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Effects of seed pelleting, polymer coating and packaging materials on seed quality characters of tomato (*Lycopersicon esculentum* L.) seeds after five months of storage

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Abstract
The present storage experiment was conducted at Department of Genetic and Plant Breeding, Sam Higginbottom University of Agriculture, Technology and Sciences, Uttar Pradesh during 2017–2018 with tomato seeds (Pusa Ruby). The seeds were coated with polymer in combination with fungicide, insecticide and maintained untreated seeds (control) where T_0 is control, T_1-Acacia (*Acacia nilotica)* leaf powder@4mg/kg seed, T_2-Imidacloprid @ 3ml /kg seed, T_3-Neem leaf powder @ 10 g per kg of seed, T_4-$ZnSO_4$@ 3.0mg/kg seed, T_5 Polymer @ 2ml/kg seed, Acacia leaf powder+ Polymer @ 4ml/kg seed and T_7-Imidacloprid +polymer@ 4ml/kg seed,T_8-Imidacloprid +polymer@6ml/kg seed,T_9-*Trichoderma viridae* @4gm/kg seed T_{10}-Neem leaf powder+polymer@8ml/kg seed T_{11}-Vitavax+polymer @6ml/kg seed. Data was subjected to factorial experiment laid out in completely randomized design Treated seeds were packed in aluminium foil pouch and high density polythene bag (factor P_1 and P_2) 5 months and assessment of seed quality was done in terms of germination per cent, seedling length, seedling dry weight, seedling vigour indices, speed of germination, moisture content and electrical conductivity where. Percent germination, seedling length, seedling dry weight, seedling vigour indices showed maximum in treatment T_{11}-Vitavax+polymer @6ml/kg as compared to other treatments. However, electrical conductivity and moisture content were lowest in T_{11}-Vitavax+polymer @6ml/kg.

Keywords: tomato, vitavax, imidacloprid, acacia leafpowder, polymer, neem leaf powder, aluminium foil pouch, high density polythene bag

Introduction
Tomato (*Lycopersicon esculentum*) 2n=24 a self-pollinated crop is one of the important solanaceous vegetable crops grown widely all over the world because of its special nutritive value and also its wide spread production. It is the world's largest vegetable crops next to potato and sweet potato, but it tops the list of commercial vegetables. Health wise tomatoes are one of the "Highest perch" because they contain an antioxidant "lycopene" and for its ability to reduce the risk of prostate cancer in men. Tomato ranks third in priority on consumption basis after Potato and Onion in India but ranks second after potato in the world. India ranks second in the area as well as in production of Tomato. The major tomato growing countries are China, USA, Italy, Turkey, India and Egypt. In India major tomato producing states are Andhrapradesh, Karnataka, Telangana, Odisha, Gujarat. Tomato is one of the important vegetable crops being cultivated throughout India. Rapid deterioration of stored vegetable seeds is a serious problem which occurs at an increasing rate in uncontrolled storage environment. Seed pelleting is the process of enclosing a seed with small quantity of inert material just large enough to produce globular unit of standard size to provide small amount of nutrients to young seedlings **(**Roos, 1979, Scott, 1989 and Krishnasamy, 2003) [18, 22, 12]. A knowledge on the use of pelleted seeds in improving the productivity of the tomato crop as well as proper storage of pelleted tomato seeds in suitable containers under ambient temperature, relative humidity and at relatively low cost with minimum deterioration in quality for a period of at least one or more season will be of immense useful to the seed industry in general and farming community in particular. The application of polymers to seed serves as an extra exterior shell in order to give the desired seed characteristics viz., quick or delayed water uptake and enhanced germination that would be beneficial for better emergence and establishment in the given condition.

Packaging materials play a major role in prolonging the shelf life of a seed during storage as they separate seeds from the surrounding environment. This increases storage or shelf life by inhibiting the growth of microorganisms and improves hygiene by reducing the danger of cross contamination. Therefore the present study was undertaken to know the effect of treatment and packaging materials on seed quality.

Materials and Methods

After imposition of seed treatments, the treated seed along with untreated seeds (control) were packed in aluminium foil pouch and high density polythene bag and stored under ambient conditions of Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, Uttar Pradesh for 5 months.

Variety- Pusa ruby

Treatments – Twelve (12)

T_0 - control
T_1 - Acacia (*Acacia nilotica)* leaf powder@4mg/kg seed,
T_2 - Imidacloprid @ 3ml /kg seed,
T_3 -Neem leaf powder @ 10 g per kg of seed,
T_4 - $ZnSO_4$@ 3.0mg/kg seed,
T_5 -Polymer @ 2ml/kg seed,
T_6 -Acacia leaf powder+ Polymer @ 4ml/kg seed
T_7 -Imidacloprid +polymer@ 4ml/kg seed,
T_8 -Imidacloprid +polymer@6ml/kg seed,
T_9 -*Trichoderma viridae* @4gm/kg seed
T_{10} -Neem leaf powder+polymer@8ml/kg seed
T_{11} -Vitavax+polymer @6ml/kg seed)

Packaging materials

P1-aluminium foil pouch
P2-high density polythene bag

Moisture content: Seeds were stored at 8 % moisture content

Temperature: Ambient storage conditions.

Observations

Germination per cent: It refers to the proportion by number of seeds which have produced seedlings classified as normal under the conditions and within the period specified that is the percentage of normal seedlings. (ISTA, 2017)
The equation to calculate germination percent is:

$$GP = \frac{\text{No. of seeds germinated}}{\text{Total no. of seeds}} \times 100$$

Shoot Length (cm)

Ten normal seedlings used for root length measurement were also used for the measurement of shoot length. The shoot length was measured from the base of the primary leaf to the base of the hypocotyls and mean shoot length was expressed in centimeters.

Root length (cm)

From the germination test, ten normal seedlings were selected randomly in each treatment from all the replication on 8th day. The root length was measured from the tip of the primary root to base of hypocotyls and mean root length was expressed in centimeters.

Seedling length (cm)

Seedling length is the best indicator of seed vigour. The relative length of root and shoot of seedlings would predict their subsequent growth and performance

Dry matter (g)

Dry weight were based on weights determined before and after oven drying of seedling samples at 103^0C for 4hours.

Vigour index: The computed vigour index, which is the totality of performance, has been regarded as a good index to measure the quality of seed lots (Abdul-Baki and Anderson 1973).

Vigour index I: Germination (%) x seedling length (cm).

Vigour index II: Germination (%) x seedling dry weight (cm).

Moisture content

Moisture content of seed was determined as per ISTA rules (1996). Five grams of seed was weighed, ground and placed in aluminium cups. The aluminium cups along with ground seed material was dried in hot air oven maintained at 130± 1 ^{0}C temperature for four hours.
Methodology:-(Air oven method) in this method the seed moisture content is determined by removing the moisture content from the seeds in an air oven the submitted sample meant for moisture testing must be in an intact moisture proof container from which as much as air is excluded. The determination should be made as soon as possible. (Weight of submitted sample for tomato 70gm).
The moisture content was determined on dry weight basis using the following formula.

$$\text{Moisture content (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where, W_1 - Weight of the empty container with its cover (g)
W_2- Weight of container its cover and ground seeds before drying
W_3- Weight of container its cover and ground seeds after drying

Speed of germination

Seeds were germinated in paper medium with four replications of 100 seed each. The number of seeds germinated was recorded daily upto the day of final count. The speed of germination was calculated by using the formula suggested by Maguire (1962).
Speed of germination = + + ---------- Where, Xn: Number of seeds germinated at nth count Yn: Number of days from sowing to nth count.

Electrical conductivity (dSm^{-1}) Twenty-five seeds were taken randomly from each treatment in four replicates and they were surface sterilized to remove chemical residues, if any. Then they were soaked in 100 ml distilled water for 12 hours at a temperature of 25+/-1 0C. After incubation the conductivity of seed leachate was measured in a digital conductivity meter (model-DI909/DS-7007) and the EC was expressed in dSm^{-1} (AOSA 1983) [5].

Experiment was laid out in completely randomized design with factorial concept in four replications. The seed samples drawn at end of 5th month were evaluated for various seed

quality parameters in order to determine the suitable treatment for better storage

Results and Discussion

Significant results were obtained due to seed pelleting with polymer coating for the seed quality parameters. Results were significantly recorded higher in seeds coated with T_{11}-Vitavax+polymer @6ml/kg seed followed by T_7-Imidacloprid +polymer@ 4ml/kg seed stored in aluminium foil pouch compared to all other treatments and the lowest germination percent, shoot length, root length, Seedling length, seedling dry weight, vigour index I and II speed of germination recorded in T_0 (control) at the end of 5 months storage (Table). Similar results were also reported by Geetharani *et al*, 2006, Kamara *et al.* (2014) [11], Almeida (2014) [4]. At the end of 5 months of storage period, the lowest moisture content and electrical conductivity was recorded in the seeds coated with T_{11}-Vitavax+polymer @6ml/kg seed followed by T_7-Imidacloprid +polymer@ 4ml/kg seed stored in aluminium foil pouch and the highest moisture content and electrical conductivity was recorded in T_0 (control).The film formed around the seed act as a physical barrier, which has been reported to reduce leaching of inhibitors from the seed covering and may restrict oxygen diffusion to the embryo (Duan and Burris, 1997).

Germination percent in T_{11}-Vitavax+polymer @6ml/kg (88.75%) recorded higher germination

followed by T_7-Imidacloprid +polymer@ 4ml/kg(88.00%) lower in T_0P_1 (85.52) because of lower respiration rate and metabolic activity and inactivation of enzymes required for retention of germination for longer period Dhatt *et al*., 2009 it is evidenced by higher germination at end of five months.

Higher Shoot length (6.80), root length (9.79), Seedling length (16.55), seedling dry weight(38.44) was obtained in T_{11}-Vitavax+polymer @6ml/kg seed followed by T_7-Imidacloprid + polymer@ 4ml/kg (6.54), (9.22), (15.49), (37.73) and lower in T_0P_2 (4.78), (7.85), (12.12), (30.71) respectively. It was due to higher percentage and better germination of seedlings in seeds coated with polymer fungicide and insecticide this protects fungi invasion thereby good and better germination and subsequent higher root and shoots lengths, seedling dry weight Basavaraj *et al*. (2008) in onion, higher seedling length and seedling dry weight is an indication of maintenance of vigour in the seeds preserved in ambient storage.

Higher seed vigour index I(1499), II (3543) was obtained in T_{11}-Vitavax+polymer @6ml/kg seed followed by T_7-Imidacloprid +polymer@ 4ml/kg (1469), (3479), and lower in T_0P_1 (1278), (3246), respectively in polymer coating along with fungicide and insecticide it is due to more germination, root and shoot length, seedling dry weight, lesser infection by storage fungi.

Higher speed of germination(37.32) was obtained in T_{11}-Vitavax+polymer @6ml/kg seed followed by T_7-Imidacloprid + polymer@ 4ml/kg (36.80) and lower in T_0P_1(34.67) it was due Coating of seeds with polymer and fungicides might have protected the seed from influence of above factors resulting in maintenance of seed viability for a comparatively longer period.

These finding are in agreement with the results obtained by Jitendra *et al.* (2007) [10], Pawar *et al.* (2015).

The lower electrical conductivity (0.505) was obtained in T_{11}-Vitavax+polymer @6ml/kg seed followed by T_7-Imidacloprid +polymer@ 4ml/kg (0.545) higher in T_0P_1 (0.602) this was mainly governed by lower cell wall permeability which indicated lower respiration rate and metabolic activity maintenance of vigour during storage. This finding in supported by Doijode 2000 [8] in winter squash and kumar *et al.* 2011 [14] in karanj seeds.

The Lower moisture content was observed is (8.18) in T_{11}-Vitavax+polymer @6ml/kg seed followed by T_7-Imidacloprid +polymer@ 4ml/kg (8.21) higher in T_0P_2 (8.64) is mainly because maintenance of lower moisture content 8 % during the storage period, container viz., aluminium foil pouch and high density polythene bag acted as moisture proof containers this is evidenced by lower moisture content 8% in the seeds packed in aluminium foil pouch and high density polythene bag. This lower moisture content resulted in lower respiration rate, lower metabolic activity and maintenance of high seed vigour during storage. This results are in similarity with Chattha *et al.* (2012).

Seeds preserved in ambient storage in P1 aluminium foil pouch recorded higher germination, seedling length, seedling dry weight, vigour indices compared to P2 high density polythenebag and lower electrical conductivity and moisture content is the indication of lower metabolic activity and respiration rate and maintenance of vigour during the storage. It was observed that under ambient condition loss off seed quality at slow rate could be due to reduced metabolic activities and inactivation of enzymes required for longer period. Whereas with course of time decline in viability could be due to depletion of food reserves increase fatty acidity, ultra structural changes reduced activity of enzymes and weakening of membrane integrity. These results are in line with the findings of Banovetz and schiener 1994 [6] and Diojide 2000 [8].

Conclusion

It is concluded that from the present investigation that tomato seeds pelletized and treated with the combined treatment of polymer and fungicide and insecticide T_{11}-Vitavax+polymer @6ml/kg seed followed by T_7-Imidachloprid +polymer@ 4ml/kg recorded significantly higher seed quality parameters. These two seed treatments were found effective in improving the shelf life of seed and it is more beneficial to the farmers. Tomato seeds packed in aluminium foil pouch found more effective for extending seed longevity and maintaining the storability by safe guarding seed from deteriorating.

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Author is thankful to Advisor Dr. Abhinav Dayal, Co-Advisor Dr. Prasanth kumar Rai and advisory committee for continuous support, guidance and co-operation. Author feels immense pleasure to thank all the advisory committee members for their constructive criticism and especially Head and Dean of Post Graduate studies Prof (Dr.) P. W. Ramteke Department of Genetics and Plant Breeding, SHUATS, Allahabad, Uttar Pradesh (U.P), India for providing necessary facilities.

Table 1: Analysis of variance for 5 months of storage in Tomato.

S. No.	Characters	Mean squares				
		Treatments (d.f =23)	Factor A (d.f =1)	Factor B (d.f =11)	Factor AXB (d.f =11)	Error (d.f=69)
1.	Germination (%)	3.42	21.09	4.97**	0.26	0.07
2.	Root length (cm)	1.86	3.65	3.30**	0.25**	0.17
3.	Shoot length (cm)	1.22	0.22**	2.50**	0.039**	0.004
4.	Seedlinglength (cm)	7.49	0.002**	15.59**	0.072	0.194
5.	Seedlingdry weight (g)	14.66	16.91**	28.89**	0.232	0.166
6.	Vigour Index I	24407	21690**	47368**	1693	1141
7.	Vigour Index II	53422	153680**	95726**	2003	2841
8.	Electrical conductivity(dsm-1)	0.009	0.079	0.001**	0.009**	0.009
9.	Speedof germination	26.41	5.33**	29.73**	25.01	22.66
10.	Moisture content (%)	0.141	0.030	0.275**	0.020**	0.011
*, ** indicate significant at 5% and 1 % level of significance respectively.						

Table 2: Mean performance for 5 months of storage in tomato

Treatments	Germination (%)			Shoot length(cm)			Root length(cm)			Seedling length(cm)			Seedling dryweight(g)		
	P1	P2	mean	P1	P2	mean	P1	P2	mean	P1	P2	mean	P1	P2	mean
T0	86.00	85.25	85.63	4.79	4.78	4.78	7.92	7.85	7.88	12.56	12.12	12.34	30.71	30.75	30.73
T1	86.00	85.25	85.63	5.65	5.42	5.53	8.84	8.65	8.74	14.29	14.06	14.17	36.58	35.60	36.09
T2	86.75	86.00	86.38	5.96	5.50	5.73	8.88	8.82	8.85	14.50	14.32	14.41	36.99	36.02	36.50
T3	86.50	85.75	86.13	5.47	5.36	5.41	8.83	8.79	8.81	14.14	14.15	14.14	36.44	35.46	35.95
T4	87.50	85.50	86.50	5.27	5.24	5.25	8.50	8.08	8.29	13.45	13.27	13.36	36.18	34.90	35.54
T5	86.75	86.00	86.38	6.08	6.06	6.07	8.73	8.54	8.63	14.24	14.37	14.31	37.02	36.28	36.65
T6	86.38	85.75	86.06	6.19	6.16	6.18	8.12	8.53	8.32	14.31	14.64	14.47	35.97	34.77	35.37
T7	88.00	86.88	87.44	6.54	6.52	6.53	9.22	9.16	9.19	15.49	14.87	15.18	37.73	37.07	37.40
T8	87.75	86.75	87.25	6.27	6.21	6.24	8.50	8.43	8.46	15.04	14.74	14.89	37.65	36.76	37.20
T9	86.25	85.50	85.88	5.76	5.66	5.71	8.45	8.48	8.46	14.11	14.10	14.10	35.30	34.34	34.82
T10	87.25	86.25	86.75	5.87	5.78	5.82	8.67	8.67	8.67	14.53	14.36	14.44	35.11	34.19	34.65
T11	88.75	87.75	88.25	6.80	6.76	6.78	9.79	9.56	9.68	16.55	16.36	16.45	38.44	37.91	38.17
Grand mean	86.99	86.05	86.52	5.88	5.79	5.83	8.70	8.63	8.66	14.43	14.28	14.35	36.17	35.33	35.75
	T	P	T×P	T	P	T×P	T	P	T×P	T	P	T×P	T	P	T×P
SEm±	0.040	0.098	0.028	9.12	0.02	6.45	0.017	0.04	0.012	0.04	0.10	0.03	0.05	0.14	0.04
CD at 5%	0.159	0.189	NS	36.29	0.038	12.44	NS	0.07	0.023	0.15	0.19	0.05	0.199	0.270	0.077
Treatments	Vigour index-I			vigour index-II			Speed of germination			Electrical conductivity			Moisture content (%)		
	P1	P2	Mean	P1	P2	mean	P1	P2	mean	P1	P2	mean	P1	P2	Mean
T0	1278.75	1315.00	1296.88	3246.75	3239.00	3242.88	34.67	34.12	34.39	0.605	0.682	0.644	8.88	8.64	8.76
T1	1371.50	1337.25	1354.38	3344.25	3265.25	3304.75	35.49	34.62	35.05	0.610	0.585	0.598	8.48	8.50	8.49
T2	1382.00	1347.00	1364.50	3401.00	3318.50	3359.75	36.40	35.75	36.07	0.582	0.625	0.604	8.50	8.52	8.51
T3	1337.00	1312.00	1324.50	3337.50	3234.50	3286.00	35.61	34.54	35.07	0.610	0.642	0.626	8.66	8.60	8.63
T4	1322.00	1284.75	1303.38	3299.00	3208.25	3253.63	35.52	35.01	35.26	0.607	0.635	0.621	8.72	8.73	8.72
T5	1383.25	1344.25	1363.75	3385.50	3248.25	3316.88	36.74	36.15	36.44	0.587	0.637	0.612	8.41	8.48	8.44
T6	1264.00	1264.50	1264.25	3235.00	3148.00	3191.50	35.33	34.81	35.07	0.575	0.702	0.639	8.67	8.70	8.68
T7	1469.50	1393.00	1431.25	3479.00	3390.00	3434.50	36.80	35.79	36.29	0.545	0.622	0.584	8.21	8.30	8.25
T8	1446.50	1392.00	1419.25	3437.00	3346.00	3391.50	36.50	35.78	36.14	0.553	0.626	0.590	8.21	8.32	8.26
T9	1247.00	1224.00	1235.50	3200.00	3112.25	3156.13	35.79	35.30	35.54	0.617	0.697	0.657	8.49	8.75	8.62
T10	1237.70	1222.00	1229.85	3197.00	3146.75	3171.88	35.78	35.01	35.39	0.612	0.622	0.617	8.56	8.71	8.63
T11	1499.25	1441.00	1470.13	3543.25	3489.75	3516.50	37.32	36.89	37.10	0.505	0.587	0.546	8.18	8.25	8.21
Grand mean	1353.20	1323.06	1326.135	3342.10	3262.21	3282.67	35.99	35.31	35.65	0.584	0.639	0.611	8.49	8.54	8.51
	T	P	T×P	T	P	T×P	T	P	T×P	T	P	T×P	T	P	T×P
SEm±	4.87	11.94	3.44	7.6	18.80	5.44	0.06	0.154	0.044	0.01	0.03	9.68	0.01	0.03	9.68
CD at 5%	19.382	23.044	6.639	30.24	36.28	10.49	0.23	0.29	0.08	0.039	0.057	18.682	0.039	0.057	18.68

Conclusion

It is concluded that from the present investigation that tomato seeds pelletized and treated with the combined treatment of polymer and fungicide T_{11}-Vitavax+polymer @6ml/kg seed followed by T_7-Imidachloprid +polymer@ 4ml/kg recorded significantly higher seed quality parameters. These two seed treatments were found effective in improving the shelf life of seed and it is more beneficial to the farmers. Tomato seeds packed in aluminium foil pouch found more effective for extending seed longevity and maintaining the storability by safe guarding seed from deteriorating.

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