Effect of different seed coating treatments on longevity of okra [*Abelmoschus esculentus* (L). Moench] seeds

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Abstract

The effect of different seed coating treatments, comprising polymer, fungicide, insecticide, polymer-fungicide and polymer-insecticide combinations was studied on the longevity and seed quality parameters of okra during a twelve month storage period (January 2018 to December 2018). The experimental material consisted of carry over okra seeds (variety P-8) from the Kharif season 2015. The seeds were coated during December 2016 and stored for 24 months, however, here only the findings from 13th to 24th month are presented. At the end of storage period (24 months), recorded data revealed that irrespective of seed coating, seed deteriorated due to decline in vigour probably because increased fungal infection and aging of seed. However, two treatments *viz.,* T_6 - polymer + vitavax 200 @ 2 g/kg of seed and T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed were found significantly superior for all seed quality parameters viz., germination (%) - first count (%), final count (%), speed of germination, seedling length (cm), seedling dry weight (g), seedling vigour index-I, seedling vigour index -II, electrical conductivity (m mho/cm/g) and field emergence (%) over T_1 - untreated control at the end of storage period. Hence, these treatments offer an effective alternative means to secure safe seed storage.

Key words: Seed coating, seed quality and seed longevity.

Seed is a biological entity, hence like other life forms the deterioration in its physical and physiological condition is unavoidable, irreversible and inexorable. Seed ageing is a natural and irreversible process; once seed has reached its physiological maturity, it is at its peak of its germinability and vigour. From that point on, the deterioration sets in, although the rate of ageing is greatly influenced by different intrinsic and extrinsic factors that also affect the post harvest life of the seed. Maintaining seed vigour and viability till next sowing is a matter of prime concern. It is stipulated that 80 per cent of certified seed produced in India requires storage for one planting season and 20 per cent of seed is carried over for subsequent sowing (Bal 1976). Since quality seed is the key for successful crop production and acts as a fundamental unit for realizing potential of all other inputs, it becomes pertinent to develop ways that could retain the planting value of the seed.

In Himachal Pradesh, storing okra seeds under ambient condition leads to rapid loss of essential seed quality parameters. Moreover due to humid climatic conditions, the moisture content of the seed keeps on fluctuating, most the times, thus making the regime favourable to deterioration. Therefore, in order to reduce the crucial impact of external forces on the rate of deterioration, specialized storage practices are needed. Among a range of sophisticated storage techniques, seed coating offers a cost effective and easy to apply approach for safe storage. Seed coating technology is a process of applying precise amount of formulations on the seed surface without obscuring its shape. It acts as an insurance to protect the seed quality parameters from deterioration. The seed coating facilitates uniform imbibition of water during germination and prevents damage during sowing through mechanized drill while making the sowing operation easier. Hence an attempt was made to understand the effect of polymer coating along with fungicide and insecticide on seed longevity and seed quality parameters on okra during storage.

Materials and Methods

The current study was executed at the Department of Seed Science and Technology, CSKHPKV Palampur. The experimental material consisted of well graded carry over okra seeds (variety P-8) from the Kharif season 2015, which were procured from the Directorate of Extension Education, CSKHPKV, Palampur. The experiment was conducted to study the effect of seed coating with polymer in combination with fungicide and insecticide (Table 1) for seed stored in HDPE (high density polyethylene) bags. Seed coating of 1kg of seed per treatment was done manually by applying the specific polymer and/or chemical directly onto the seed and gently shaking the mixture until the sign of complete coverage of seed was visible. The coated seeds were shade dried for 72 hours at room temperature and moisture content brought down to around 10% before packing in HDPE bags for storage. The seed was stored under ambient conditions at Seed Technology Laboratory, Department of Seed Science and Technology, CSKHPKV, Palampur.

The experiment was conducted under a completely randomized design (CRD) and each treatment was replicated three times. The seed quality parameters were evaluated at bimonthly interval for twelve months (13^{th} to 24^{th} month) i.e. from January 2018 to December 2018 after 12 months of storage. The seeds were drawn at random from each treatment bag replication-wise. Germination test was conducted using 100 seeds by adopting Blotter paper method as described by ISTA procedures (Anonymous 1999). Seeds were incubated in germinator at a temperature of 25±1°C and RH of 90 per cent. Normal germinated seeds were counted on 4^{th} (First Count) and 21^{st} (Second Count) day after incubation and total germination percentage was calculated using the following formula at the end of test period:

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

Ten normal seedlings from the first count were selected from each replication of the treatment for measuring the seedling length and the average was worked out in centimeters. The same ten normal seedlings were then used for seedling dry weight measurements. The seedlings were put in butter paper pocket and kept in hot air oven at 80 ℃ for 24 hours. The dry weight of the seedlings was recorded and expressed in grams. The seedling vigour index-I and vigour index-II were calculated as per the formulae respectively, as suggested by Abdul Baki and Anderson (1973).

Germination (%) × Seedling length (cm), and

Germination (%) × 10 Seedlings dry weight (g)

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.

Field emergence count was taken on the 7^{th} day after sowing and the emergence percentage was calculated taking into account the number of seedlings emerging above the soil surface. Moisture content of seeds was recorded in percentage using a Non-Destructive moisture meter.

Electrical conductivity (m mho/cm/g) was recorded by soaking five gram seeds in 100 ml distilled water in a beaker which was kept in an incubator maintained at 25 ± 1°C. After 17 hours of soaking, the solution was decanted and electrical conductivity of the solution was measured using digital conductivity meter and expressed in m mho/cm/g.

Seed infection (%) was tested using blotter method prescribed by ISTA (Anonymous 1966). Twenty five seeds of each treatment per replication were placed equidistant on two layered moistened blotter paper taken in petri plates and incubated at 20 ± 2°C for eight days. On eighth day, the plates were examined under stereo-bionocular microscope (50X) for the presence of seed borne fungi. The number of infected seeds was counted and expressed in percentage. Besides this, kinds of fungi present were also identified and recorded. Seed infestation (%) was tested on three hundred seeds taken out from three replications of each treatment. Thereafter, infested seeds were counted and results were expressed in percentage.

The laboratory data was statistically analyzed using Completely Randomized Design (CRD) and the software used was OPSTAT (Sheoran *et al.* 1998). The data on germination (%) and field emergence (%) were transformed into arcsine root percentage and transformed data were used for statistical analysis. The data on fungal infection (%) and insect infestation (%) were transformed into square root percentage and transformed data were used for statistical analysis.

Results and Discussion

Most of the seed quality parameters declined with the advancement of storage period. The germination percentage in the beginning and at the end of storage period was 91.43 per cent and 69.27per cent, respectively (Table 2). After 14 months of storage, significantly higher germination percentage over T_1 - untreated control (88.00%) was recorded for treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (94.00%), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (93.67%), followed by T_5 - vitavax 200 @ 2 g/kg of seed (92.67%), T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 4 ml/kg of seed (92.33%), T_3 - flowable thiram @ 2.4 ml/kg of seed

(92.00%), T_9 - polymer + flowable thiram @ 2.4ml/kg of seed + imidacloprid @ 4 ml/kg of seed (91.33%), T_8 - polymer + imidacloprid @ 4 ml/kg of seed (91.00%), T_7 - imidacloprid @ 4 ml/kg of seed (90.00%) and T_2 - polykote @ 3 ml/kg of seed (89.33%). The same pattern was recorded till the end of storage period. Significantly higher germination percentage (final count) over T_1 - untreated control (66.00%) at the end of storage (24 months) was recorded for treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (72.67%), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (72.00%), while the lowest germination was recorded for treatment T_1 - untreated control (66.00%).The decline in germination percentage with the advancement of storage period may be attributed to ageing effect leading to depletion of stored food that leads to starvation of meristematic tissue and decline in synthetic activity of embryo, apart from death of seed because of fungal invasion, fluctuating temperature, relative humidity and storage container in which seeds were stored. Coating of seeds with polymer, insecticide and fungicide protected the seed from influence of above factors resulting in maintenance of seed viability for a comparatively longer period. At the end of storage period the germination percentage in treatment of polymer and vitavax 200 (T_6) was 6.67 per cent more than control (T_1). The results are in accordance with the findings in soybean (Thakur and Dhiman 2016). Soybean seeds treated with polymer @ 3.0 ml/kg of seed and flowable thiram @ 2.4 ml/kg of seed showed significantly higher germination percentage (final count) over untreated control at the end of one year of storage. Similarly, paddy seeds treated with polymer @ 4 ml + vitavax 200 @ 2 g/kg of seed also recorded significantly higher germination percentage over untreated control after 7 months of storage (Padhi *et al.* 2017).

The speed of germination varied significantly throughout the storage period till the end (Table 2). Irrespective of the seed coating treatments, the speed of germination continued to decrease during storage period. On an average the rate of germination in the beginning and end of the storage period was 40.03 and 34.94, respectively. In the initial month of storage, significantly higher rate of germination was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (41.27), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (41.23), followed by T_5 - vitavax 200 @ 2 g/kg of seed (40.83), T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 4 ml/kg of seed (40.33), T_3 - flowable thiram @ 2.4 ml/kg of seed (39.83), T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid @ 4 ml/kg of seed (39.53), T_8 - polymer + imidacloprid @ 4 ml/kg of seed (39.43) and T_7 - imidacloprid @ 4 ml/kg of seed (39.40) as compared to T_1 - untreated control (39.13). At the end of storage period, significantly higher rate of germination at the end of storage period was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (35.80), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (35.70) over T_1 - untreated control (34.13). Speed of germination decreased with the increase in storage period. Higher speed of germination was recorded for polymer and chemical treated seeds. This may be due to protection of seeds from fungal infection and insect attack. Similar findings were reported by Sharma *et al.* (2017) who studied the effect of coating on seed quality of HQPM 1 hybrid maize during storage and observed that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed recorded

Table 1. Details of different seed treatments employed in the study

Treatment	Details
T_1	Uncoated seeds
T_2	Polykote @ 3 ml/kg of seeds, diluted with 5 ml of water
T_3	Flowable thiram @ 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 @ 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

significantly higher speed of germination over untreated control at the end of one year of storage. Significantly higher speed of germination over untreated control at the end of one year of storage was also observed in paddy seeds treated with polymer + vitavax 200 @ 2 g/kg of seed (Sharma and Dhiman 2017).

The seedling length varied significantly with different seed treatments (Table 3). Average seedling length recorded at the beginning and at the end of storage was 25.90 cm and 23.35 cm, respectively. The decline in seedling length may be attributed to age induced decline in germination and production of toxic metabolites which may have hindered the seedling growth. After 14 months of storage, significantly longer seedling length (cm) was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (26.60 cm), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (26.50 cm), followed by T_5 - vitavax 200 @ 2 g/kg of seed (26.27 cm), T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 4 ml/kg of seed (26.10 cm), T_3 - flowable thiram @ 2.4 ml/kg of seed (25.87 cm), T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid @ 4 ml/kg of seed (25.80 cm), T_8 - polymer + imidacloprid @ 4 ml/kg of seed (25.73 cm), T_7 - imidacloprid @ 4 ml/kg of seed (25.57 cm) and T_2 - polykote @ 3 ml/kg of seed (25.43cm) as compared to T_1 - untreated control (25.17 cm). The same pattern continued till the end of the storage period and significantly higher seedling length (cm) as compared to T_1 - untreated control (22.63 cm) at the end of storage (24 months) was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (23.93 cm), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (23.87 cm).At the end of storage period the seedling length (cm) of polymer and vitavax 200 (T_6) coated seeds was 1.67 cm more as compared to (T_1) uncoated seeds. It can be due to higher germination percentage and better initial growth of seedlings in seed coated with polymer and fungicide, as it prevents fungal invasion and thereby results in better germination and subsequent higher seedling length. Patel *et al*. (2017) reported that soybean seeds when treated with Mancozeb @ 2 g/kg of seeds resulted in significantly higher seedling length as compared to control during 2 years of storage period. Similarly paddy seeds treated with polymer @ 4 ml + vitavax 200 2 g/kg of seed recorded significantly higher seedling length over untreated control after 7 months of storage (Padhi *et al*. 2017).

Almost similar trends were recorded for seedling dry weight (g).The seedling dry weight continued to decrease from 14^{th} month to last month of storage period irrespective of seed coating treatments (Table 3). On an average the dry weight of ten seedlings in the beginning and end of the storage period was 0.236 g and 0.206 g, respectively. After 14 months of storage, significantly more seedling dry weight (g) was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (0.241 g), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (0.240 g), followed by T_5 - vitavax 200 @ 2 g/kg of seed (0.238 g).The same pattern was observed till the end of storage period and significantly higher seedling dry weight (g) was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (0.212 g), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (0.211 g) over T_1 - untreated control (0.201 g). It indicates that there is positive effect of seed coating polymer which can be effective for better storage of seeds. The dry matter production of seedling is the ultimate manifestation of physiological vigour. This is a physiological phenomenon influenced by reserve metabolites, enzyme activities and growth regulators. These results are in conformity with findings of Thakur and Dhiman (2016) who observed significantly higher seedling dry weight in soybean seeds treated with polymer and flowable thiram @ 2.4 ml/kg of over untreated seeds at the end of one year of storage period.

The computed vigour index, which is the totality of seed performance, has been regarded as a good index to measure the quality of seed lots. Irrespective of seed coating treatments, the vigour of stored seed decreased gradually with advancement in the storage period. Average seedling vigour index-I and II recorded at the beginning and at the end of storage declined from 2035 to 1623 and 21.62 to 14.32, respectively (Figure 1 and 2).The decrease in vigour index may be due to decline in germination, decrease in seedling length and seedling dry weight. The seedling vigour indices – I and II varied significantly throughout the storage period. After 14 months of storage, significantly higher seedling vigour indices – I and II were recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (2500 and 22.65), which were at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (2482 and 22.51), followed by T_5 - vitavax 200 @ 2g/kg of seed (2434 and 22.05). The same pattern was recorded till the end of the storage period and significantly higher vigour indices –I and II were recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (1739 and 15.38), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (1718 and 15.19) as compared to T_1 - untreated control (1494 and 13.24)at the end of storage period of 24

Table 2. Effect of seed coating treatments on germination (%) and speed of germination during storage in okra

Treatment	Months after storage											
	Germination (%)						Speed of germination					
	14	16	18	20	22	24	14	16	18	20	22	24
T_1	88.00 (69.71)	85.67 (67.72)	82.33 (65.12)	77.00 (60.64)	72.00 (58.03)	66.00 (54.31)	39.13	38.17	37.37	36.43	35.23	34.13
T_2	89.33 (70.91)	86.33 (68.27)	83.00 (65.62)	78.00 (62.01)	73.00 (58.67)	67.33 (55.12)	39.30	38.47	37.57	36.73	35.47	34.40
T_3	92.00 (73.54)	88.67 (70.30)	85.33 (67.45)	81.33 (64.37)	75.67 (60.42)	69.00 (56.14)	39.83	39.13	38.17	37.33	35.93	34.97
T_4	93.67 (75.40)	90.33 (71.86)	87.00 (68.84)	83.00 (65.62)	78.67 (62.46)	72.00 (58.03)	41.23	40.37	39.13	38.37	36.80	35.70
T_5	92.67 (74.26)	89.33 (70.91)	86.00 (68.00)	82.00 (64.87)	77.33 (61.54)	71.00 (57.39)	40.83	39.87	38.93	38.13	36.63	35.50
T_6	94.00 (75.82)	90.67 (72.18)	87.33 (69.12)	83.33 (65.88)	79.00 (62.71)	72.67 (58.45)	41.27	40.40	39.20	38.43	36.87	35.80
T_7	90.00 (71.55)	87.00 (68.84)	83.67 (66.13)	79.00 (62.70)	74.67 (59.75)	68.00 (55.52)	39.40	38.67	37.60	36.93	35.53	34.43
T_8	91.00 (72.53)	88.00 (69.71)	84.00 (66.40)	79.67 (63.17)	75.00 (59.97)	68.33 (55.73)	39.43	38.70	37.83	37.17	35.73	34.63
T_9	91.33 (72.85)	88.33 (70.00)	85.00 (67.18)	81.00 (64.13)	75.33 (60.19)	68.67 (55.93)	39.53	38.77	37.93	37.23	35.87	34.83
T_{10}	92.33 (74.90)	89.00 (70.60)	85.67 (68.72)	81.67 (64.62)	76.67 (61.09)	69.67 (56.56)	40.33	39.43	38.43	37.70	36.17	35.03
Mean	91.43	88.33	84.93	80.50	75.73	69.27	40.03	39.19	38.21	37.44	36.02	34.94
SE (m±)	0.44	0.33	0.31	0.33	0.29	0.29	0.03	0.03	0.03	0.03	0.03	0.04
CD (P=0.05)	1.33	1.04	0.93	0.99	0.88	0.86	0.11	0.10	0.11	0.10	0.11	0.13

Figures in parenthesis indicates 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

Table 3. Effect of seed coating treatments on seedling length (cm) and seedling dry weight (g) during storage in okra

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	25.17	24.83	24.53	24.10	23.23	22.63	0.232	0.229	0.228	0.224	0.217	0.201
T_2	25.43	25.10	24.86	24.26	23.40	22.83	0.234	0.232	0.230	0.226	0.218	0.203
T_3	25.87	25.53	25.30	24.50	23.73	23.43	0.237	0.234	0.231	0.229	0.220	0.207
T_4	26.50	26.06	25.83	25.03	24.30	23.87	0.240	0.236	0.234	0.231	0.222	0.211
T_5	26.27	25.90	25.70	24.83	24.16	23.73	0.238	0.235	0.232	0.230	0.221	0.209
T_6	26.60	26.16	25.90	25.10	24.40	23.93	0.241	0.237	0.235	0.232	0.223	0.212
T_7	25.57	25.26	24.96	24.36	23.43	23.07	0.234	0.232	0.229	0.227	0.218	0.204
T_8	25.73	25.40	25.13	24.43	23.50	23.17	0.235	0.233	0.230	0.228	0.219	0.205
T_9	25.80	25.50	25.23	24.46	23.53	23.27	0.236	0.233	0.231	0.228	0.220	0.206
T_{10}	26.10	25.76	25.50	24.53	24.03	23.63	0.237	0.234	0.232	0.229	0.221	0.209
Mean	25.90	25.53	25.29	24.56	23.77	23.35	0.236	0.233	0.231	0.228	0.219	0.206
SE (m±)	0.04	0.04	0.04	0.04	0.04	0.03	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
CD (P=0.05)	0.13	0.13	0.14	0.12	0.13	0.09	0.0012	0.0013	0.0013	0.0012	0.0012	0.0013

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

months. Higher vigour index in polymer + vitavax 200 (T_6) may be due to more germination, seedling length, no infection by storage fungi and no infestation by insects. The polymer coating provides protection from the stress imposed by accelerated ageing, which includes fungal invasion. Similar results were reported by Patel *et al.* (2017) who recorded that soybean seeds treated with Mancozeb @ 2 g/kg of seeds resulted in significantly higher seedling vigour indices –I and II as compared to control during 2 years storage period. The similar trend was observed in paddy seeds treated with polymer + vitavax 200 @ 2 g/kg of seed which recorded significantly higher vigour indices - I and II over untreated control at the end of one year of storage (Sharma and Dhiman 2017).

The field emergence declined gradually with advancing storage period due to different seed coating treatments. On an average, the field emergence recorded at the beginning and end of the storage period was 76.57% and 56.17%, respectively (Table 4).This could be due to decrease in germination, seedling vigour, seed ageing, seed deterioration and loss of seed viability over a period of storage. After 14 months of storage, significantly higher field emergence (%) over T_1 - untreated control (74.00%) was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (79.00%), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (78.67%). The same pattern was observed till the end of the storage period and significantly higher field emergence (%) was recorded in T_6 - polymer + vitavax @ 200 @ 2.4 ml/kg of seed (58.67%), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (58.00%) as compared to T_1 - untreated control (54.00%).Higher field emergence was recorded in chemical treated seeds which may be due to protection of seeds from microorganisms which in turn helps in establishment of seedling in the field. The results recorded for field emergence are similar to the findings in cotton (Rathinavel 2015), where it was observed that

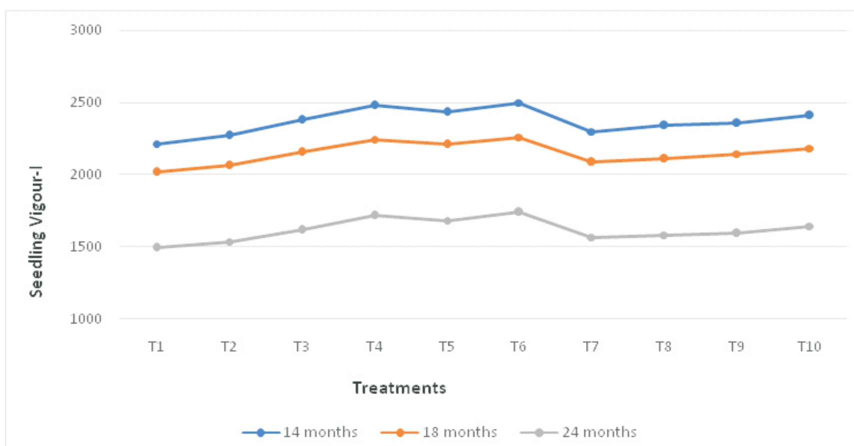

Fig. 1 Effect of seed coating treatments on vigour index - I during storage in okra

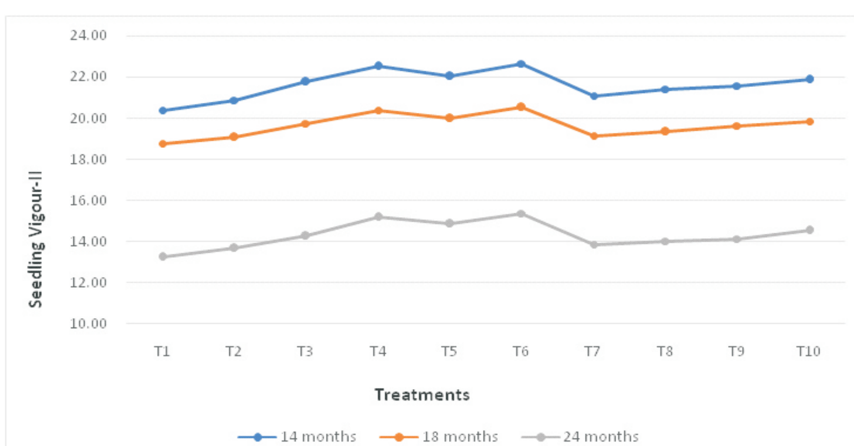

Fig. 2 Effect of seed coating treatments on vigour index - II during storage in okra

cotton seeds coated with polymer @ 3 ml/kg + Thiram @ 2.5 g/kg+ Super red @ 5 ml/kg + Cruiser @ 5 g/kg of seeds resulted in significantly higher field emergence as compared to untreated control at the end of 26 months of storage period.

The 100 seed weight of the seed varied gradually with the advancement of storage period (Table 4). On an average seed weight recorded at the beginning and end of the storage period was 6.416 g and 6.385 g. After 14 months of storage, significantly higher seed weight was recorded for treatment T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 6 ml/kg of seed (6.461 g)followed by T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid @ 4 ml/kg of seed (6.441 g), T_6 - polymer + vitavax 200 @ 2 g/kg of seed (6.429 g). Similar findings were reported in chickpea (Sushma 2013). The chickpea seeds treated with polymer @ 10 ml/kg along with Deltamethrin 2.8 EC @ 0.4 ml/kg of seed + Vitavax @ 2 g/kg of seeds recorded significantly higher 100 seed weight as compared to untreated seeds after 4 months storage period.

The moisture content (%) increased and decreased gradually during storage period as per fluctuations in the prevalent temperature and relative humidity (Table 5). Under storage conditions especially at night, relative humidity fluctuates and the seed moisture content also fluctuates for maintaining equilibrium with atmospheric moisture content. On an average, the moisture content recorded after 14 months of storage (Feb 2018) and at the end of storage period (December 2018) was 9.70 per cent and 8.56 per cent, respectively. After 14 months of storage, significantly lower moisture content (%) was recorded in T_{10} - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid @ 4 ml/kg of seed (9.53%), which was at par with T_9 - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 4 ml/kg of seed (9.57%), T_6 - polymer + vitavax 200 @ 2 g/kg of seed (9.60%), T_5 - vitavax 200 @ 2 g/kg of seed (9.63%), followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (9.70%), T_3 - flowable thiram @ 2.4 ml/kg of seed (9.73%), followed by T_7 - imidacloprid @ 4 ml/kg of seed (9.77%), T_8 - polymer + imidacloprid @ 4 ml/kg of seed (9.80%), and T_2 - polykote @ 3 ml/kg of seed (9.83%), while the highest moisture content (%) was recorded in T_1 - Untreated control (9.87%). At the end of storage period, the lowest moisture content (%) was recorded in T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 4 ml/kg of seed (8.40%), which was at par with T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid @ 4 ml/kg of seed (8.43%), T_6 - polymer + vitavax 200 @ 2 g/kg of seed (8.47%), and T_5 - vitavax 200 @ 2 g/kg of seed (8.50%) while the highest moisture content was recorded in T_1 - untreated control (8.80%).Seeds coated with synthetic polymer and seed treatment chemicals cover the pores in the seed coat and prevent the entry of water. Similar results were reported in pigeon pea (Patil *et al*. 2014), where pigeon pea seeds treated with thiram @ 3 g/kg of seed + spinosad @ 0.04 ml/kg resulted in lowest seed moisture content at the end of 6 months of storage period.

The electrical conductivity of seed leachates is used to quantify seed deterioration. Irrespective of seed coating treatments, the electrical conductivity continued to increase from 14 months to the end of the storage period (Table 5). Increase in electrical conductivity may be attributed to higher incidence of fungi that caused loss of membrane integrity. The electrical conductivity varied significantly throughout the storage period. After 14 months of storage, significantly less electrical conductivity was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (0.859 m mho/cm/g), followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (0.864 m mho/cm/g), T_5 - vitavax 200 @ 2 g/kg of seed (0.873 m mho/cm/g). The same pattern was recorded till the end of the storage period and significantly lower electrical conductivity was recorded inT_6 - polymer + vitavax 200 @ 2 g/kg of seed (1.120 m mho/cm/g) over T_1 - untreated control (1.152m mho/cm/g). The polymer coating holds the seeds intact and covers the cracks and aberrations of the seed coat, thus reducing the leaching of electrolytes.The results are in conformity with the findings in chilly (Manoharapaladagu *et al*. 2017). The chilly seeds treated with polymer @ 7 ml/kg + thiram @ 2 g/kg of seeds resulted in significantly lower electrical conductivity over untreated seeds at the end of six months of storage period.

Irrespective of seed coating treatments the fungal infection (%) gradually increased with advancement of storage period in control and seed coating with polymer (Table 6). However, rest of the seed coating treatments reduced the extent of damage due to fungal infection. The storage fungi, infecting seeds were identified as *Rhizopus* spp. and *Fusarium* spp. After 14 months of storage period fungal infection was only found in T_1 - untreated control and T_2 - polymer @3 ml/kg of seed. However, with the advancement of storage period fungal infection was observed in all the treatments. At the end of storage period, significantly less fungal infection was recorded in T_6 - polymer + vitavax 200 @

Table 4. Effect of seed coating treatments on field emergence (%) and 100-seed weight (g) during storage in okra

Treatment	Months after storage											
	Field emergence (%)						100-seed weight (g)					
	14	16	18	20	22	24	14	16	18	20	22	24
T_1	74.00 (59.32)	71.33 (57.60)	68.67 (55.93)	64.00 (53.11)	59.00 (50.16)	54.00 (47.27)	6.376	6.350	6.381	6.444	6.358	6.332
T_2	75.00 (59.97)	72.33 (58.24)	69.00 (56.14)	65.33 (53.90)	60.00 (50.74)	54.67 (47.65)	6.390	6.363	6.394	6.461	6.380	6.351
T_3	76.67 (61.09)	73.67 (59.10)	70.67 (57.18)	66.33 (54.51)	62.00 (51.92)	56.33 (48.61)	6.405	6.380	6.415	6.483	6.398	6.372
T_4	78.67 (62.47)	76.00 (60.64)	73.00 (58.67)	68.67 (55.93)	63.67 (52.91)	58.00 (49.58)	6.409	6.386	6.420	6.498	6.424	6.395
T_5	77.33 (61.54)	74.33 (59.53)	71.67 (57.81)	67.67 (55.32)	62.67 (52.31)	57.00 (49.01)	6.428	6.405	6.433	6.501	6.427	6.398
T_6	79.00 (62.70)	76.67 (61.09)	74.33 (59.53)	69.00 (56.14)	64.33 (53.30)	58.67 (49.97)	6.429	6.407	6.434	6.507	6.434	6.407
T_7	75.67 (60.42)	72.67 (58.45)	69.33 (56.35)	65.67 (54.10)	60.33 (50.94)	55.00 (47.85)	6.407	6.382	6.418	6.496	6.409	6.384
T_8	76.00 (60.64)	73.00 (58.67)	70.00 (56.76)	66.00 (54.31)	61.00 (51.33)	55.33 (48.04)	6.413	6.384	6.419	6.490	6.419	6.390
T_9	76.33 (60.86)	73.33 (58.88)	70.33 (56.97)	66.33 (54.51)	61.67 (51.72)	56.00 (48.42)	6.441	6.415	6.440	6.509	6.438	6.413
T_{10}	77.00 (61.32)	74.00 (59.32)	71.00 (57.39)	67.00 (54.91)	62.33 (52.12)	56.67 (48.81)	6.461	6.432	6.449	6.512	6.443	6.417
Mean	76.57	73.73	70.80	66.60	61.70	56.17	6.416	6.390	6.420	6.490	6.413	6.385
SE (m±)	0.34	0.27	0.28	0.27	0.28	0.29	0.0007	0.0004	0.0004	0.0004	0.0004	0.0004
CD (P=0.05)	1.02	0.81	0.83	0.80	0.84	0.86	0.002	0.001	0.001	0.001	0.001	0.001

Figures in parentheses indicate arc sine 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

Table 5. Effect of seed coating treatments on moisture content (%) and electrical conductivity (m mho/cm/g) during storage in okra

Treatment	Months after storage											
	Moisture content (%)						Electrical conductivity (m mho/cm/g)					
	14	16	18	20	22	24	14	16	18	20	22	24
T_1	9.87	8.87	12.27	11.63	9.47	8.80	0.889	0.921	0.955	0.998	1.121	1.152
T_2	9.83	8.83	12.23	11.57	9.43	8.70	0.886	0.916	0.952	0.994	1.117	1.147
T_3	9.73	8.80	12.17	11.50	9.27	8.57	0.876	0.907	0.941	0.984	1.112	1.139
T_4	9.70	8.77	12.13	11.50	9.30	8.57	0.864	0.894	0.929	0.971	1.095	1.124
T_5	9.63	8.70	12.10	11.40	9.20	8.50	0.873	0.903	0.938	0.981	1.108	1.135
T_6	9.60	8.70	12.10	11.40	9.20	8.47	0.859	0.890	0.925	0.967	1.091	1.120
T_7	9.77	8.80	12.17	11.50	9.30	8.57	0.884	0.914	0.949	0.991	1.116	1.145
T_8	9.80	8.83	12.17	11.50	9.37	8.63	0.880	0.910	0.945	0.988	1.115	1.144
T_9	9.57	8.67	12.00	11.30	9.10	8.43	0.876	0.908	0.945	0.985	1.113	1.141
T_{10}	9.53	8.63	12.00	11.27	9.07	8.40	0.875	0.906	0.940	0.983	1.110	1.138
Mean	9.70	8.76	12.13	11.45	9.27	8.56	0.876	0.906	0.941	0.984	1.110	1.139
SE (m±)	0.04	0.04	0.04	0.04	0.04	0.04	0.0004	0.0004	0.0004	0.0003	0.0004	0.0003
CD (P=0.05)	0.12	0.12	0.12	0.14	0.14	0.13	0.0012	0.0011	0.0013	0.0009	0.0011	0.0010

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 6. Effect of seed coating treatments on fungal infection (%) during storage in okra

Treatment	Months after storage					
	Fungal infection (%)					
	14	16	18	20	22	24
T_1	2.33	2.67	3.33	4.00	5.00	6.00
	(1.82)	(1.91)	(2.07)	(2.22)	(2.44)	(2.64)
T_2	1.67	2.00	2.33	3.00	4.33	5.33
	(1.62)	(1.71)	(1.82)	(1.98)	(2.30)	(2.51)
T_3	0.00	0.00	0.67	1.67	2.33	3.33
	(1.00)	(1.00)	(1.27)	(1.62)	(1.82)	(2.07)
T_4	0.00	0.00	0.00	0.67	1.33	2.33
	(1.00)	(1.00)	(1.00)	(1.27)	(1.52)	(1.82)
T_5	0.00	0.00	0.33	1.00	1.67	2.67
	(1.00)	(1.00)	(1.13)	(1.38)	(1.62)	(1.91)
T_6	0.00	0.00	0.00	0.33	0.67	1.67
	(1.00)	(1.00)	(1.00)	(1.13)	(1.27)	(1.62)
T_7	0.00	0.33	1.33	2.33	3.00	4.00
	(1.00)	(1.13)	(1.52)	(1.82)	(1.98)	(2.22)
T_8	0.00	0.33	1.00	2.00	2.67	3.67
	(1.00)	(1.13)	(1.41)	(1.71)	(1.91)	(2.15)
T_9	0.00	0.00	0.67	1.33	2.00	3.00
	(1.00)	(1.00)	(1.27)	(1.52)	(1.73)	(1.98)
T_{10}	0.00	0.00	0.00	0.33	1.00	2.00
	(1.00)	(1.00)	(1.00)	(1.13)	(1.41)	(1.73)
Mean	0.04	0.53	0.96	1.63	2.4	3.4
SE (m±)	0.04	0.08	0.09	0.14	0.09	0.09
CD (P=0.05)	0.13	0.25	0.27	0.41	0.29	0.28

Figures in parentheses indicate square root transformed 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

2 g/kg of seed (1.00%), which was at par with T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 4 ml/kg of seed (2.00%), followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (2.33%), T_5 - vitavax 200 @ 2g/kg of seed (2.67%), T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid @ 4 ml/kg of seed (3.00%), T_3 - flowable thiram @ 2.4 ml/kg of seed (3.33%), T_8 - polymer + imidacloprid @ 4 ml/kg of seed (3.67%), T_7 - imidacloprid @ 4 ml/kg of seed (4.00%) and T_2 - polykote @ 3 ml/kg of seed (5.33%) as compared to T_1 - untreated control (6.00%). Seeds treated with polymer and fungicides had significantly less fungal infection under storage conditions. This could be due to the inhibition of seed borne pathogens thus preventing seed deterioration and loss of membrane integrity. Similar finding was reported in maize (Sharma *et al*. 2017). The seeds treated with polymer + vitavax 200 @ 2 g/kg of seed resulted in significantly lower fungal infection over untreated control at the end of one year of storage. Paddy seed treated with polymer + vitavax 200 @ 2 g/kg also resulted in significantly lower fungal infection over untreated seeds at the end of one year of storage period (Sharma and Dhiman 2017).

Conclusion

The study revealed that the seed quality parameters declined progressively with the increase in storage period, irrespective of seed coating treatments. The results have shown that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed (T_6) and polymer + flowable thiram @ 2.4 ml/kg of seed (T_4) recorded significant superiority for most of the seed quality parameters over untreated control (T_1) during the storage. It can be concluded that for enhancing seed longevity and to maintain seed quality during storage, the seeds of okra can either be treated with polymer coating @ 3 ml/kg of seed + vitavax 200 @ 2 g/kg of seed or polymer coating @ 3 ml/kg of seed + flowable thiram @ 2.4 ml/kg of seed.

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