Seed Research 47(1): 44-52, June, 2019

Effect of Coating on Quality of Okra Seeds in Storage

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(Received: March, 2019; Revised: April 2019; Accepted: May, 2019)

ABSTRACT: Preserving the planting value of the seed from harvest to next sowing is an integral component of seed industry. It is important to keep intact the physiology of the seed throughout the storage period through various dynamic technological interventions that could result in optimum field stand. Seed coating is one such simple and efficient technology for maintaining seed physiology and health during storage. The seeds of 'P-8' variety of okra were coated with nine different treatments comprising of polymer, fungicides, insecticide, polymer-fungicides and polymer-insecticide combinations and there after stored in HDPE (high density polyethylene) inter woven non-laminated bags for 12 months. Amongst various treatments, seed coated with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed recorded the highest germination percentage (95.00%), rate of germination (44.83), seedling length (28.80 cm), seedling dry weight (0.246 g), seedling vigour index (2755), field emergence (84.00%) and lowest electrical conductivity (0.829 m mho/cm/g) at the end of 12 months of storage over the untreated control. Lower seed infection (0%) was recorded in treatments over untreated control (2.00%). The present study concluded that okra seeds coated with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed and packed in high density polyethylene (HDPE) interwoven non-laminated bag could help in maintaining the seed quality up to 12 months of storage under ambient conditions of Palampur.

Keywords: Okra, Seed coating, Seed quality, Storability

Okra [*Abelmoschus esculentus* (L.) Moench] or lady's finger, also known as 'Bhindi ', is one of the important summer vegetable crops. It is grown for its tender green fruits which are generally marketed at fresh stage, but sometimes in canned or dehydrated form. In India, okra occupies an area of 0.51 m ha with total production of 5849 thousand MT and productivity of 11.45 MT/ha [1]. In Himachal Pradesh, it occupies an area of 2760 hectares with a production of 34030 MT and productivity of 12.33 MT/ha [2]. It contains vitamin A, vitamin B complex, vitamin C and minerals like calcium, magnesium, sodium and iron. It is an excellent source of iodine and useful for control of goitre. The roots and stems of okra are used for clearing the cane juice. It is said to be very useful against genitourinary disorders, spermatorrhoea and chronic dysentery. The crop is also used in paper industry as well as for the extraction of fiber. The nutritional value of 100 g of edible okra is characterized by 1.9 g protein, 0.2 g fat, 6.4 g carbohydrate, 0.7 g minerals and 1.2 g fibers.

The seeds are stored after harvest till the next sowing or until further use. It has to be stored safely so that the viability and vigour remains intact. During storage, the viability and vigour of the seeds not only vary from genera to genera and variety to variety, but it is also regulated by many physiological factors like seed moisture content, atmospheric relative humidity, temperature, initial seed quality, physical and chemical composition of seed, gaseous exchange, storage structure, packaging materials, seed production location and techniques [3]. Deterioration of seed during storage is inevitable, irreversible and leads to detrimental changes at cellular level *viz.,* impairment or shift in metabolic activity, compositional changes, decline or change in enzyme activities, phenotypic and cytological changes apart from quantitative losses. However, the rate of seed deterioration can be slowed down either by storing the seeds under controlled conditions or by imposing polymer film coating along with seed treatment chemicals. As the controlled condition involves huge cost, seed treatment remains the best alternative approach to maintain the seed quality. Recently, various quality enhancement treatments are given to the seeds before storage and sowing. Among these, seed coating is one of the techniques wherein external materials, *viz*., polymers, fungicides and insecticides are applied directly on to the seed surface to maintain the quality and production potential of seed without significantly increasing the size or weight of the seed and obscuring the seed shape [4]. The polymer film coat provides protection from the stress imposed by accelerated ageing, which includes fungal invasion. The coat is thin (8 ìm), simple to apply, diffuses rapidly and non-toxic to the seedlings during germination. It improves plant stand and emergence of seeds, helps in accurate application of the chemical, reduces chemical wastage and helps to make room including all required ingredients, protectants, nutrients, plant growth promoters, hydrophobic/hydrophilic substance and oxygen suppliers.

Further, the availability of good quality seed remains one of the major constraints for okra cultivation as seeds are moderate storer and sensitive to various insect-pest infestation and fungal infection. Proper conservation of okra seed is therefore important so as to provide guaranteed seed supply for planting purpose. Keeping in view the above facts, the present study was undertaken to investigate the utility of coating of seed with polymer alone, in combination with fungicides and insecticide for improving the storability and to know the effect of these treatments on seed quality during storage.

MATERIALS AND METHODS

Well graded carry over seeds from 2015-2016 produce were procured from the Department of Seed Science and Technology, CSK HPKV Palampur. The seeds used in the present study were dried to about eight per cent moisture content. Nine treatments *viz*., T_1 - polymer coating (polykote @ 3 ml per kg of seed, diluted with 5 ml of water), T_2 - flowable thiram (Royal flow 40 SC) @ 2.4 ml per kg of seed, T_3 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml per kg of seed, T_4 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g per kg of seed, T_5 - polymer + vitavax 200 (containing thiram, 37.5% and carboxil, 37.5%) @ 2 g per kg of seed, T_6 - imidacloprid (Gaucho) @ 4 ml per kg of seed, T_7 - polymer + imidacloprid (Gaucho) @ 4 ml per kg of seed, T_8 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml per kg of seed + imidacloprid (Gaucho) @ 4 ml per kg of seed, T_9 - polymer + vitavax 200 (containing thiram, 37.5% and carboxil, 37.5%) @ 2 g per kg of seed + imidacloprid (Gaucho) @ 4 ml per kg of seed along with T_0 - untreated control were evaluated for different quality attributes in completely randomized design (CRD) with three replications. The coated seeds after shade drying were packed in HDPE (high density polyethylene) inter woven non-laminated bags and stored in the month of December, 2016 for twelve months under ambient condition in Seed Technology Laboratory of Department of Seed Science and Technology, CSKHPKV, Palampur. Details of variation in temperature and relative humidity during storage are given in table 1.

Table 1. Ambient temperature and relative humidity during storage of P 8 variety of okra (December 2016 to December 2017)

Months	Temperature (^{0}C)		RH (%)
	Mean Max.	Mean Min.	
December 2016	17.16	15.88	36.27
January 2017	12.63	11.71	33.99
February 2017	16.07	15.09	46.85
March 2017	18.43	17.35	40.16
April 2017	24.43	23.10	34.86
May 2017	26.08	24.61	40.36
June 2017	26.04	24.63	51.24
July 2017	25.13	24.7	75.82
August 2017	23.50	23.52	81.65
September 2017	24.00	22.8	73.35
October 2017	22.68	22.21	49.00
November 2017	17.37	15.88	44.90
December 2017	17.39	15.89	44.91

Evaluation of seed quality parameters, namely, germination (%), rate of germination, seedling length (cm), seedling dry weight (g), seedling vigour index, field emergence (%), seed moisture content (%), electrical conductivity (m mho/cm/g) and seed health status *i.e.* insect infestation (%) and fungal infection (%) was made initially and subsequently at bimonthly interval in order to identify the suitable polymer-chemical combination(s) for better storage of okra.

Germination test was conducted using 100 seeds drawn at random from each treatment replication-wise by adopting between paper method as described by ISTA procedures [5]. The temperature of 25±1 /C and RH of 90 per cent was maintained during the germination test. First count (%) and final count (%) was taken for each treatment of every replication. The first count was taken on 4^{th} day, while final count was taken on 21^{th} day from the day when germination test was performed. The germination percentage was calculated as:

$$\text{Germination Percentage (First and final count)} = \frac{\text{Number of normal seedlings}}{\text{Number of seeds placed for germination}} \times 100$$

The rate of germination was recorded using hundred seeds from each treatment in three replications. Seeds were grown in petriplates by adopting blotter paper method and the daily germination count was made up to the final count. The germination rate index (GRI) was calculated using the following formula and expressed in number.

$$GRI = \frac{G1}{T1} + \frac{G2}{T2} + \ldots + \frac{Gn}{Tn}$$

Where G1, G2 … Gn are the number of seeds germinated
T1, T2…Tn are the days of germination test

For recording seedling length, ten normal seedlings from the standard germination test were randomly selected for each treatment of three replications during final count and length of the seedlings was measured from the tip of the primary leaf to the root tip and mean seedling length was expressed in centimeters.

Further, the data on seedling dry weight was obtained by using the same ten normal seedlings which were used for seedling length measurements. The seedlings were put in butter paper pocket, kept in hot air oven at 7^0C for 18 hours and mean dry weight was recorded in grams.

The seeding vigour index was calculated by adopting the method suggested by Abdul- Baki and Anderson [6] and expressed in number by using the following formulae.

Seedling vigour index - I = Germination (%) × Seedling length (cm)

Seedling vigour index - II = Germination (%) × Seedling dry weight (g)

Field emergence was recorded of stored one hundred seeds drawn at random from each treatment in three replications. The seeds were sown in well prepared soil at 2 to 3 cm depth and covered with soil. Field emergence count was taken on the 7th day after sowing and the emergence percentage was calculated taking into account the number of seedlings emerged above the soil surface.

$$\text{Field emergence (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds placed for emergence}} \times 100$$

For recording seed moisture content, a seed sample of 200 g weight (as per specification of moisture meter) was drawn randomly from bags of each treatment of three replications and then moisture content in percentage was recorded using moisture meter (Non - Destructive Moisture Meter PM 600).

For measuring electrical conductivity, five grams of seeds from each treatment of three replications were weighed. Then these seeds were soaked in 50 ml distilled water in a beaker and kept in an incubator maintained at 25±1°C temperature. 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.

Storage fungi present on seeds were tested using blotter paper method as prescribed by ISTA. Twenty five seeds of each treatment replication-wise were placed equidistantly on two layered moistened blotter paper taken in sterilized petri plates. Each treatment was replicated three times. They were incubated at 20 ± 2°C for seven days. On eighth day, the plates were examined under stereobionocular microscope (50X) for the presence of seed borne fungi. The number of infected seeds were counted and expressed in percentage. Besides, the kinds of fungi present were also identified. Moreover, to determine the insect infestation, three hundred seeds in three replications from each treatment replication-wise were taken, the infested seeds were counted and results were expressed in percentage. Data was subjected to standard statistical analysis [7].

RESULTS AND DISCUSSION

Seed coatings generated significant variation in all the seed quality parameters evaluated in the laboratory (Table 2). At the beginning of storage, significantly higher germination percentage was recorded for all the treatments over untreated control (95.00%). Irrespective of treatments, mean seed germination declined gradually from 95.49 to 93.03 per cent by the end of 12 months of storage. After 12 months of storage, seed coated with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5) exhibited significantly higher germination (95.00%) which was at par (94.66%) with coating of polymer @ 3 ml per kg of seed + flow able thiram @ 2.4 ml/kg of seed (T_3). The decline in germination percentage over the storage period can be attributed to ageing effect leading to depletion of food reserves and decline in synthetic activity of embryo apart from loss of viability

Table 2. Effect of seed coating treatments on germination (%) and field emergence (%) of seeds of P 8 variety of okra

Treatment	Months after storage													
	Germination (%)							Field emergence (%)						
	0	2	4	6	8	10	12	0	2	4	6	8	10	12
T_0	95.00	94.00	93.66	92.66	92.00	91.33	91.00	84.66	83.33	82.00	82.00	80.00	79.66	79.00
	(77.09)	(75.82)	(75.40)	(74.27)	(73.54)	(72.85)	(72.53)	(66.92)	(65.88)	(64.87)	(64.87)	(63.41)	(63.17)	(62.70)
T_1	95.33	94.66	94.33	93.33	92.33	91.66	91.33	85.00	83.60	83.33	82.66	80.66	80.00	79.33
	(77.50)	(76.62)	(76.21)	(75.01)	(73.90)	(73.19)	(72.85)	(67.19)	(66.13)	(65.88)	(65.37	(63.89)	(63.41)	(63.93)
T_2	96.33	96.00	95.33	94.66	94.33	93.66	93.33	86.00	85.00	84.66	84.00	83.00	82.66	81.66
	(78.95)	(78.49)	(77.50)	(76.62)	(76.20)	(75.40)	(75.01)	(68.00)	(67.19)	(66.92)	(66.40)	(65.62)	(65.37)	(64.62)
T_3	98.33	97.66	97.00	96.33	96.33	96.00	94.66	87.33	86.33	85.66	85.33	84.66	84.00	83.66
	(82.63)	(81.22)	(80.08)	(78.95)	(78.95)	(78.43)	(76.62)	(69.12)	(68.27)	(67.72)	(67.45)	(66.92)	(66.40)	(66.13)
T_4	98.00	97.00	96.33	96.00	96.00	94.66	93.33	86.33	85.33	85.00	84.66	83.66	83.33	82.33
	(82.01)	(80.09)	(78.95)	(78.95)	(78.49)	(76.63)	(75.01)	(68.27)	(67.45)	(67.19)	(67.19)	(66.40)	(65.88)	(65.12)
T_5	98.66	98.33	98.00	97.00	96.66	96.33	95.00	87.66	86.66	86.00	85.66	85.00	84.66	84.00
	(83.43)	(82.63)	(82.01)	(79.99)	(79.47)	(79.01)	(77.09)	(69.41)	(68.55)	(68.00)	(67.72)	(67.19)	(66.92)	(66.40)
T_6	95.33	94.66	94.33	93.66	93.33	92.66	92.33	85.00	84.00	83.66	83.00	81.00	80.66	79.66
	(77.50)	(76.62)	(76.20)	(75.40)	(75.01)	(74.26)	(73.90)	(67.19)	(68.55)	(66.13)	(65.62)	(64.13)	(63.89)	(63.17)
T_7	95.66	95.00	94.66	94.00	93.66	93.33	92.66	85.33	84.33	84.00	83.33	81.66	81.33	80.33
	(77.97)	(77.09)	(76.62)	(75.82)	(75.40)	(75.01)	(74.26)	(67.45)	(66.65)	(66.40)	(65.88)	(64.62)	(64.87)	(64.65)
T_8	95.66	95.00	94.66	94.00	93.66	93.33	92.66	85.66	84.66	84.33	83.66	82.66	82.00	81.00
	(79.97)	(77.09)	(76.62)	(75.82)	(75.40)	(75.01)	(74.26)	(67.72)	(66.92	(66.65)	(66.13)	(65.37)	(64.87)	(64.13)
T_9	96.33	96.33	95.66	95.33	95.00	94.33	93.66	86.33	85.33	85.00	84.33	83.66	82.33	82.00
	(78.95)	(78.95)	(77.97)	(77.50)	(77.09)	(76.20)	(75.40)	(68.27)	(67.45)	(67.19)	(66.65)	(66.13)	(65.12)	(64.87)
Mean	95.49	95.93	95.43	94.73	94.36	94.76	93.03	85.93	84.85	84.39	83.39	82.59	82.06	81.27
	(79.45)	(78.55)	(77.34)	(76.82)	(76.39)	(75.77)	(74.42)	(68.11)	(67.14)	(66.72)	(66.30)	(65.32)	(64.64)	(64.37)
SEm(±)	0.72	0.67	0.70	0.50	0.53	0.46	0.43	0.35	0.34	0.33	0.33	0.35	0.31	0.33
CD(p=0.05)	2.14	2.00	2.07	1.46	1.60	1.37	1.30	1.03	1.00	0.96	0.96	0.99	0.93	0.97

Figures in parenthesis indicates arc sine values;

T_o - control (untreated seeds), T_1 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water), T_2 - flowable thiram (Royal Flow 40 SC) @ 2.4 ml/ kg of seed , T_3 - polymer + flowable thiram (Royal Flow 40 SC) @ 2.4 ml/ kg of seed , T_4 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed, T_5 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed, T_6 - imidacloprid (Gaucho) @ 4 ml/kg of seed, T_7 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed, T_8 - polymer + flowable thiram (Royal Flow 40 SC) @ 2.4 ml/ kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed and T_9 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed

and storage condition. Similar results were reported by [8] in hybrid rice, [9] in cotton, [10] in soybean and [11] in high quality protein maize hybrid. All the researchers inferred that seeds coated with polymer + vitavax or thiram recorded higher germination percentage during the end of test period. Similar trend was observed in case of field emergence which decreased progressively with the advancement of storage period, irrespective of seed coating treatments. Significantly higher field emergence (84.00 %) was recorded in T_5 (polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed) which was at par with T_3 (polymer @ 3 ml per kg of seed + flowable thiram @ 2.4 ml/kg of seed) at the end of 12 months of storage. All other treatments had lower field emergence after 12 months of storage. This could be due to age induced deteriorative changes in cell and cell organelles resulting in lower germination capacity of seed under natural soil conditions. The results recorded for field emergence are similar to the findings of [12] in soybean seeds. There result outlined that coating with a hydrophilic polymer regulated the rate of water uptake, reduced imbibitional damage and improved the emergence. Similarly, [13] reported that the chilli seeds coated with polymer @ 7 g/kg and thiram @ 2 g/kg of seed recorded significantly higher germination and field emergence as compared to control which recorded the lowest germination and field emergence at the end of twelve months of storage.

The seedling length (cm) and dry weight (g) varied significantly among different seed coating treatments as recorded after different months of storage (Table 3). Mean seedling length over all treatments recorded at the beginning and the end of storage was 30.39 cm and 27.02 cm, respectively. At the beginning of storage, higher seedling length (30.90 cm) was recorded for seed coated with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5), which was at par with the treatment (T_3) polymer @ 3 ml per kg of seed + flowable thiram @ 2.4 ml/kg of seed (30.79 cm). Similar trend was evident after 12 months of storage wherein significantly higher seedling length (28.80 cm) was recorded for seed coated with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5), which was at par with (T_3) polymer @ 3 ml per kg of seed + flowable thiram @ 2.4 ml/kg of seed (28.71 cm). It may be due to better germination and healthy seedling formation in seeds coated with polymer and fungicide, as it protects the seeds from fungal invasion and thereby results in good and better germination and subsequently higher seedling length. Similar results were reported by [14] in maize and [15] in pigeon pea. Their studies revealed that maize seeds treated with polymer @ 9 ml + Thiram @ 2 g/Kg and pigeon pea seeds treated with Thiram @ 3 G/Kg + Spinosad @ 0.04 ml/Kg recorded significantly higher shoot length, root length, total seedling length, seed viability, seedling fresh weight and vigour index after six months of storage. Almost similar results were observed for seedling dry weight (g). Significantly higher seedling dry weight (0.246 g) was recorded for the treatments *viz.,* polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5), which was at par with (T_3) polymer @ 3 ml per kg of seed + flow able thiram @ 2.4 ml/kg of seed (0.245 g) at the end of 12 months of storage. Seeds treated with polymer, fungicide and insecticide showed highest seedling dry weight due to advantage of polymer seed coating. This is essentially a physiological phenomenon influenced by the reserve metabolites, enzyme activities and growth regulators. These results are in conformity with the findings of [16], who worked on the effect of polymer coating and chemicals seed treatment on seed storability and field performance of chickpea revealing that the treatment

Table 3. Effect of seed coating treatments on seedling length (cm) and seedling dry weight (g) ofseeds of P 8 variety of okra

	Months after storage													
Treatment	Seedling length (cm)							Seedling dry weight (g)						
	0	2	4	6	8	10	12	0	2	4	6	8	10	12
T_0	30.10	29.93	28.93	28.60	28.00	26.86	25.73	0.269	0.265	0.263	0.259	0.258	0.249	0.236
T_1	30.13	30.03	29.43	28.93	28.16	27.00	26.13	0.270	0.266	0.264	0.260	0.259	0.250	0.238
T_2	30.30	30.23	30.00	29.73	28.86	28.00	27.00	0.273	0.270	0.268	0.264	0.262	0.254	0.242
T_3	30.79	30.75	30.59	30.13	29.74	28.15	28.71	0.276	0.273	0.271	0.267	0.265	0.257	0.245
T_4	30.63	30.50	30.46	29.96	28.96	28.43	27.56	0.275	0.272	0.270	0.266	0.264	0.256	0.244
T_5	30.90	30.86	30.70	30.23	29.83	29.00	28.80	0.277	0.274	0.272	0.268	0.266	0.258	0.246
T_6	30.16	30.10	29.70	29.20	28.43	27.23	26.26	0.271	0.267	0.265	0.261	0.259	0.251	0.239
T_7	30.20	30.13	29.86	29.46	28.56	27.33	26.40	0.272	0.268	0.266	0.262	0.260	0.252	0.240
T_8	30.23	30.20	29.96	29.60	28.73	27.73	26.53	0.273	0.269	0.267	0.263	0.261	0.253	0.241
T_9	30.43	30.33	30.31	29.83	28.93	28.13	27.43	0.274	0.271	0.269	0.265	0.263	0.255	0.243
Mean	30.39	30.30	29.99	29.57	28.57	27.86	27.02	0.273	0.269	0.267	0.263	0.261	0.253	0.241
SEm(±)	0.05	0.04	0.04	0.04	0.03	0.04	0.04	0.0006	0.0005	0.0005	0.0006	0.0005	0.0005	0.0006
CD (p=0.05)	0.13	0.12	0.13	0.12	0.11	0.12	0.13	0.0017	0.0016	0.0017	0.0017	0.0016	0.0016	0.0017

T_o - control (untreated seeds), T_1 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water), T_2 - flow able thiram (Royal Flow 40 SC) @ 2.4 ml/ kg of seed , T_3 - polymer + flow able thiram (Royal Flow 40 SC) @ 2.4 ml/ kg of seed , T_4 - vitavax 200 (containing thiram 37.5% and carboxyl 37.5%) @ 2 g/kg of seed, T_5 - polymer + vitavax 200 (containing thiram 37.5% and carboxyl 37.5%) @ 2 g/kg of seed, T_6 - imidacloprid (Gaucho) @ 4 ml/kg of seed, T_7 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed, T_8 - polymer + flowable thiram (Royal Flow 40 SC) @ 2.4 ml/ kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed and T_9 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed combination of polymer coated seed @ 10 ml/kg along with Deltamethrin 2.8 EC @ 0.4 ml/kg of seed + Vitavax power @ 2 g/kg of seed recorded significantly higher seedling dry weight as compared to untreated seeds at the end of storage period.

Irrespective of the seed coating treatments, the mean value for rate of germination decreased from 47.68 to 42.10 after 12 months of storage (Table 4). Initially rate of germination was recorded highest (49.03) for seed coated with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5), which was at par with (T_3) polymer @ 3 ml per kg of seed + flowable thiram @ 2.4 ml/kg of seed (48.90) that after 12 months of storage reduced to 44.83 for seed coated with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5). The reduction in rate of germination may be due to ageing effect. Maize seeds treated with polymer @ 3 g/kg and cotton seeds treated with Thiram @ 1.5 g + polymer @ 5 g/kg of seeds also recorded similar results for germination throughout the storage period [17, 18].

The electrical conductivity of seed leachates was lower in the beginning of storage with average electrical conductivity of seed leachates of 0.438 m mho/cm/g that increased to 0.844 m mho/cm/g after 12 months of storage. In the beginning lowest electrical conductivity (0.434 m mho/cm/g) was recorded in treatment of polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5), which was at par with (0.436 m mho/cm/g) for treatment of polymer @ 3 ml per kg of seed + flowable thiram @ 2.4 ml/kg of seed (T_3). After 12 months of storage, lowest electrical conductivity (0.829 m mho/ cm/g) was recorded in treatment of polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5), which was at par with (0.830 m mho/cm/g) for treatment of polymer @ 3 ml per kg of seed + flowable thiram @ 2.4 ml/kg of seed (T_3). Electrical conductivity increased with the advancing storage period that indicates the membrane integrity and quality of seed and it is negatively correlated with seed quality. Increase in electrical conductivity may be attributed to increase in permeability of the seed membrane as seed ages, many substances such as sugars, free amino acids, and organic acids will leach out in the presence of water. In earlier studies, soybean seeds treated with vitavax coupled with polymer (5 g/kg of seed) recorded lower electrical conductivity which was statistically at par with seed treatment with bavistin coupled with polymer throughout the storage [19].

Table 4. Effect of seed coating treatments on rate of germination and electrical conductivity (m mho/cm/g) ofthe seeds of P 8 variety of okra

Treatment	Months after storage													
	Rate of germination							Electrical conductivity (m mho/cm/g)						
	0	2	4	6	8	10	12	0	2	4	6	8	10	12
T_0	46.20	44.10	44.13	43.16	42.23	41.43	40.26	0.446	0.559	0.570	0.602	0.729	0.757	0.859
T_1	46.50	45.20	44.33	43.60	42.53	41.76	40.53	0.445	0.557	0.569	0.601	0.727	0.754	0.856
T_2	47.86	46.86	45.53	44.70	44.40	43.50	42.66	0.439	0.547	0.560	0.592	0.720	0.748	0.842
T_3	48.90	48.72	47.43	46.69	46.47	45.17	44.74	0.436	0.544	0.553	0.589	0.713	0.739	0.830
T_4	48.50	47.80	46.60	45.83	45.73	44.66	43.50	0.437	0.545	0.557	0.590	0.716	0.741	0.836
T_5	49.03	48.83	47.53	46.80	46.60	45.70	44.83	0.434	0.540	0.550	0.587	0.710	0.737	0.829
T_6	46.80	45.33	44.40	43.56	42.70	41.90	40.43	0.443	0.556	0.565	0.598	0.726	0.752	0.854
T_7	47.30	45.50	44.63	43.86	42.90	42.00	40.73	0.442	0.553	0.564	0.596	0.723	0.750	0.850
T_8	47.53	46.53	45.26	44.70	43.59	42.60	40.50	0.440	0.550	0.562	0.594	0.721	0.749	0.848
T_9	48.23	47.33	46.23	45.33	45.40	44.33	42.86	0.438	0.546	0.559	0.591	0.717	0.747	0.840
Mean	47.68	46.62	45.60	44.82	44.25	43.30	42.10	0.438	0.549	0.560	0.594	0.720	0.747	0.844
SEm(±)	0.05	0.04	0.04	0.04	0.05	0.18	0.04	0.0005	0.0005	0.0006	0.0006	0.0005	0.0005	0.0005
CD (p=0.05)	0.14	0.13	0.12	0.12	0.55	0.11	0.12	0.0016	0.0017	0.0017	0.0017	0.0017	0.0016	0.0016

T_o - control (untreated seeds), T_1 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water), T_2 - flow able thiram (Royal Flow 40 SC) @ 2.4 ml/ kg of seed , T_3 - polymer + flowable thiram (Royal Flow 40 SC) @ 2.4 ml/ kg of seed , T_4 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed, T_5 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed, T_6 - imidacloprid (Gaucho) @ 4 ml/kg of seed, T_7 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed, T_8 - polymer + flowable thiram (Royal Flow 40 SC) @ 2.4 ml/ kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed and T_9 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed

The fungal infection gradually increased with advancing storage period in control whereas in rest of the treatments where seeds were coated with polymer no infection was observed (Table 5). The storage fungi, infecting seeds were identified as *Rhizopus* spp. and *Fusarium* spp. Out of which, *Rhizopus* spp. was predominant. Significantly lowest (1.33%) seed infection was recorded for seed coated with polymer @ 3 ml per kg of seed (T_1), followed by (2.00%) in untreated control (T_0) at the end of 12 months of storage period. Storage fungi have been reported to invade and destroy seeds of several species. Under favourable conditions they can invade any kind of seeds. This invasion leads to loss of viability, development of musty odour and discoloration of seeds. Seed treated with polymer and fungicides significantly inhibited fungal colonies on okra seeds when stored for a period of 12 months. This might be due to the inhibition of seed borne pathogens by presence of fungicides and thus preventing seed deterioration and loss of membrane integrity. In maize the seed treatment with polymer @ 3 ml/kg + vitavax @ 2 g/kg of seed has been reported to lead to no seed infection after eight months of storage [20]. No insect infestation (%) was found in any of the treatment including untreated control till the end of storage period.

Table 5. Effect of seed coating treatments on fungal infection (%) and insect infestation (%) in seeds of P 8 variety of okra

	Months after storage													
Treatment	Fungal infection (%)							Insect infestation (%)						
	0	2	4	6	8	10	12	0	2	4	6	8	10	12
T_0	0.50	0.66	0.83	1.00	1.16	1.50	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.21)	(1.28)	(1.35)	(1.41)	(1.46)	(1.57)	(1.73)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
T_1	0.33	0.50	0.50	0.83	0.83	1.16	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.14)	(1.21)	(1.21)	(1.34)	(1.34)	(1.47)	(1.52)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
T_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
T_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
T_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
T_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
T_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
T_7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
T_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
T_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
Mean	0.08	0.12	0.13	0.18	0.20	0.27	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.03)	(1.05)	(1.05)	(1.07)	(1.08)	(1.10)	(1.13)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
SEm(±)	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD (p=0.05)	0.13	0.12	0.12	0.11	0.12	0.10	0.09	NS	NS	NS	NS	NS	NS	NS

Figures in parenthesis indicates square root transformed values;

T_o - control (untreated seeds), T_1 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water), T_2 - flowable thiram (Royal Flow 40 SC) @ 2.4 ml/ kg of seed , T_3 - polymer + flowable thiram (Royal Flow 40 SC) @ 2.4 ml/ kg of seed , T_4 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed, T_5 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed, T_6 - imidacloprid (Gaucho) @ 4 ml/kg of seed, T_7 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed, T_8 - polymer + flowable thiram (Royal Flow 40 SC) @ 2.4 ml/ kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed and T_9 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed

The vigour of stored seeds decreased gradually with advancement in the storage period irrespective of all seed coating treatments (Figure 1). Seeds coated with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5) recorded significantly higher (2755) vigour index, which was at par with $T_{3,}$ treatment of polymer @ 3 ml per kg of seed + flowable thiram @ 2.4 ml/kg of seed (2732) at the end of 12 months of storage. The decrease in the vigour index may be due to natural ageing induced decline in germination, decrease in dry matter accumulation in seedlings and decrease in seedling length. Higher vigour index in polymer coating along with fungicide and insecticide is probably due to more germination, seedling length, lesser infection by storage fungi and almost nil infestation by insects. Similar results have been reported in pigeon pea [21] and sunflower [22]. Pigeon pea seeds treated with deltamethrin 2.8 EC @ 0.3 ml/kg + vitavax powder @ 3g/kg + polymer coating @ 5 ml/kg were reported to have higher seed vigour index at the end of eleven months of seed storage as compared to other treatments.

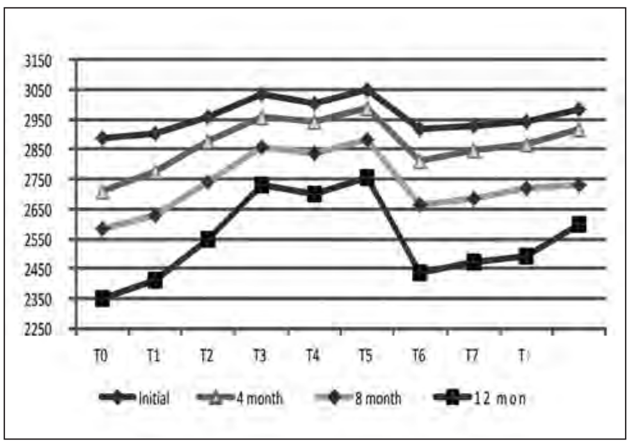

Figure 1. Effect of seed coating treatments on seedling vigour index-I of seeds of P 8 variety of okra

Seed moisture content (%) increased and decreased during storage period as per fluctuations in the prevalent temperature and relative humidity in the environment (Figure 2). It increased after 4th month and decreased after 8th month of storage as the ambient RH was less during that period, but thereafter seeds gained moisture and then again decreased with the decrease in RH. The moisture content of seed due to seed coating treatments recorded non-significant differences during the initial month of storage period, however, it varied significantly after second month of storage period.

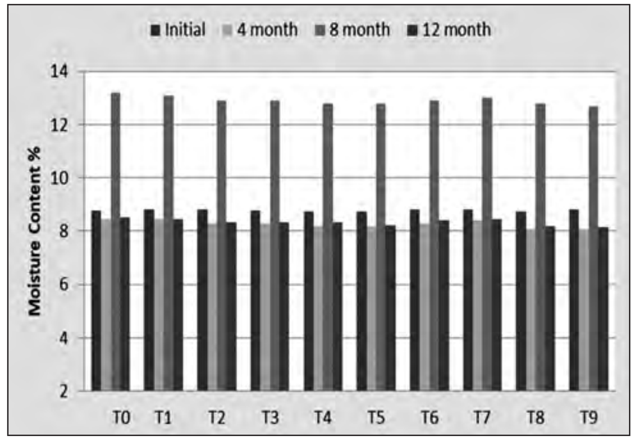

Figure 2. Effect of seed coating treatments on moisture content (%) of seeds of P 8 variety of okra

Among the different treatments, lowest moisture content was recorded in (T_9) polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (8.16 %) which was at par with (T_8) polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (8.20%) and (T_5) polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (8.22%) at the end of 12 months of storage. Similar results were reported by Harish *et al*. [23] who studied the effect of seed treatments on seed quality parameters of tomato seeds and concluded that seeds treated with vitavax @ 2 g + polymer coating @ 20 ml/kg of seeds recorded significantly lower moisture content (7.03%) at the end of storage period.

CONCLUSION

The present study concluded that okra seed coating with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed or polymer @ 3 ml per kg of seed + flowable thiram @ 2.4 ml/kg of seed and packed in high density polyethylene (HDPE) interwoven non-laminated bag can help in maintaining better seed quality up to 12 months of storage.

ACKNOWLEDGEMENT

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.

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