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

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**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 (T6) 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 (T1). 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 (12th to 24th 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 8th day and germination percentage was calculated using the following formula:

\[ \text{Germination \%} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100\]

Field emergence count was taken on the 14th 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 \[ \text{Germination} \% \times \text{Seedling dry weight (g)} \]
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.

\[
\text{Speed of germination} = \frac{n_1}{d_1} + \frac{n_2}{d_2} + \frac{n_3}{d_3} + \ldots
\]

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 |
|-----------|-------------|
| T₁        | Uncoated seeds - Control |
| T₂        | Polykote @ 3 ml/Kg of seeds, diluted with 5 ml of water |
| T₃        | Flowable Thiram was applied on seeds @ 2.4 ml/Kg of seeds |
| T₄        | Polykote @ 3 ml/Kg of seeds, diluted with 5 ml of water and flowable Thiram @ 2.4 ml/Kg of seeds |
| T₅        | Vitavax 200 @ 2 g/Kg of seeds |
| T₆        | Polykote @ 3 ml/Kg of seeds diluted in 5 ml of water and Vitavax 200 @ 2 g/Kg of seeds |
| T₇        | Imidacloprid @ 4 ml/Kg of seeds |
| T₈        | Polykote @ 3 ml/Kg of seeds and Imidacloprid @ 4 ml/Kg of seeds |
| T₉        | 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 |
| T₁₀       | Polykote @ 3 ml/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 (T₉) exhibited significantly highest germination (93.00 \%) that was at par with (T₅) 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.
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 T₆ (polymer @ 3 ml per Kg of seed and Vitavax 200 @ 2 g per Kg of seed) which was at par with T₅ (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.

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

| Treatment | Germination (%) | Field emergence (%) |
|-----------|-----------------|---------------------|
|           | 14  | 16  | 18  | 20  | 22  | 24  | 14  | 16  | 18  | 20  | 22  | 24  | 14  | 16  | 18  | 20  | 22  | 24  |
| T1        | 88.66 | 88.33 | 88.00 | 87.00 | 86.66 | 86.33 | 75.00 | 73.67 |
|           | (70.32) | (70.03) | (69.72) | (68.85) | (68.56) | (68.28) | (59.99) | (59.11) |
| T2        | 90.33 | 90.00 | 89.66 | 88.66 | 88.33 | 88.00 | 80.33 | 78.67 |
|           | (71.88) | (71.55) | (71.23) | (70.30) | (70.03) | (69.72) | (63.65) | (62.47) |
| T3        | 91.00 | 91.00 | 90.00 | 89.33 | 89.00 | 88.66 | 78.33 | 76.33 |
|           | (72.53) | (72.53) | (71.55) | (70.91) | (70.61) | (70.33) | (62.24) | (60.87) |
| T4        | 89.66 | 89.00 | 88.33 | 88.00 | 87.33 | 87.00 | 79.33 | 77.67 |
|           | (71.23) | (70.60) | (69.74) | (69.13) | (68.84) | (62.94) | (61.77) | (59.98) |
| T5        | 94.33 | 94.00 | 93.66 | 93.00 | 92.66 | 92.00 | 83.67 | 82.00 |
|           | (76.24) | (75.82) | (74.65) | (74.27) | (73.56) | (66.14) | (64.96) | (64.38) |
| T6        | 95.00 | 94.66 | 94.00 | 93.66 | 93.33 | 93.00 | 88.00 | 85.33 |
|           | (77.09) | (76.70) | (75.44) | (75.02) | (74.70) | (69.72) | (67.46) | (67.73) |
| T7        | 92.00 | 91.66 | 91.66 | 90.66 | 90.33 | 90.00 | 85.00 | 83.67 |
|           | (73.56) | (73.20) | (72.19) | (71.86) | (71.55) | (67.31) | (66.14) | (64.88) |
| T8        | 92.33 | 92.00 | 91.66 | 91.00 | 90.66 | 90.00 | 83.33 | 84.00 |
|           | (73.95) | (73.56) | (72.56) | (72.19) | (71.55) | (65.88) | (66.50) | (65.88) |
| T9        | 89.66 | 89.33 | 89.00 | 88.00 | 87.66 | 87.33 | 81.00 | 79.67 |
|           | (71.23) | (70.91) | (69.72) | (69.42) | (69.13) | (64.14) | (63.17) | (62.24) |
| T10       | 91.33 | 91.00 | 90.33 | 90.00 | 89.66 | 89.00 | 82.00 | 81.33 |
|           | (72.89) | (72.53) | (71.89) | (71.55) | (71.23) | (64.89) | (63.88) | (63.17) |
| Mean      | 91.43 | 91.10 | 90.63 | 89.93 | 89.56 | 89.13 | 81.60 | 80.23 |
|           | (73.09) | (72.74) | (72.27) | (71.59) | (71.23) | (64.69) | (63.68) | (62.72) |
| SE(m±)    | 0.68  | 0.65  | 0.59  | 0.62  | 0.41  | 0.59  | 0.43  | 0.62  |
| CD (%      | 2.03  | 1.85  | 1.77  | 1.86  | 1.24  | 1.75  | 1.29  | 1.85  |

Figures in parenthesis indicated arcsine values

T1 - control (untreated seeds), T2 - polymer coating [polykote @ 3 ml/Kg of seed, diluted with 5 ml of water], T3 - flowable Thiram [Royal Flow 40 SC] @ 2.4 ml/Kg of seed, T4 - polymer + flowable Thiram [Royal Flow 40 SC] @ 2.4 ml/Kg of seed, T5 - Vitavax 200 [containing Thiram 37.5% and Carboxil 37.5%] @ 2 g/Kg of seed, T6 - polymer + Vitavax 200 [containing Thiram 37.5% and Carboxil 37.5%] @ 2 g/Kg of seed, T7 - Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T8 - polymer + Imidacloprid (Gaucho) @ 4 ml/Kg of seed + Imidacloprid (Gaucho) @ 4 ml/Kg of seed and T9 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed + Imidacloprid (Gaucho) @ 4 ml/Kg of seed.
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 | 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       | 16.63    | 16.43    | 16.36    | 16.00    | 15.83    | 15.50    | 0.0118   | 0.0115   | 0.0119   | 0.0113   | 0.0108   | 0.0101   |
| T_3       | 16.70    | 16.43    | 16.13    | 15.86    | 15.67    | 15.45    | 0.0112   | 0.0111   | 0.0112   | 0.0113   | 0.0108   | 0.0101   |
| T_4       | 16.50    | 16.40    | 15.40    | 15.16    | 14.83    | 14.53    | 0.0115   | 0.0112   | 0.0112   | 0.0111   | 0.0107   | 0.0104   |
| T_5       | 16.63    | 16.83    | 16.70    | 16.26    | 16.00    | 0.0134   | 0.0131   | 0.0127   | 0.0125   | 0.0121   | 0.0115   | 0.0112   |
| T_6       | 16.70    | 16.83    | 16.66    | 16.50    | 15.96    | 15.66    | 0.0127   | 0.0125   | 0.0122   | 0.0120   | 0.0114   | 0.0107   |
| T_7       | 16.80    | 16.60    | 16.23    | 15.93    | 15.73    | 15.46    | 0.0117   | 0.0113   | 0.0112   | 0.0108   | 0.0103   | 0.0096   |
| T_8       | 16.90    | 16.76    | 16.53    | 16.30    | 15.90    | 15.60    | 0.0125   | 0.0121   | 0.0119   | 0.0117   | 0.0112   | 0.0106   |
| T_9       | 16.80    | 16.60    | 16.23    | 15.93    | 15.73    | 15.46    | 0.0117   | 0.0113   | 0.0112   | 0.0108   | 0.0103   | 0.0096   |
| T_10      | 16.87    | 16.60    | 16.38    | 16.06    | 15.74    | 15.35    | 0.0123   | 0.0120   | 0.0118   | 0.0115   | 0.0110   | 0.0093   |
| Mean      | 16.87    | 16.60    | 16.38    | 16.06    | 15.74    | 15.35    | 0.0123   | 0.0120   | 0.0118   | 0.0115   | 0.0110   | 0.0093   |
| n          | 200      | 200      | 200      | 200      | 200      | 200      | 200      | 200      | 200      | 200      | 200      | 200      |
| SE (±t)   | 0.201    | 0.246    | 0.229    | 0.193    | 0.236    | 0.244    | 0.0003   | 0.0002   | 0.0004   | 0.0003   | 0.0004   | 0.0003   |

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. 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 over time may be attributed to age-induced decline in germination, and damage caused by toxic metabolite accumulation and damage caused by seed deterioration as the storage period progressed. 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.
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 T₆ (a combination of polymer and Vitavax 200 used as 2 g per Kg of seed) - (1494), that was at par with T₅ (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 T₆ (polymer and Vitavax 200 used as 2 g per Kg of seed) - (1.079), that was at par with T₅ (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 |
| T1        | 1332 | 1312 | 1290 | 1264 | 1239 | 1136 | 0.955 | 0.950 | 0.933 | 0.887 | 0.858 | 0.768 |
| T2        | 1520 | 1497 | 1473 | 1418 | 1398 | 1364 | 1.066 | 1.038 | 1.007 | 0.987 | 0.928 | 0.889 |
| T3        | 1534 | 1519 | 1473 | 1441 | 1411 | 1380 | 1.105 | 1.083 | 1.041 | 1.013 | 0.953 | 0.896 |
| T4        | 1506 | 1468 | 1448 | 1355 | 1324 | 1290 | 1.028 | 1.028 | 1.000 | 0.942 | 0.885 | 0.821 |
| T5        | 1647 | 1613 | 1576 | 1553 | 1507 | 1472 | 1.264 | 1.232 | 1.202 | 1.162 | 1.085 | 1.058 |
| T6        | 1662 | 1628 | 1613 | 1570 | 1536 | 1494 | 1.286 | 1.259 | 1.203 | 1.202 | 1.149 | 1.079 |
| T7        | 1576 | 1540 | 1518 | 1480 | 1442 | 1409 | 1.169 | 1.146 | 1.091 | 1.085 | 1.048 | 0.963 |
| T8        | 1604 | 1548 | 1527 | 1501 | 1447 | 1412 | 1.206 | 1.172 | 1.151 | 1.109 | 1.049 | 0.972 |
| T9        | 1506 | 1483 | 1462 | 1401 | 1379 | 1350 | 1.052 | 1.022 | 1.002 | 0.950 | 0.927 | 0.834 |
| 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 | 20.57 | 0.022 | 0.024 | 0.089 | 0.014 | 0.011 | 0.015 |
CD (5%) | 76.63 | 71.23 | 65.87 | 65.87 | 65.87 | 65.87 | 0.066 | 0.072 | 0.950 | 0.043 | 0.032 | 0.044 |

T1 - control (untreated seeds), T2 - polymer coating (polykote @ 3 ml/Kg of seed, diluted with 5 ml of water), T3 - flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed, T4 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed, T5 - Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed, T6 - polymer + Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed, T7 - Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T8 - polymer + Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T9 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed + Imidacloprid (Gaucho) @ 4 ml/Kg of seed and T10 - 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 |
| T1        | 18.00 | 17.80 | 17.74 | 17.72 | 17.69 | 17.60 | 12.33 | 11.20 | 12.50 | 11.80 | 11.50 |
| T2        | 18.43 | 18.39 | 18.35 | 18.30 | 18.26 | 18.23 | 12.33 | 10.90 | 12.53 | 11.30 | 11.20 |
| T3        | 18.47 | 18.44 | 18.40 | 18.36 | 18.31 | 18.25 | 11.86 | 10.70 | 12.53 | 11.50 | 11.00 |
| T4        | 18.29 | 18.37 | 18.30 | 18.26 | 18.23 | 18.23 | 11.63 | 10.63 | 12.53 | 11.00 | 10.90 |
| T5        | 19.56 | 19.44 | 18.90 | 18.75 | 18.73 | 18.40 | 11.40 | 10.63 | 12.10 | 11.30 | 11.00 |
| T6        | 19.60 | 19.48 | 19.00 | 18.80 | 18.78 | 18.45 | 11.03 | 10.50 | 12.00 | 11.50 | 10.70 |
| T7        | 18.90 | 18.86 | 18.75 | 18.73 | 18.66 | 18.55 | 11.66 | 10.70 | 12.13 | 12.50 | 11.20 |
| T8        | 18.92 | 18.87 | 18.78 | 18.73 | 18.69 | 18.38 | 11.00 | 10.50 | 11.00 | 11.10 | 10.70 |
| T9        | 18.40 | 18.37 | 18.34 | 18.32 | 18.27 | 18.24 | 10.86 | 10.40 | 10.86 | 10.70 | 10.66 |
| Mean      | 18.72 | 18.65 | 18.50 | 18.45 | 18.38 | 18.33 | 11.46 | 10.63 | 11.65 | 12.06 | 11.08 |

SE(m±) | 0.127 | 0.053 | 0.02 | 0.015 | 0.018 | 0.018 | 0.113 | 0.084 | 0.125 | 0.094 | 0.075 |
CD (5%) | 0.376 | 0.315 | 0.165 | 0.078 | 0.078 | 0.078 | 0.297 | 0.100 | 0.015 | 0.015 | 0.015 |

T1 - control (untreated seeds), T2 - polymer coating (polykote @ 3 ml/Kg of seed, diluted with 5 ml of water), T3 - flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed, T4 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed, T5 - Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed, T6 - polymer + Vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/Kg of seed, T7 - Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T8 - polymer + Imidacloprid (Gaucho) @ 4 ml/Kg of seed, T9 - polymer + flowable Thiram (Royal Flow 40 SC) @ 2.4 ml/Kg of seed + Imidacloprid (Gaucho) @ 4 ml/Kg of seed and T10 - 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 T6 - polymer @ 3ml/Kg of seed + Vitavax 200 @ 2 g/Kg of seed (18.45) which was at par with T5 - 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 T10 - polymer + Vitavax 200 @ 2 gram/Kg + Imidacloprid @ 4 millilitre/Kg of seed, that was at par with T9 - 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 + Vitavax 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.

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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).

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