.001	0.001

T_1 - control (untreated seeds), T_2 - polymer coating (polykote @ 3 ml/Kg of seed, diluted with 5 ml of water), T_3 - flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed , T_4 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed , T_5 - Vitavax 200 (containing thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed, T_6 - polymer + Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed, T_7 - Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T_8 - polymer + Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T_9 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed + Imidacloprid (Gaucho) @ 4 ml/Kg of seed and T_{10} - polymer + Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed + Imidacloprid (Gaucho) @ 4 ml/Kg of seed.

respectively, at the start and 1370 and 0.922, respectively, at the end of the storage period. The drop in vigour index-I could be attributable to a decrease in seedling length and germination, while that of vigour index-II can be attributed to a decrease in seedling dry weight and germination percentage (Table 4.). The decrease in vigour index-I and II may be related to natural ageing, which resulted in decreased germination, dry matter accumulation in seedlings, and seedling length. Throughout the storage period, the seedling vigour index - I changed dramatically, wherein significantly higher seedling vigour index - I was observed in treatment T_6 (a combination of polymer and Vitavax 200 used as 2 g per Kg of seed) - (1494), that was at par with T_5 (Vitavax 200 @ 2 g per Kg of seed) – (1472) (Fig. 2). A similar trend was observed for seedling vigour index - II where significantly highest value was observed for T_6 (polymer and Vitavax 200 used as 2 g per Kg of seed) - (1.079), that was at par with T_5 (Vitavax 200 @ 2 g per Kg of seed) - (1.058) (Fig. 3.). Higher vigour index in polymer treatment along with fungicide is due to better germination, seedling length and dry weight. In addition, the polymer treatment protects the seed against the stress associated with rapid ageing. The polymer barrier also defends the seed against fungal invasion. In pigeon pea, a similar outcome was reported by Kumar *et al.* (2013).

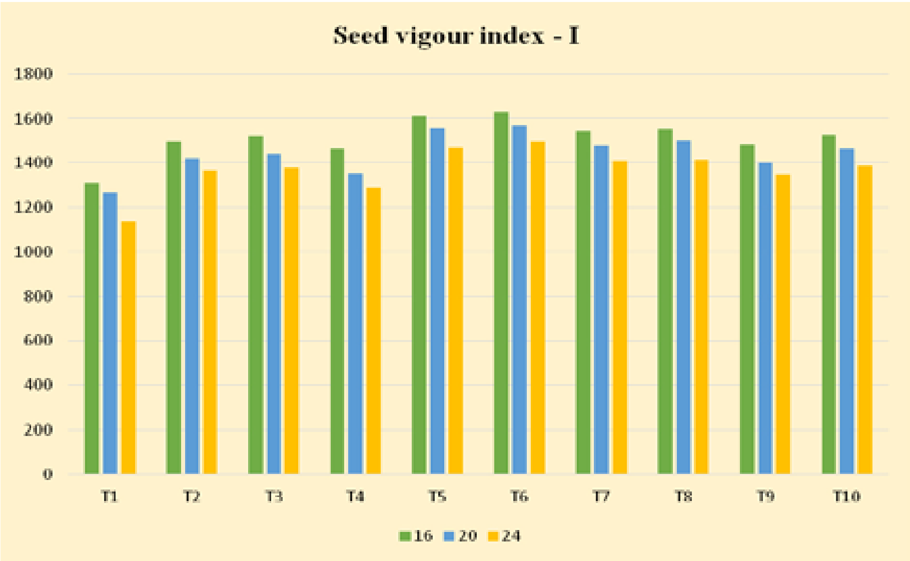

Fig. 2. Effect of seed coating treatments on seedling vigour index-I during storage in wheat variety HPW 155.

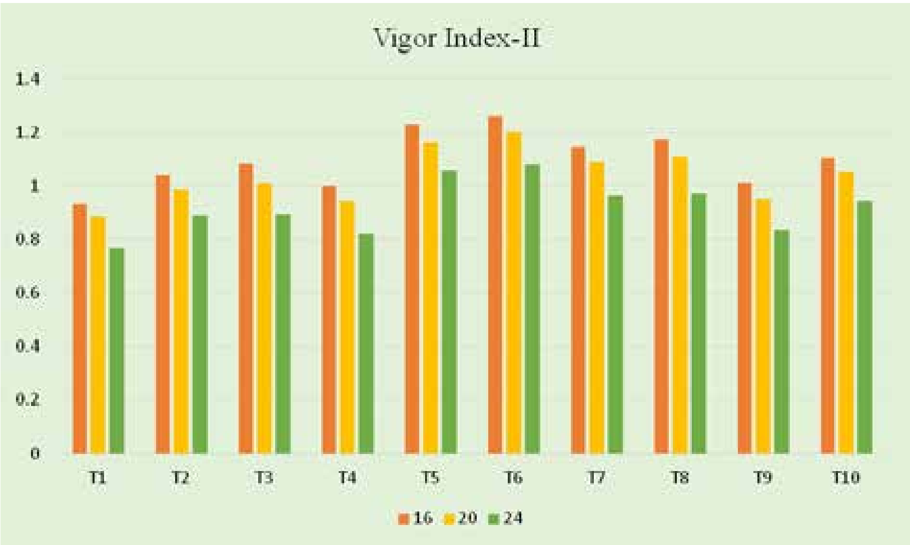

Fig. 3. Effect of different seed treatments on seedling vigour index-II during storage in wheat variety HPW 155.

Table 4. Effect of seed coating treatments on vigour index-I and vigour index-II of seeds of HPW 155 variety of wheat

Treatment	Months after storage											
	Vigour index-I						Vigour index-II					
	14	16	18	20	22	24	14	16	18	20	22	24
T_1	1332	1312	1290	1264	1239	1136	0.955	0.950	0.933	0.887	0.858	0.768
T_2	1520	1497	1473	1418	1398	1364	1.066	1.038	1.007	0.987	0.928	0.889
T_3	1534	1519	1473	1441	1411	1380	1.105	1.083	1.041	1.013	0.953	0.896
T_4	1506	1468	1448	1355	1324	1290	1.028	1.000	1.000	0.942	0.885	0.821
T_5	1647	1613	1576	1553	1507	1472	1.264	1.232	1.202	1.162	1.085	1.058
T_6	1662	1628	1613	1570	1536	1494	1.286	1.259	1.203	1.202	1.149	1.079
T_7	1576	1540	1518	1480	1442	1409	1.169	1.146	1.091	1.085	1.048	0.963
T_8	1604	1548	1527	1501	1447	1412	1.206	1.172	1.151	1.109	1.049	0.972
T_9	1506	1483	1462	1401	1379	1350	1.052	1.022	1.002	0.950	0.927	0.834
T_{10}	1543	1525	1493	1466	1425	1388	1.139	1.104	1.075	1.053	1.001	0.943
Mean	1543	1513	1487	1445	1411	1370	1.127	1.098	1.070	1.040	0.988	0.922
SE(m±)	25.79	23.97	22.17	20.57	21.10	25.07	0.022	0.024	0.089	0.014	0.011	0.015
CD (5%)	76.63	71.23	65.87	61.12	62.70	74.49	0.066	0.072	0.950	0.043	0.032	0.044

T_1 - control (untreated seeds), T_2 - polymer coating (polykote @ 3 ml/Kg of seed, diluted with 5 ml of water), T_3 - flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed , T_4 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed , T_5 - Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed, T_6 - polymer + Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed, T_7 - Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T_8 - polymer + Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T_9 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed + Imidacloprid (Gaucho) @ 4 ml/Kg of seed and T_{10} - polymer + vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed + Imidacloprid (Gaucho) @ 4 ml/Kg of seed.

Table 5. Effect of seed coating treatments on speed of germination and moisture content (%) of the seeds of HPW 155 variety of wheat

Treatment	Months after storage											
	Speed of germination						Moisture content (%)					
	14	16	18	20	22	24	14	16	18	20	22	24
T_1	18.00	17.80	17.76	17.74	17.72	17.69	12.33	11.20	12.50	13.86	11.80	11.50
T_2	18.43	18.39	18.35	18.33	18.30	18.26	12.33	10.90	12.70	13.10	11.70	11.20
T_3	18.47	18.44	18.40	18.38	18.36	18.31	11.86	10.70	12.53	12.90	11.50	11.00
T_4	18.39	18.37	18.30	18.26	18.25	18.23	11.63	10.63	11.20	12.43	11.00	10.90
T_5	19.56	19.44	18.90	18.75	18.73	18.40	11.40	10.63	11.86	12.13	11.03	10.86
T_6	19.60	19.48	19.00	18.80	18.78	18.45	11.03	10.50	11.20	11.50	10.70	10.60
T_7	18.90	18.86	18.75	18.73	18.66	18.35	11.66	10.70	12.13	12.50	11.20	11.00
T_8	18.92	18.87	18.78	18.73	18.69	18.38	11.00	10.50	11.00	11.10	10.70	10.43
T_9	18.40	18.37	18.34	18.32	18.27	18.24	10.86	10.40	10.86	10.70	10.66	10.33
T_{10}	18.56	18.53	18.50	18.48	18.45	18.32	10.50	10.20	10.53	10.43	10.50	10.10
Mean	18.72	18.65	18.50	18.45	18.38	18.33	11.46	10.63	11.65	12.06	11.08	10.79
SE(m±)	0.127	0.053	0.055	0.02	0.015	0.018	0.113	0.084	0.125	0.104	0.075	0.100
CD (5%)	0.377	0.156	0.164	0.06	0.044	0.053	0.336	0.251	0.371	0.308	0.221	0.297

T_1 - control (untreated seeds), T_2 - polymer coating (polykote @ 3 ml/Kg of seed, diluted with 5 ml of water), T_3 - flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed , T_4 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed , T_5 - Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed, T_6 - polymer + Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed, T_7 - Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T_8 - polymer + Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T_9 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed + Imidacloprid (Gaucho) @ 4 ml/Kg of seed and T_{10} - polymer + Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed + Imidacloprid (Gaucho) @ 4 ml/Kg of seed.

Irrespective of the seed treatments, speed of germination gradually declined with advancement in the storage period. The average value for the speed of germination declined from 18.72 to 18.33 (Table 5). The reduction in the speed of germination with the passage of time could be attributed to age induced deteriorative processes. After 24 months of storage, significantly highest speed of germination was recorded in treatment T_6 - polymer @ 3ml/Kg of seed + Vitavax 200 @ 2 g/Kg of seed (18.45) which was at par with T_5 - Vitavax 200 @ 2 g/Kg of seed polymer (18.40). Similar results were also reported by Kunkur (2006) in cotton, Padhi *et al.* (2017) in rice, Sharma and Dhiman (2017) in paddy, Parihar *et al.* (2019) in okra, Prasher *et al.* (2020) in okra, and Kotia *et al.* (2020) in radish seeds.

During the storage period, the moisture content (%) grew and dropped steadily in response to changes in the ambient temperature and relative humidity. The moisture content recorded at the start of the storage period (January 2020) and at the end of the storage period (December 2020) was 11.46 per cent and 10.79 per cent, respectively (Table 5). After 24 months of storage in laboratory, lowest moisture content (10.10%) was documented for T_{10} - polymer + Vitavax 200 @ 2 gram/Kg + Imidacloprid @ 4 millilitre/Kg of seed, that was at par with T_9 - a mix of polymer, flowable Thiram @ 2.4 ml per Kg (10.33%). The moisture content per cent of the seed altered as the storage period progressed. Under the prevalent storage conditions, particularly during the night, atmospheric moisture as well as relative humidity swings, influencing the moisture content of the seed lot, but wherein the pores in seeds coated with a polymer and chemical get covered consequentially preventing the entry of water in the seeds. Udbal *et al.* (2014) in sunflower seeds, Thakur and Dhiman (2016) in soybean, and Kotia *et al.* (2020) in radish reported similar results in their respective investigations.

4. Conclusion

From the current investigation, it can be concluded that seed ageing is an inexorable and irreplaceable process. It cannot be stopped but can successfully be delayed keeping the seed in acceptable limits of germination, field emergence and vigour. The treatment (T6) polymer + Vitvax 200 @ 2 g/Kg of seeds significantly recorded superiority over all the other treatments in maintaining the quality attributes viz., germination, field emergence, seedling length, seedling dry weight and vigour till the end of 24 months of storage. Hence, combination of polymer with vitavax can effectively be utilized to prevent the rapid deterioration of the seed during storage thereby maintaining the quality for a longer period of time.

Acknowledgements

The authors are thankful to the Department of Seed Science and Technology, CSKHPKV, Palampur for providing necessary laboratory facility and support for carrying out the study.

Conflict of Interest

Author declare that they have no conflict of interests.

Ethical Compliance Statement

NA

Author's Contribution

Conceptualization of research (RC, KCD, RK); Designing of the experiments (KCD, RK, RC); Contribution of experimental materials (KCD, RC); Execution of field/lab experiments and data collection (RC, KCD, RK); Analysis of data and interpretation (KCD, RK, RC); Preparation of the manuscript (RC, KCD, RK).

5. Reference

1. Abdul Baki AS and JD Anderson. 1973. Vigour deterioration in soybean by multi criteria. *Crop Science* **13**: 630-633.
2. Anonymous. 2021. Foreign Agriculture Services, U.S. Department of Agriculture (USDA), USA.
3. Anonymous 1999. International rules for seed testing. *Seed Science Technology* **27**: 27-32.
4. Baig I, NK Biraderpatil, BT Ninganur and RH Patil. 2012. Effect of fungicides and polymer coating on storability of soybean seeds. *Jawaharlal Nehru Krishi Vishwa Vidyalaya Research Journal* **46**:78-83.
5. Dixit S, P Singh, CB Singh, A Kumar and VK Yadava. 2018. Effect of seed coating treatments on germination and vigour of wheat (*Triticum aestivum* L.) during ambient storage. *Journal of Pharmacognosy and Phytochemistry* **7**(3): 1145-1147.
6. Doijode SD. 1990. The influence of storage containers on germination of onion seeds. *Journal of Maharashtra Agriculture University* **15**: 34-35.

7. Goswami AP, K Vishnukant, M Chander and S Ravi. 2017. Effect of seed coating, storage periods and storage containers on soybean (*Glycine max* (L.) Merill) seed quality under ambient conditions. *Journal of Applied and Natural Science* **9**: 598-602.
8. Kaushik SK, AK Rai and V Singh 2014. Seed quality of maize with polymer film coating in storage. *International Journal of Innovative Research in Science, Engineering and Technology* **3**: 14353-14358.
9. Kotia K, KC Dhiman and R Kanwar. 2020. Effect of seed treatments on quality and storability of radish (*Raphanus sativus* L.) seeds. *Agriculture Research Journal* **57**: 414-424.
10. Kumar V, BS Vyakaranahal, P Dhananjaya, H Yegappa and AM Asha. 2013. Effect of seed polymer coating on field performance and quality of pigeon pea (*Cajanus cajan* (L.) millsp). *Environment and Ecology* **31**: 43-46.
11. Kunkur V. 2005. Effect of fungicide, insecticide and polymer coating on storability of cotton seeds. Master's Thesis, University of Agricultural Sciences, Dharwad, India, 82 p.
12. Padhi SK, S Behera, SP Mishra, AK Padhiary and B Nayak. 2017. Effect of seed coating materials on seed quality during storage of paddy. *Journal of Pharmacognosy and Phytochemistry* **6**(6): 1263-1279.
13. Parihar P, KC Dhiman, RK Kapila and R Kanwar.2019. Effect of coating on quality of okra seeds in storage. *Seed Research* **47**:36-43.
14. Patel JB, S Jyoti, CA Babariya, RR Rathod and VJ Bhatiya. 2017. Effect of different storage condition and seed treatments on seed viability in soybean (*Glycine max* (L) Merr.). *Journal of Applied and Natural Science* **9**(1): 245-252.
15. Rahraw R, PK Rai, A Kumar, BA Singh, AK Chaurasia and N Bala. 2013. Influence of polymer seed coating, biocides and packaging materials on storability of wheat (*Triticum aestivum* L.) *Report and Opinion* **5**(12): 51-55.
16. Rathinavel K. 2015. Extension of shelf life of cotton (*Gossypium hirsutum* L.) seeds through polymer coating under ambient storage condition. *Indian Journal of Agricultural Research* **49**: 447-451.
17. Roopashree B, RB Jolli, SS Ashok, BN Motagi.2018. Effect of Polymer coating and fungicide on storage performance of kabuli chickpea varieties. *International Journal of Current Microbiology and Applied Sciences* **7**: 954-961.
18. Sharma A. 2017. Effect of seed coating with synthetic polymer and chemicals on seed quality and storability of rice (*Oryza sativa* L.). Master's Thesis, Department of Seed Science and Technology, CSK Himachal Pradesh KrishiVishvavidalaya, Palampur, India, 52 p.
19. Sharma J, KC Dhiman, JK Sharma and R Kumar. 2017. Effect of coating on seed quality of quality protein maize hybrid and storability under hill conditions. *Seed Research* **45**: 147-155.
20. Sheoran OP, DS Tonk, LS Kaushik, RC Hasija and RS Pannu.1998. Statistical Software Package for Agricultural Research Workers. Recent Advances in information theory, Statistics and Computer Applications by DS Hooda & RC Hasija, Department of Mathematics Statistics, CCS HAU, Hisar (139-143).
21. Thakur S and KC Dhiman. 2016. Effect of seed coating with synthetic polymer and additives on storability of soybean seeds under mid hill condition of Himachal Pradesh. *Himachal Journal of Agricultural Research* **42**: 34-40.
22. Tilebeni GH and A Golpayegani. 2011. Effect of seed aging on physiological and biochemical changes in rice seed (Oryza sativa L.). *International Journal of Agricultural Science* **1**(3): 138-143.
23. Udbal N, R Hunje and P Kote. 2014. Effect of containers and seed treatments on storability of sunflower (Helianthus annuus L.). *International Journal of Agricultural Sciences* **10**: 774-781.