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Effect of Coating on Seed Quality of Radish Seeds during Storage

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ABSTRACT: A laboratory experiment was conducted at Seed Technology Laboratory, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during 2015-16 to study the effect of seed coating treatments on seed quality of radish variety 'Japanese White'. The seeds were coated with 10 different treatments of polymer, fungicides, insecticide, polymer-fungicides and polymer-insecticide combinations and stored in HDPE (high density polyethylene) inter woven non-laminated bags for 12 months. Data recorded on 10 seed quality parameters at bi-monthly interval was analysed following standard statistical methods (CRD). Irrespective of seed coating treatments, the seed deteriorated and the vigour declined with increased fungal infection and insect infestation after twelve months of storage. Amongst various treatments, seed coated with polymer @ 3ml per kg of seed and vitavax 200 @ 2g per kg of seed (T_5) recorded the highest germination percentage (90.00%), rate of germination (84.23), seedling length (16.80cm), seedling dry weight (0.096g), seedling vigour index (1523), field emergence (73.00%), lowest electrical conductivity (0.808m mho/cm/g) and lowest fungal infection (4.50%) at the end of 12 months of storage over the untreated control (T_0). Lowest insect infestation (0.00%) was recorded in treatment T_6 - imidacloprid (Gaucho) @ 4ml per kg of seed over (T_0) untreated control (10.33%). The present study concluded that radish seeds coated with polymer @ 3ml per kg of seed and vitavax 200 @ 2g per kg of seed can help maintaining the seed quality up to 12 months of storage under ambient conditions of Palampur.

Keywords: Radish, Seed coating, Seed quality, Storability

Radish (*Raphanus sativus* L.) is an important vegetable crop of the *Brassicaceae* family widely cultivated for its tender roots as well as for succulent foliage and immature pods which are used largely in salad and in culinary purposes. It is grown and consumed throughout the world. In India, radish occupies an area of 193 thousand hectares with a total production of 2743 thousand metric tonnes and productivity of 14.21 mt/ha [1]. In Himachal Pradesh, it occupies an area of 1682 ha with a production of 32974 mt and productivity of 19.60 mt/ha [2].

Deterioration of seed during storage is inevitable and leads to different changes at various levels *viz.,* impairment or shift in metabolic activity, compositional changes, decline or change in enzyme activities, phenotypic and cytological changes apart from quantitative losses. 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 recommended for 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 the seed to enhance the quality and production potential of seed, without significantly increasing the size or weight of the seed and obscuring the seed shape [3]. The polymer film coat provides protection against the stress imposed by accelerated ageing, which includes fungal invasion. The coat is thin (8μm), simple to apply, diffuses rapidly and non-toxic to the seedlings during germination. It improves plant stand and seedling emergence, facilitate precise application of the chemical, thereby optimising chemical use and helps to make room for including all required ingredients, protectants, nutrients, plant growth promoters, hydrophobic/hydrophilic substance and oxygen suppliers etc. It is stipulated that 80 per cent of certified seed produced in India requires storage for one planting season and only 20 per cent of seed is carried over for subsequent sowing [4]. However, a substantial quantity of seeds may be stored for few planting seasons as a safeguard against monsoon failure and as a precaution against production of poor quality seeds. Besides, the availability of good quality seed for effective radish cultivation remains one of the major constraints as radish seeds are found to be moderate storer and are sensitive to various insect-pest infestation and fungal infection. Keeping in view the above, the present study was undertaken to investigate the effectiveness of seed coating with polymer alone, in combination with fungicides and insecticide for maintaining the seed quality during storage.

MATERIALS AND METHODS

Well graded carry over seeds (left over seeds after *rabi* 2015-16 planting) of radish variety Japanese White of *rabi* 2014-2015 produce, procured from Department of Seed Science and Technology, CSK HPKV Palampur were dried to about 7% seed moisture content and used for the present study. Ten 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 @ 3 ml/kg of seeds diluted in 5 ml of water + flowable thiram (Royal flow 40 SC) @ 2.4 ml per kg of seed, T_4 - vitavax 200 (containing thiram 37.5% and carboxin 37.5%) @ 2 g per kg of seed, T_5 - polymer @ 3 ml/kg of seeds diluted in 5 ml of water + vitavax 200 (containing thiram, 37.5% and carboxin, 37.5%) @ 2 g per kg of seed, T_6 - imidacloprid (Gaucho) @ 4 ml per kg of seed, T_7 - polymer @ 3 ml/kg of seeds diluted in 5 ml of water + imidacloprid (Gaucho) @ 4 ml per kg of seed, T_8 - polymer @ 3 ml/kg of seeds diluted in 5 ml of water + flowable thiram (Royal flow 40 SC) @ 2.4 ml per kg of seed + imidacloprid (Gaucho) @ 4 ml per kg of seed, T_9 - polymer @ 3 ml/kg of seeds diluted in 5 ml of water + vitavax 200 (containing thiram, 37.5% and carboxin, 37.5%) @ 2 g per kg of seed + imidacloprid (Gaucho) @ 4 ml per kg of seed and T_{10} - Neem leaf powder @ 10 g per kg of seed along with T_0 - untreated control were evaluated in completely randomized design (CRD) with three replications. The coated seeds were shade dried, packed in HDPE (high density polyethylene) inter woven non-laminated bags and stored in the month of December, 2015 for twelve months under ambient conditions in Seed Technology Laboratory of Department of Seed Science and Technology, CSKHPKV, Palampur. The 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 intervals to identify the suitable polymer-chemical combination(s) for better storage of radish.

Germination test was conducted using 100 seeds drawn at random from each treatment replication-wise by adopting blotter 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 4th day, while final count was taken on 8th day from the day when germination test was performed. The germination percentage was calculated as:

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

The rate of germination was recorded using hundred seeds from each treatment of three replications randomly. 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.

$$GRI = \frac{G_1}{T_1} + \frac{G_2}{T_2} + \ldots + \frac{G_n}{T_n}$$

Where G1, G2 … Gn are the number of seeds germinated

T_1, T_2 … T_n 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 70°C 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 8th 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 146 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 50ml 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

Table 1. Effect of seed coating treatments on germination (%) and field emergence (%) of seeds of radish variety Japanese White

Treatment	Months after storage													
	Germination (%)							Field emergence (%)						
	0	2	4	6	8	10	12	0	2	4	6	8	10	12
T_0	93.00	92.00	91.00	89.00	87.66	85.33	82.00	82.00	81.00	79.66	76.00	73.00	70.00	63.66
	(74.62)	(73.56)	(72.53)	(70.60)	(69.41)	(67.45)	(64.86)	(64.86)	(64.13)	(63.17)	(60.64)	(58.66)	(56.76)	(52.91)
T_1	93.66	92.33	91.33	90.00	88.66	87.00	83.66	82.66	81.66	80.33	76.66	74.33	70.66	64.33
	(75.40)	(73.90)	(72.85)	(71.55)	(70.30)	(68.84)	(66.13)	(65.37)	(64.62)	(63.65)	(61.09)	(59.53)	(57.18)	(53.30)
T_2	95.33	94.66	93.66	91.66	90.66	89.00	86.00	86.33	85.00	84.00	80.00	78.66	74.00	68.00
	(77.50)	(76.62)	(75.40)	(73.19)	(72.18)	(70.60)	(67.99)	(68.27)	(67.19)	(66.40)	(63.40)	(62.46)	(59.32)	(55.52)
T_3	96.00	95.00	94.00	92.66	91.33	90.00	87.00	87.00	86.00	85.33	81.00	79.33	75.00	69.00
	(78.43)	(77.09)	(75.79)	(74.26)	(72.85)	(71.55)	(68.84)	(68.84)	(68.00)	(67.45)	(64.13)	(62.93)	(59.97)	(56.14)
T_4	97.00	96.33	96.00	95.00	93.33	91.33	89.00	89.00	88.33	87.00	83.66	81.00	77.66	72.33
	(79.99)	(78.95)	(78.49)	(77.04)	(75.01)	(72.85)	(70.61)	(70.61)	(70.00)	(68.84)	(66.13)	(64.13)	(61.77)	(58.24)
T_5	97.66	97.00	96.66	95.33	94.00	92.33	90.00	89.66	89.00	88.00	85.00	82.66	79.33	73.00
	(81.22)	(79.99)	(79.47)	(77.50)	(75.82)	(73.90)	(71.55)	(71.22)	(70.60)	(69.70)	(67.19)	(65.37)	(62.93)	(58.67)
T_6	94.33	93.33	92.00	90.66	89.00	87.66	84.00	83.66	82.33	81.33	77.33	74.66	71.66	65.66
	(76.20)	(75.01)	(73.54)	(72.18)	(70.60)	(69.41)	(66.40)	(66.13)	(65.12)	(64.37)	(61.54)	(59.75)	(57.81)	(54.10)
T_7	94.66	94.00	92.33	91.00	90.00	88.00	85.00	84.33	83.33	82.00	78.66	75.66	72.66	66.66
	(76.62)	(75.82)	(73.90)	(72.51)	(71.55)	(69.71)	(67.19)	(66.65)	(65.88)	(64.87)	(62.46)	(60.41)	(58.45)	(54.71)
T_8	95.33	94.33	93.33	91.66	90.33	88.66	85.33	85.33	84.00	83.33	79.66	76.66	73.66	67.33
	(77.50)	(76.20)	(75.01)	(73.19)	(71.86)	(70.30)	(67.45)	(67.45)	(66.40)	(65.88)	(63.17)	(61.09)	(59.10)	(55.12)
T_9	96.66	95.66	95.33	94.33	92.66	90.66	88.00	89.00	88.00	87.00	83.00	80.66	76.33	71.00
	(79.47)	(77.97)	(77.50)	(76.20)	(74.26)	(72.18)	(69.70)	(70.60)	(69.71)	(68.84)	(65.62)	(63.89)	(60.86)	(57.39)
T_{10}	94.00	93.00	92.00	90.00	89.00	87.33	84.00	83.33	81.00	80.66	77.00	74.66	69.66	65.66
	(75.82)	(74.62)	(73.56)	(71.55)	(70.60)	(69.12)	(66.39)	(65.88)	(64.13)	(63.89)	(61.32)	(59.75)	(56.55)	(54.10)
Mean	95.23	94.33	93.42	91.93	90.60	88.84	85.81	85.66	84.51	83.51	79.81	77.38	73.69	67.87
	(77.52)	(76.33)	(75.27)	(73.61)	(72.22)	(70.53)	(67.91)	(67.80)	(66.88)	(66.09)	(63.33)	(61.63)	(59.15)	(55.47)
SEm(±)	0.43	0.48	0.47	0.36	0.38	0.36	0.35	0.30	0.37	0.33	0.32	0.23	0.24	0.25
CD(p=0.05)	1.26	1.41	1.38	1.06	1.11	1.08	1.04	0.90	1.09	0.98	0.95	0.71	0.72	0.73

Figures in parenthesis indicates arcsine 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 , T_{10} - neem leaf powder @ 10 g/kg of seed

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 stereo binocular 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. 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 were subjected to standard statistical analysis as per [7].

RESULTS AND DiSCUSSION

Significant variation was observed in all the seed quality parameters evaluated in the laboratory due to seed coating treatments (Table 1). At the beginning of storage, significantly higher germination percentage over (T_0) untreated control (93.0%) was recorded for all the treatments, except T_1 and T_{10}. Mean seed germination over all the treatments declined gradually from 95.23 to 85.81 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 (90.00%) which was at par with vitavax 200 @ 2 g per kg of seed (T_4) i.e. 89.00%. 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 and storage condition. Similar results were reported in brinjal [8], cotton [9], in soybean [10] and in high quality protein maize hybrid [11]. The different studies indicated that brinjal seeds treated with Bavistin, cotton seeds coated with Thiram + polymer, soybean seeds coated with polymer + Flowable Thiram and maize seeds coated with polymer + Vitavax 200 observed maximum germination percentage at the end of storage of storage period. The same 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 (73.00%) 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_4 (vitavax 200 @ 2 g per 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 in chilli [12]. The study reported that the chilli seeds coated with polymer @ 7 g/kg and Thiram @ 2 g/kg recorded significantly highest 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) in different seed coating treatments varied significantly as recorded after different months of storage (Table 2). Average seedling length over all treatments recorded at the beginning and the end of storage was 22.01 and 14.10cm, respectively. At the beginning of storage, higher seedling length (24.50cm) was recorded for seed coated with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5), followed by (T_4) vitavax 200 @ 2 g per kg of seed (24.20 cm). Similar trend was evident after 12 months of storage, wherein significantly higher seedling length (16.80 cm) was recorded for seed coated with polymer @ 3ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5), followed by (T_4) vitavax 200 @ 2 g per kg of seed (16.60 cm). It may be due to better germination and healthy seedling development in seeds coated with polymer and fungicide, as it protects the seeds from fungal invasion and thereby results in better germination and subsequently higher seedling length. Similar results were reported in high quality protein maize hybrid seeds coated with polymer + Vitavax 200 @ 2 g/kg [11], , chilli seeds slurry coated with polymer (3 g/kg seed) along with carbendazim (2g/kg seed) and halogen mixture (3 g/kg seed) [13] and pigeon pea treated with Thiram @ 3 g/kg of seed + spinosad @ 0.04 ml/kg [14], which recorded significantly higher seedling length compared to other treatments and control at the end of storage period. Almost similar results were observed for seedling dry weight (g). Significantly higher seedling dry weight (0.096g) was recorded in treatment of polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5), followed by (T_4) vitavax 200 @ 2 g per kg of seed (0.095g) at the end of 12 months of storage. Seeds treated with polymer, fungicide and insecticide showed higher 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 in chickpea [15] and cotton [16]. The studies reported chickpea seeds coated with polymer @ 10 ml/kg along with Deltamethrin 2.8 EC @ 0.4 ml/kg of

Table 2. Effect of seed coating treatments on seedling length (cm) and seedling dry weight (g) of seeds of radish variety Japanese White

Treatment	Months after storage													
	Seedling length (cm)							Seedling dry weight (g)						
	0	2	4	6	8	10	12	0	2	4	6	8	10	12
T_0	19.86	18.80	17.63	16.70	15.80	13.23	11.60	0.119	0.116	0.114	0.111	0.108	0.102	0.086
T_1	20.13	19.13	18.30	17.50	16.30	14.10	12.33	0.120	0.117	0.115	0.112	0.109	0.103	0.089
T_2	22.43	21.70	20.83	19.73	18.63	16.53	14.63	0.123	0.120	0.118	0.114	0.112	0.106	0.092
T_3	23.10	22.20	21.33	20.23	19.40	17.50	15.13	0.124	0.121	0.119	0.115	0.113	0.106	0.093
T_4	24.20	23.20	22.30	21.50	20.70	18.60	16.60	0.126	0.123	0.121	0.117	0.115	0.109	0.095
T_5	24.50	23.83	22.43	21.83	20.96	18.83	16.80	0.127	0.124	0.122	0.118	0.116	0.110	0.096
T_6	20.70	19.63	18.83	17.96	16.43	14.80	12.53	0.121	0.118	0.116	0.113	0.109	0.104	0.089
T_7	21.30	20.43	19.43	18.40	17.13	15.40	13.23	0.122	0.119	0.117	0.113	0.110	0.105	0.090
T_8	22.20	21.43	20.63	19.60	18.53	16.43	14.40	0.123	0.119	0.118	0.114	0.111	0.106	0.091
T_9	23.43	22.53	21.53	20.50	19.60	17.83	15.50	0.124	0.122	0.120	0.116	0.114	0.108	0.094
T_{10}	20.33	19.43	18.63	17.40	16.80	14.40	12.43	0.120	0.118	0.116	0.112	0.109	0.104	0.089
Mean	22.01	21.11	20.17	19.21	18.20	16.15	14.10	0.122	0.119	0.117	0.114	0.111	0.105	0.091
SEm(±)	0.04	0.03	0.03	0.05	0.05	0.04	0.04	0.0005	0.0004	0.0005	0.0005	0.0005	0.0004	0.0004
CD(p=0.05)	0.12	0.10	0.10	0.14	0.15	0.14	0.13	0.0014	0.0013	0.0016	0.0014	0.0014	0.0012	0.0012

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 , T_{10} - neem leaf powder @ 10 g/kg of seed

seed + Vitavax power @ 2 g/kg of seed and cotton seeds treated with Thiram @ 1.50 g/kg of seed and Imidacloprid @ 7.50 g/kg observed significantly higher seedling dry weight compared to untreated seeds throughout the storage period.

Irrespective of the seed coating treatments, there was a progressive decline in rate of germination (mean 87.82 to 79.81% after 12 months of storage) as the storage period progressed (Table 3). Initially, higher rate of germination was recorded (91.40) in seed coated with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5), followed by (T_4) vitavax 200 @ 2 g per kg of seed (90.16), where as it was 84.23 after 12 months of storage for seed coated with polymer @ 3ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5), followed by T_4 (83.20). The reduction in the extent of rate of germination in comparison to control was less, which may be due to reduced ageing effect, fungal infection and insect infestation. Similar findings were reported in maize seeds coated with polykote @ 3g dissolved in 5ml of water + Imidacloprid @ 1 ml [17], cotton seeds coated with Thiram @ 1.5 g + polymer @ 5 g/kg of seeds [18] and marigold seeds treated with Calcium oxychloride ($CaOCl_2$) @ 4 g/kg of seed [19].

The electrical conductivity of seed leachates was lower at the beginning of storage with average electrical conductivity of seed leachates of 0.450 m mho/cm/g, whereas it increased to 0.834 m mho/cm/g after 12 months of storage. Initially, lowest electrical conductivity (0.424 m mho/cm/g) was recorded in T_5 *i.e.* polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed, followed by T_4-vitavax 200 @ 2 g per kg of seed (0.442 m mho/cm/g). At the end of the storage period, lowest electrical conductivity (0.808 m mho/cm/g) was observed in T_{5-} polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed, followed by (0.813 m mho/cm/g) vitavax 200 @ 2 g per kg of seed (T_4). Electrical conductivity increased with the advancement in storage period, which determines the membrane integrity and it is negatively correlated with seed quality. Increase in electrical conductivity may be attributed to 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. These results are in conformity with the findings in cotton [20], which envisaged that cotton seeds coated with polymer recorded slower imbibition rate, reduced the imbibitional damage, lowered the electrical conductivity values and improved the seed germination.

Table 3. Effect of seed coating treatments on rate of germination and electrical conductivity (m mho/cm/g) of the seeds of radish variety Japanese White

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	84.40	83.20	82.10	81.10	80.00	78.73	76.23	0.464	0.558	0.589	0.657	0.763	0.789	0.853
T_1	85.56	84.10	83.30	82.53	81.43	79.70	77.10	0.459	0.555	0.586	0.653	0.759	0.786	0.849
T_2	87.83	87.30	86.40	85.83	84.30	82.60	80.10	0.452	0.535	0.570	0.638	0.741	0.779	0.836
T_3	89.50	88.50	87.33	86.63	85.53	83.60	81.20	0.450	0.534	0.568	0.636	0.718	0.769	0.833
T_4	90.16	90.23	89.19	88.33	87.40	85.30	83.20	0.442	0.529	0.564	0.631	0.713	0.758	0.813
T_5	91.40	91.60	90.33	89.50	88.63	86.40	84.23	0.424	0.525	0.556	0.630	0.677	0.746	0.808
T_6	86.03	85.50	84.23	83.23	82.43	80.53	78.30	0.456	0.541	0.580	0.646	0.754	0.782	0.843
T_7	87.23	86.33	85.10	84.63	83.50	81.20	78.80	0.453	0.539	0.576	0.644	0.750	0.780	0.841
T_8	87.60	86.83	86.13	85.23	84.10	82.30	79.60	0.452	0.536	0.577	0.642	0.744	0.779	0.839
T_9	89.60	88.33	87.53	86.83	85.80	83.80	81.60	0.446	0.533	0.567	0.633	0.716	0.765	0.817
T_{10}	86.00	84.80	83.90	82.80	82.00	80.20	77.60	0.457	0.545	0.583	0.649	0.756	0.784	0.845
Mean	87.82	86.97	85.95	85.14	84.10	82.21	79.81	0.450	0.539	0.574	0.641	0.735	0.774	0.834
SEm(±)	0.04	0.06	0.20	0.04	0.03	0.05	0.04	0.0008	0.0007	0.0013	0.0007	0.0009	0.0006	0.0011
CD(p=0.05)	0.13	0.18	0.58	0.11	0.90	0.16	0.12	0.0025	0.0023	0.0038	0.0023	0.0027	0.0019	0.0034

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 , T_{10} - neem leaf powder @ 10 g/kg of seed

The fungal infection increased throughout the storage period, irrespective of seed coating treatments (Table 4). The storage fungi, infecting seeds were identified as *Alternaria, Penicillium* spp. and *Rhizophous* spp. out of which, *Alternaria* was predominant. Significantly lower (4.50%) seed infection was recorded in T_5 for seed coated with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed, followed by 5.00% in vitavax 200 @ 2 g per kg of seed (T_4) 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 vitavax exerted a significant influence on total fungal colonies on radish 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. Similar findings were reported in high quality protein maize hybrid [11], onion [21] and soybean [22]. In all these studies, it was seen that seeds coated with polymer and fungicide viz., Vitavax 200 @ 2g/kg, Thiram @ 2 g/kg and Fludioxonil + Metalaxyl @ 1 ml/Kg respectively, was able to withhold the fungal growth and development and simultaneously maintained the quality of the seeds till the end of storage period. Similarly, the insect infestation (%) gradually increased with advancing storage period in specific seed coating treatments. The insect found in the seed was Indian meal moth (*Plodia interpunctella*), which is a storage pest. There were non-significant differences in insect infestation (%) up to 8 months of storage. However, after 10 months of storage, all treatments had lesser incidence of insect infestation as compared to the control. The incidence of storage insects in T_6, T_7, T_8 and T_9 was recorded as negligible at the end of 12 months of storage period. Seed health is a major consideration in any seed production programme next to vigour and viability of seeds. Imidacloprid (Gaucho) was found most effective to control the insects, which might be due to its systemic insecticidal action. These results are in conformity with results in cotton [3] and soybean [22].

The vigour of stored seed decreased gradually with advancement in the storage period over all seed coating treatments. Seeds coated with polymer @ 3 ml per kg of seed and vitavax 200 @ 2 g per kg of seed (T_5) recorded significantly higher (1523) vigour index, followed by T_4

Table 4. Effect of seed coating treatments on fungal infection (%) and insect infestation (%) in seeds of radish variety Japanese White

Treatment	Months after storage													
	Fungal infection (%)							Insect infestation (%)						
	0	2	4	6	8	10	12	0	2	4	6	8	10	12
T_0	2.66 (1.91)	3.16 (2.04)	3.66 (2.15)	4.66 (2.37)	5.66 (2.58)	6.33 (2.70)	7.33 (2.88)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	6.66 (2.76)	10.33 (3.36)
T_1	2.50 (1.87)	2.83 (1.95)	3.33 (2.08)	4.33 (2.30)	4.83 (2.41)	5.50 (2.54)	6.50 (2.73)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	4.66 (2.37)	7.00 (2.82)
T_2	1.66 (1.63)	2.00 (1.73)	2.66 (1.91)	3.50 (2.12)	3.83 (2.19)	4.83 (2.41)	5.50 (2.54)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	4.33 (2.30)	6.33 (2.70)
T_3	1.50 (1.58)	1.83 (1.68)	2.50 (1.87)	3.33 (2.08)	3.83 (2.19)	4.66 (2.37)	5.33 (2.51)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	4.00 (2.23)	5.33 (2.51)
T_4	1.16 (1.46)	1.33 (1.52)	2.16 (1.77)	2.83 (1.95)	3.33 (2.08)	4.16 (2.27)	5.00 (2.44)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	3.33 (2.07)	4.33 (2.30)
T_5	0.33 (1.14)	1.16 (1.46)	2.00 (1.73)	2.33 (1.82)	2.83 (1.95)	3.33 (2.08)	4.50 (2.34)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	2.66 (1.91)	4.00 (2.22)
T_6	2.33 (1.82)	2.50 (1.87)	3.00 (2.00)	3.83 (2.19)	4.66 (2.37)	5.33 (2.51)	6.33 (2.70)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_7	2.16 (1.77)	2.33 (1.82)	3.00 (2.00)	3.66 (2.15)	4.33 (2.30)	5.16 (2.48)	5.83 (2.61)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_8	1.83 (1.68)	2.16 (1.77)	2.83 (1.91)	3.66 (2.15)	4.16 (2.27)	5.00 (2.44)	5.66 (2.58)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_9	1.33 (1.52)	1.50 (1.58)	2.33 (1.82)	2.83 (1.95)	3.66 (2.15)	4.50 (2.34)	5.16 (2.48)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_{10}	2.33 (1.82)	2.66 (1.91)	2.83 (1.95)	4.16 (2.27)	4.83 (2.41)	5.16 (2.48)	5.83 (2.61)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
Mean	1.79 (1.65)	2.32 (1.75)	2.75 (1.92)	3.55 (2.12)	4.17 (2.26)	4.90 (2.42)	5.72 (2.58)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	2.33 (1.69)	3.39 (1.90)
SEm(±)	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.05	0.06
CD(p=0.05)	0.14	0.11	0.10	0.11	0.10	0.08	0.07	NS	NS	NS	NS	NS	0.14	0.18

Figures in parenthesis indicates arcsine 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 , T_{10} - neem leaf powder @ 10 g/kg of seed

i.e. vitavax 200 @ 2 g per kg of seed (1477) at the end of 12 months of storage (Figure 1). 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 and lesser infection by storage fungi and very low infestation by insects. The polymer coat provides protection from the stress imposed by accelerated ageing, which includes fungal invasion. These results are in conformity with the findings in high quality protein maize hybrid [11], bajra [23], tomato [24] and [25] sunflower. The studies revealed that maize seeds coated with polymer + Vitavax 200 @ 2 g/kg of seed, bajra seeds coated with hitron @ 5 g/kg of seed, tomato seeds coated with Vitavax @ 2 g + polymer coating @ 20 ml/kg of seeds and sunflower seeds treated with Vitavax (3 g/kg) reported significantly higher values for vigour index during and at the end of storage period.

The seed moisture content (%) increased and decreased during storage period in accordance with the fluctuations in the prevalent temperature and relative humidity in the environment (Figure 2). It decreased from 2nd to 4th month of storage as the ambient RH was less during that period, but thereafter seeds gained moisture up to 8th month of storage 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

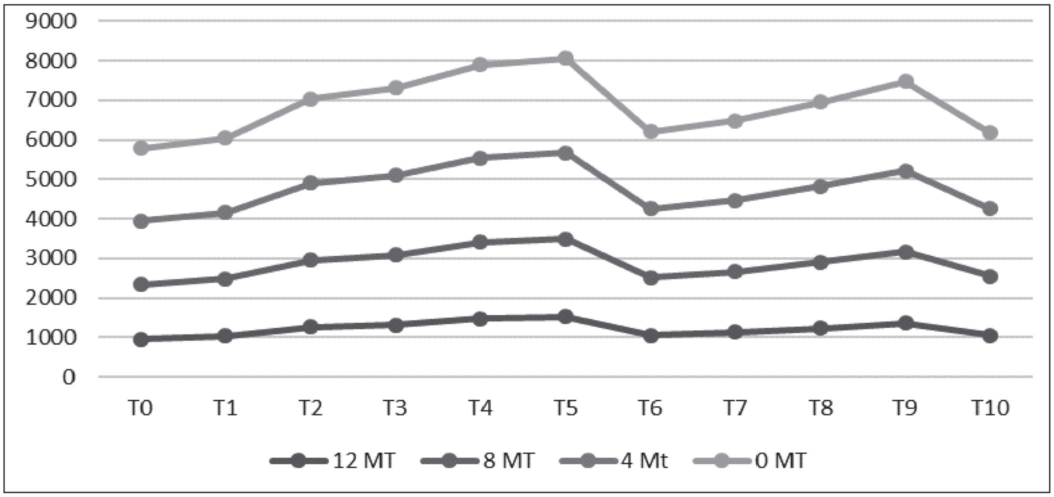

Figure 1. Effect of seed coating treatments on seedling vigour index-I of seeds of Japanese White variety of radish

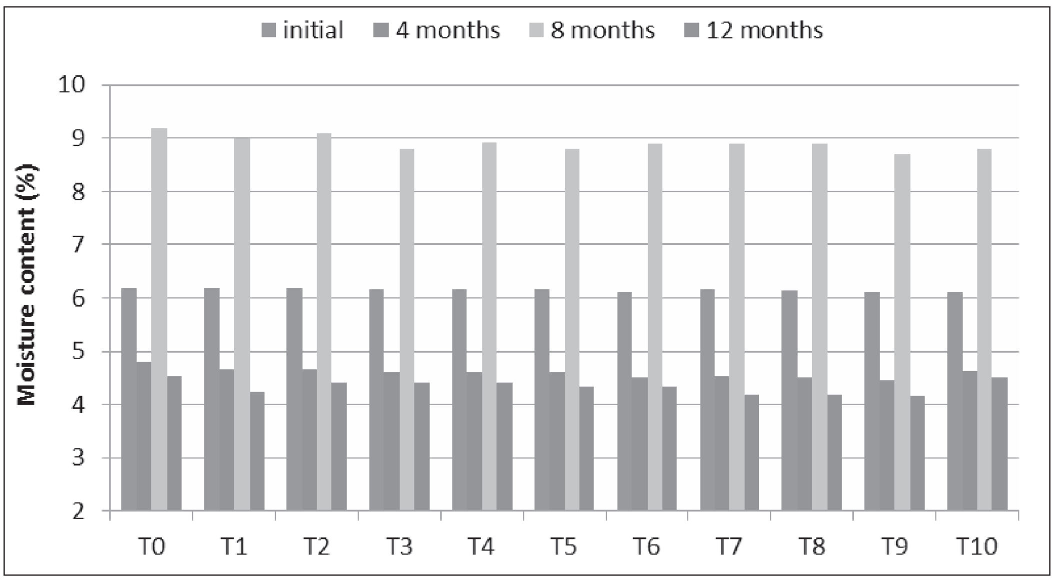

Figure 2. Effect of seed coating treatments on moisture content (%) of seeds of Japanese White variety of radish

significantly after second month of storage period. Among the different treatments, lowest seed moisture content of 4.16% was recorded in polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (T_9) which was at par with 4.20% in polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (T_8), polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed (T_7) and 4.23% polykote @ 3 ml/kg of seed (T_1) at the end of 12 months of storage. Similar results were reported in sunflower [25], and soybean [26]. Sunflower seeds treated with Vitavax (3 g/kg) and soybean seeds treated with Captan (2 g/Kg) recorded significantly lower seed moisture content 9.14 and 10.06%, respectively, at the end of seed storage as compared to other treatments and untreated control.

CONCLUSION

The present study concluded that radish seed coating with polymer @ 3ml per kg of seed and vitavax 200 @ 2g per kg of seed can help in maintaining better seed quality upto 12 months of storage.

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