Seed Res. 51 (1): 26-33, June, 2023

Effect of Seed Treatments, Packaging Materials and Storage Conditions on Seed Longevity in Onion (*Allium cepa* l.)

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(Received March 2023; Revised April 2023; Accepted April 2023)

ABSTRACT: An investigation was carried out from summer 2020 onwards to evaluate the effect of moisture resistant containers and treatments with botanicals on the storability of onion seeds stored at ambient and cold storage conditions. The experimental material comprising three different factors, storage conditions [S_1: Ambient storage condition and S_2: Cold storage condition (10 + 2^0C)]; packaging materials (P_1: Plastic storage box, P_2: Air tight plastic container, P_3: Aluminium foil bag and P_4: Aluminium foil bag with vacuum packing); and seed treatments (T_1: Control, T_2: Neem seed Kernel powder 5g/kg, T_3: Sweet flag rhizome powder 5g/kg and T_4: Black pepper powder 5g/kg) was carried out in Junagadh, Gujarat for 14 months. Germination percentage and other quality parameters evaluated at every 2 month's interval decreased gradually, while seed moisture content with increased in storage period. Seeds packed in Aluminium foil bag with vacuum packing after seed treatment with sweet flag rhizome powder @ 5g/kg seed and stored in cold storage condition recorded the highest germination percentage and vigour, followed by seeds packed in Aluminium foil bag with vacuum packing after seed treatment with black pepper powder @ 5g/kg and stored in cold storage condition after fourteen months of storage period.

Keywords: Longevity, Onion, Packaging materials, Seed treatments, Storage Conditions

INTRODUCTION

Onion (*Allium cepa* L.) belongs to genus *Allium* under the *family Alliaceae*. According to a recent classification based on cladistics, genomics and molecular polygenetic relationships, onion is a monophyletic monocot under clad *Liliales* [1]. Onion is a cross pollinated monocoat grown in cool climate. It is an important crop across the globe and has been used in various forms as food and for medicinal purposes as fresh, cooked and dehydrated forms.

Being hygroscopic in nature, the viability and vigour of seeds under storage are known to be regulated by variations in the physico-chemical factors, initial seed quality, storage structure and packaging materials *etc* [2]. To combat these factors effectively, storing the seeds in moisture vapour proof containers like polythene bag, aluminium foils, tins or any sealed containers are found to be more useful in maintaining the desired quality for longer period, unlike those stored in moisture pervious containers like cloth bag and gunny bag [3]. A knowledge of proper storage of onion seeds under ambient temperature, relative humidity and at relatively low cost with minimum deterioration in quality for a period of at least one or more seasons will be of immense use to seed industry and farming community.

The main purpose of seed storage is to preserve economic crops from one season to another. Major constraints in onion cultivation are the limited availability of vigorous seeds at the time of sowing due to poor storability under fluctuating ambient temperatures and higher relative humidity. The rate of loss of seed viability is mainly a function of temperature and seed moisture content [4]. Seed moisture affect storability more than the temperature. The speed of declined seed quality is largely dependent on temperature, seed moisture, length of storage, type of seed and storage containers [5]. Therefore, the present investigation was carried out to study the influence of seed treatments, packaging materials and storage conditions on storability of onion seeds

MATERIALS AND METHODS

The experiment was initiated in the summer 2020 at laboratory of Department of Seed Science and

Technology, College of Agriculture, Junagadh Agricultural University, Junagadh. The initial germination percentage of seeds at the time of seed treatment was 98.00 per cent. Onion seeds were treated with four different seed treatments *viz*. T_1: Control, T_2: Neem seed kernel powder 5g/kg, T_3: Sweet flag rhizome powder 5g/kg, and T_4: Black pepper powder 5g/kg. The treated seeds were packed in four different packaging materials *viz*.,P_1: Plastic storage box, P_2: Air tight plastic container, P_3: Aluminium foil bag, and P_4: Aluminium foil bag with vacuum packing. The treated seeds after packing in different containers were stored in two different storage conditions *viz*.,S_1: Ambient storage condition and S_2: Cold storage (10 + 2°C).The observations *viz.,* germination percentage, seedling length (cm), seedling dry weight (mg), seedling vigour index I, seedling vigour index II and seed moisture content (%) were recorded at two months interval as per ISTA standards (up to germination went down below 70%) *i.e*. up to 14 months. The data were analyzed using Completely Randomized Design (factorial) as per the method suggested by Cochran and Cox [6].

RESULTS AND DISCUSSIONS

It was found that, germination and all vigour parameters, viz. seedling length, seedling dry weight, seedling vigour index I and seedling vigour index II decreased steadily with increased in storage period (Table 1-5), while seed moisture content in the seeds were increased gradually with increased in storage period (Table 6).

Effect of storage conditions

Irrespective of different packaging materials and seed treatments, storage conditions exhibited significant difference for germination, seedling length, seedling dry weight, seedling vigour index I, seedling vigour index II and seed moisture content for different storage period. After fourteen months of storage period, significantly the maximum germination (76.40%), seedling length (6.44 cm), seedling dry weight (7.89 mg), seedling vigour index I (493.91) and seedling vigour index II (606.26) was recorded in S_2 (cold storage condition) in comparison to S_1 (ambient storage condition) (69.79%, 4.47 cm, 6.81 mg, 314.65 and 479.19, respectively). After fourteen months of storage period, significantly the lower seed moisture content (7.81%) was recorded in S_2 (cold storage condition) in comparison to S_1 (ambient storage condition) (9.31%). The results are in agreement with the findings of [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17] and [18].

The onion seeds packed in different containers and stored in cold storage condition gained moisture content and this is evidenced by rise in moisture content from initial moisture content of 6.05 to 7.81 per cent. This was due to prevalence of higher RH or vapour pressure and low temperature in cold storage. The seeds stored in ambient condition also gained moisture content and it is evidenced by rise in moisture content to 9.31 per cent from 6.27 per cent due to prevalence of higher vapour pressure (Table 6). The seeds stored in cold storage condition (S_2)

Table 1. Effect of storage conditions, packaging materials and seed treatments on germination (%) in onion seeds during storage

Factor	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage	14 months after storage
S_1	95.83	94.63	91.38	84.31	78.08	73.08	69.79
S_2	96.56	95.83	93.31	89.71	83.00	79.40	76.40
S.Em+	0.17	0.19	0.22	0.36	0.39	0.49	0.50
C.D. at 5%	0.48	0.54	0.62	1.01	1.11	1.37	1.40
P_1	95.25	94.33	91.29	85.92	79.46	73.50	70.21
P_2	96.50	95.67	92.67	87.25	80.75	76.29	73.00
P_3	95.50	94.50	91.83	86.75	80.13	74.83	71.83
P_4	97.54	96.42	93.58	88.13	81.83	80.33	77.33
S.Em+	0.24	0.27	0.31	0.50	0.56	0.69	0.70
C.D. at 5%	0.68	0.77	0.88	1.42	1.58	1.94	1.98
T_1	95.33	94.25	90.38	84.04	77.67	72.29	68.71
T_2	96.50	95.63	93.17	88.17	81.67	77.79	74.79
T_3	97.29	96.38	93.75	88.71	82.21	78.33	75.33
T_4	95.67	94.67	92.08	87.13	80.63	76.54	73.54
S.Em+	0.24	0.27	0.31	0.50	0.56	0.69	0.70
C.D. at 5%	0.68	0.77	0.88	1.42	1.58	1.94	1.98

Table 2. Effect of storage conditions, packaging materials and seed treatments on seedling length (cm) in onion seeds during storage

Factor	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage	14 months after storage
S_1	12.63	10.44	10.32	9.16	8.43	7.71	4.47
S_2	13.09	12.36	11.92	10.59	9.41	8.45	6.44
S.Em+	0.09	0.07	0.08	0.05	0.06	0.05	0.04
C.D. at 5%	0.26	0.21	0.23	0.15	0.16	0.14	0.10
P_1	12.49	11.06	10.81	9.54	8.56	7.78	5.24
P_2	12.98	11.49	11.22	9.88	8.97	8.06	5.49
P_3	12.62	11.25	10.97	9.80	8.83	8.08	5.36
P_4	13.33	11.81	11.49	10.29	9.33	8.43	5.73
S.Em+	0.13	0.10	0.11	0.08	0.08	0.07	0.05
C.D. at 5%	0.36	0.29	0.32	0.22	0.23	0.20	0.14
T_1	11.21	9.86	9.43	8.32	7.54	6.77	4.30
T_2	13.87	12.31	12.10	10.81	9.78	8.79	6.25
T_3	14.11	12.60	12.36	11.10	10.12	9.27	6.56
T_4	12.25	10.83	10.60	9.28	8.25	7.50	4.71
S.Em+	0.13	0.10	0.11	0.08	0.08	0.07	0.05
C.D. at 5%	0.36	0.29	0.32	0.22	0.23	0.20	0.14
S x T							
S_1T_1	10.85	8.91	8.56	7.54	7.20	6.40	3.43
S_1T_2	13.75	11.32	11.33	10.11	9.20	8.26	5.21
S_1T_3	13.96	11.64	11.59	10.37	9.54	8.90	5.53
S_1T_4	11.95	9.89	9.81	8.64	7.80	7.29	3.72
S_2T_1	11.58	10.82	10.30	9.10	7.88	7.15	5.17
S_2T_2	13.99	13.30	12.86	11.51	10.36	9.32	7.28
S_2T_3	14.25	13.56	13.13	11.84	10.70	9.63	7.60
S_2T_4	12.55	11.78	11.40	9.92	8.70	7.71	5.69
S.Em+	0.18	0.15	0.16	0.11	0.12	0.10	0.07
C.D. at 5%	NS	NS	NS	NS	NS	0.29	NS
P x T							
P_1T_1	11.03	10.01	9.66	8.37	7.48	6.63	4.27
P_1T_2	13.23	11.69	11.48	10.19	9.18	8.29	5.78
P_1T_3	13.94	12.39	12.07	10.78	9.76	8.87	6.37
P_1T_4	11.78	10.14	10.03	8.84	7.83	7.32	4.54
P_2T_1	11.46	9.87	9.45	8.04	7.42	6.60	4.18
P_2T_2	14.02	12.48	12.27	10.98	9.92	8.91	6.50
P_2T_3	13.99	12.55	12.33	11.04	10.01	9.13	6.56
P_2T_4	12.47	11.05	10.84	9.48	8.51	7.59	4.72
P_3T_1	10.84	9.55	9.09	8.36	7.59	7.06	4.40
P_3T_2	13.94	12.37	12.16	10.87	9.84	8.67	6.08
P_3T_3	14.08	12.45	12.23	10.94	9.92	9.25	6.32
P_3T_4	11.64	10.62	10.41	9.02	7.98	7.32	4.63
P_4T_1	11.53	10.03	9.53	8.52	7.67	6.81	4.35
P_4T_2	14.28	12.68	12.49	11.20	10.18	9.29	6.63
P_4T_3	14.42	13.01	12.80	11.66	10.78	9.82	7.00
P_4T_4	13.12	11.52	11.14	9.78	8.68	7.79	4.94
S.Em+	0.26	0.21	0.23	0.15	0.17	0.14	0.10
C.D. at 5%	NS	NS	NS	0.44	NS	0.40	0.29

Table 3. Effect of storage conditions, packaging materials and seed treatmentson seedling dry weight (mg) in onion seeds during storage

Factor	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage	14 months after storage
S_1	32.52	28.49	24.90	18.81	15.03	9.94	6.81
S_2	33.86	30.85	27.25	21.53	18.64	11.85	7.89
S.Em+	0.09	0.13	0.13	0.12	0.09	0.08	0.05
C.D. at 5%	0.26	0.36	0.38	0.34	0.25	0.21	0.13
P_1	32.71	29.03	25.43	19.56	16.23	10.37	6.84
P_2	33.37	29.92	26.32	20.43	17.12	11.15	7.60
P_3	32.73	29.39	25.79	19.85	16.57	10.65	7.07
P_4	33.94	30.35	26.75	20.83	17.42	11.40	7.89
S.Em+	0.13	0.18	0.19	0.17	0.13	0.11	0.07
C.D. at 5%	0.37	0.51	0.53	0.48	0.36	0.30	0.19
T_1	31.87	28.37	24.78	18.61	15.15	9.11	5.54
T_2	33.71	30.09	26.49	20.65	17.41	11.53	8.00
T_3	34.54	31.05	27.45	21.66	18.33	12.40	8.88
T_4	32.63	29.17	25.58	19.74	16.44	10.53	6.97
S.Em+	0.13	0.18	0.19	0.17	0.13	0.11	0.07
C.D. at 5%	0.37	0.51	0.53	0.48	0.36	0.30	0.19

recorded higher germination compared to ambient storage condition (S_1) throughout out the storage period of 14 months. Seeds stored in cold storage have retained the germination above certification standard up to 14 months during the storage, while seeds stored in ambient condition retained germination up to minimum seed certification standard (70%) up to 12 months (Table 1). Seeds preserved in the cold storage maintained higher seed quality because of lower respiration rate and metabolic activity as it is evidenced by higher germination (76.40%) at the end of 14 months of storage period. [19] have also observed higher germination up to three years in onion seeds, when the moisture content was maintained from 6.0 to 6.8 per cent (dry treatment) or 3.6 to 3.7 per cent (ultra dry treatment) and stored under a temperature of 2-20^{0}C. [9, 12 and 19] reported that onion seeds stored in the cold storage maintained higher vigour, which supports the present findings on seed vigour (Table 4-5). Higher rate of germination is an indication of higher vigour. Seeds preserved in cold storage (S_2) recorded higher seedling length, seedling dry weight, seedling vigour index I and seedling vigour index II compared to ambient storage condition (S_1), mainly due to lower respiration rate and metabolic activity, which were governed by lower temperature during the storage period in onion [19 and 9].

Effect of packaging materials

Irrespective of storage conditions and seed treatments, different packaging materials exerted significant difference for germination, seedling length, seedling dry weight, seedling vigour index I, seedling vigour index II and seed moisture content during different storage period (Table 1-6). After fourteen months of storage, significantly the maximum germination (77.33%), seedling length (5.73 cm), seedling dry weight (7.89 mg), seedling vigour index I (447.60) and seedling vigour index II (613.67)was recorded in seeds packed in Aluminium foil bag with vacuum packing (P_4) and it was followed by seeds packed in air tight plastic container (P_2) with germination of 73.00 per cent, seedling length of 5.49 cm, seedling dry weight of 7.60 mg, seedling vigour index I of 405.82 and seedling vigour index II of 559.45 (Table 1-5). Significantly the minimum germination (70.21%), seedling length (5.24 cm), seedling dry weight (6.84 mg), seedling vigour index I (373.58) and seedling vigour index II (485.87) was recorded in seeds packed in plastic storage box (P_1).After fourteen months of storage period, significantly the minimum seed moisture content (8.35%) was recorded in seeds packed in Aluminium foil bag with vacuum packing (P_4) and it was followed by seeds packed in air tight plastic container (P_2) with seed moisture content of 8.60 per cent (Table 6). Significantly the maximum seed moisture content (8.65%) was recorded in seeds packed in plastic storage box (P_1).The similar results are in line with the findings of [5, 9 -14,18 20 and 21].

Seeds packed in plastic storage box recorded significantly higher moisture content (8.65%) compared to Aluminium foil bag with vacuum packing (8.35%) after 14 months of storage. Seeds packed in Aluminium foil bag with vacuum

Table 4. Effect of storage conditions, packaging materials and seed treatments on seedling vigour index I in onion seeds during storage

Factor	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage	14 months after storage
S_1	1211.13	988.93	945.16	775.34	660.29	566.29	314.65
S_2	1265.14	1185.71	1113.89	951.71	782.66	673.36	493.91
S.Em+	8.86	7.19	7.34	5.91	4.79	4.26	2.85
C.D. at 5%	25.03	20.32	20.73	16.71	13.54	12.03	8.06
P_1	1190.67	1044.29	989.18	823.96	682.65	575.32	373.58
P_2	1253.79	1100.49	1042.09	866.51	726.84	617.85	405.82
P_3	1206.54	1064.68	1009.58	853.20	709.68	606.34	390.12
P_4	1301.54	1139.82	1077.26	910.45	766.73	679.80	447.60
S.Em+	12.53	10.17	10.38	8.36	6.78	6.02	4.04
C.D. at 5%	35.40	28.73	29.32	23.63	19.15	17.01	11.40
T_1	1069.25	930.14	853.24	701.99	586.41	490.49	298.00
T_2	1338.35	1177.55	1128.05	954.92	800.22	685.76	470.64
T_3	1372.36	1215.07	1159.55	987.17	833.12	727.45	497.85
T_4	1172.59	1026.53	977.26	810.03	666.16	575.61	350.62
S.Em+	12.53	10.17	10.38	8.36	6.78	6.02	4.04
C.D. at 5%	35.40	28.73	29.32	23.63	19.15	17.01	11.40
S x T							
S_1T_1	1031.12	832.65	766.36	604.67	534.80	445.29	224.43
S_1T_2	1320.91	1077.20	1044.72	867.94	731.65	619.61	375.56
S_1T_3	1354.07	1114.81	1075.55	895.43	762.80	672.35	400.69
S_1T_4	1138.43	931.06	894.02	733.33	611.91	527.93	257.92
S_2T_1	1107.38	1027.63	940.12	799.31	638.02	535.69	371.57
S_2T_2	1355.79	1277.90	1211.39	1041.90	868.79	751.90	565.72
S_2T_3	1390.66	1315.32	1243.55	1078.90	903.44	782.56	595.02
S_2T_4	1206.74	1122.00	1060.50	886.73	720.40	623.29	443.32
S.Em+	17.72	14.38	14.68	11.83	9.58	8.52	5.71
C.D. at 5%	NS	NS	NS	NS	NS	NS	16.13
P x T							
P_1T_1	1043.86	935.96	859.11	687.71	568.53	460.63	281.64
P_1T_2	1265.74	1107.54	1056.81	889.61	740.13	628.07	421.58
P_1T_3	1338.30	1181.60	1123.41	952.17	795.96	679.02	470.38
P_1T_4	1114.81	952.06	917.38	766.34	625.98	533.56	320.73
P_2T_1	1092.25	932.83	854.03	679.26	577.23	478.53	287.99
P_2T_2	1355.13	1200.54	1153.39	975.09	816.15	694.49	488.22
P_2T_3	1371.01	1218.06	1159.69	982.52	825.56	714.47	494.96
P_2T_4	1196.77	1050.53	1001.23	829.16	688.43	583.90	352.11
P_3T_1	1026.73	892.10	822.26	710.52	594.50	508.61	306.13
P_3T_2	1337.61	1177.94	1127.17	956.41	799.99	663.49	450.34
P_3T_3	1360.09	1191.48	1138.45	964.79	807.32	708.69	469.54
P_3T_4	1101.73	997.23	950.42	781.07	636.90	544.58	334.47
P_4T_1	1114.16	959.68	877.54	730.47	605.37	514.21	316.24
P_4T_2	1394.93	1224.18	1174.84	998.57	844.62	756.98	522.42
P_4T_3	1420.05	1269.13	1216.63	1049.19	903.63	807.63	556.54
P_4T_4	1277.03	1106.29	1040.01	863.56	713.32	640.40	395.18
S.Em+	25.06	20.34	20.76	16.73	13.55	12.04	8.07
C.D. at 5%	NS	NS	NS	NS	38.29	34.03	22.81

packing showed lower rate of increasing in moisture content, which indicated the impervious nature of this container. Similar observations were made in previous studies in onion [2, 5 and 9]. Seeds packed in Aluminium foil bag with vacuum packing recorded higher germination (77.33%), which is more than minimum seed certification standard after 14 months, while in plastic storage box, it was 70.21 per cent after 14 months. This is in accordance with the findings of [2], who have reported higher germination and vigour after seven years when onion seeds cv. Nasik dried upto 6.5 per cent moisture content and packed in aluminium foil. Similar findings have been reported by [5], [9] and [12] in onion. Seeds packed in Aluminium foil bag with vacuum packing recorded higher seedling length, seedling dry weight, seedling vigour index I and seedling vigour index II compared to seed packed in other containers. These results are in accordance with earlier reports [2, 5, 9 and 12] in onion.

Effect of seed treatments

Irrespective of storage conditions and different packaging materials, seed treatments exhibited significant difference for germination, seedling length, seedling dry weight, seedling vigour index I and seedling vigour index II, and non significant difference for seed moisture content during different storage period. After fourteen months of storage period, significantly the maximum germination (75.33%), seedling length (6.56 cm), seedling dry weight (8.88 mg), seedling vigour index I (497.85) and seedling vigour index II (671.39)was recorded in seeds treated with sweet flag rhizome powder @ 5g/kg seed (T_3) and it was statistically at par with seeds treated with neem seed kernel powder @ 5g/kg seed (T_2) with germination of 74.79 per cent, seedling length of 6.25 cm, seedling dry weight of 8.00 mg, seedling vigour index I of 470.64 and seedling vigour index II of 600.27, while seed treatments recorded significantly the minimum values for these traits (68.71%, 4.30 cm, 5.54 mg, 298.00 and 383.37, respectively) in control (T_1) (table 1-5).After fourteen months of storage period, the minimum seed moisture content (8.49%) was recorded in seeds treated with sweet flag rhizome powder @ 5g/kg seed (T_3) and it was followed by seeds treated with neem seed kernel powder @ 5g/kg seed (T_2) and black pepper powder @ 5g/kg seed (T_4) with seed moisture content of 8.51 per cent and 8.54 per cent, respectively. The maximum seed moisture content (8.68%) was recorded in control (T_1) (Table 6).The results are in accordance with the findings of [9], [12], [17] and [20].

The effect of seed treatments was significant after 14 months of storage. Among the seed treatments, on an average, after 14 months of seed storage, significantly higher values were recorded by all the seed treatments over the control. However, after fourteen months of storage period, significantly the maximum germination (75.33%) was recorded in seeds treated with sweet flag rhizome powder @ 5g/kg seed (T_3) and it was statically at par with seeds treated with neem seed Kernel powder

Table 5. Effect of storage conditions, packaging materials and seed treatments on seedling vigour index II in onion seeds during storage

Factor	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage	14 months after storage
S_1	3117.82	2696.92	2276.96	1588.69	1176.45	730.16	479.19
S_2	3270.41	2958.27	2544.40	1932.67	1549.08	943.30	606.26
S.Em+	11.11	14.33	13.66	12.21	9.62	6.03	3.80
C.D. at 5%	31.40	40.49	38.58	34.50	27.17	17.04	10.73
P_1	3116.87	2740.14	2325.62	1687.96	1296.79	768.92	485.87
P_2	3221.60	2864.28	2441.42	1788.08	1388.86	855.29	559.45
P_3	3126.66	2778.73	2370.20	1726.05	1332.79	802.15	511.90
P_4	3311.32	2927.23	2505.47	1840.63	1432.62	920.56	613.67
S.Em+	15.72	20.27	19.31	17.27	13.60	8.53	5.37
C.D. at 5%	44.40	57.25	54.56	48.79	38.43	24.10	15.17
T_1	3039.02	2675.88	2241.24	1571.47	1183.90	660.92	383.37
T_2	3253.23	2877.60	2469.21	1823.89	1425.90	900.06	600.27
T_3	3361.28	2993.73	2575.12	1924.46	1511.45	974.93	671.39
T_4	3122.93	2763.16	2357.14	1722.90	1329.82	811.01	515.87
S.Em+	15.72	20.27	19.31	17.27	13.60	8.53	5.37
C.D. at 5%	44.40	57.25	54.56	48.79	38.43	24.10	15.17

Table 6. Effect of storage conditions, packaging materials and seed treatments on seed moisture content (%) in onion seeds during storage

Factor	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage	14 months after storage
S_1	6.27	6.77	6.97	7.64	8.01	8.81	9.31
S_2	6.05	6.55	6.72	6.95	7.01	7.61	7.81
S.Em+	0.04	0.04	0.04	0.05	0.05	0.05	0.06
C.D. at 5%	0.11	0.13	0.12	0.14	0.15	0.14	0.16
P_1	6.22	6.74	6.92	7.37	7.59	8.29	8.65
P_2	6.19	6.70	6.88	7.33	7.54	8.24	8.60
P_3	6.21	6.72	6.90	7.35	7.57	8.27	8.63
P_4	6.03	6.50	6.69	7.13	7.32	8.02	8.35
S.Em+	0.05	0.06	0.06	0.07	0.07	0.07	0.08
C.D. at 5%	0.15	0.18	0.17	0.19	0.21	0.20	0.23
T_1	6.29	6.79	6.97	7.42	7.63	8.33	8.68
T_2	6.12	6.62	6.80	7.25	7.46	8.16	8.51
T_3	6.09	6.60	6.78	7.23	7.44	8.14	8.49
T_4	6.15	6.65	6.83	7.28	7.49	8.19	8.54
S.Em+	0.05	0.06	0.06	0.07	0.07	0.07	0.08
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS

@ 5g/kg seed (T_2) with germination of 74.79 per cent. Significantly the minimum germination (68.71%) was recorded in control (T_1). High germination is an indicator of high seedling vigour and because of that high seedling vigout index (length and mass) observed in treated seed as compared to control. This is in accordance with the findings of [3], [9] and [12] in onion.

Interaction effect of storage conditions and packaging materials

Interaction effect of storage conditions and packaging materials (S x P) was found non-significant for all the seed quality parameters studied during all the storage period (Table 1-6).

Interaction effect of storage conditions and seed treatments

Interaction effect of storage conditions and seed treatments (S x T) was found non-significant for all the seed quality parameters studied during all the storage period except for seedling length at twelve months of storage period and for seedling vigour index I after fourteen months of storage (Table 1-6).At twelve months of storage period, significantly the maximum seedling length (9.63 cm) was recorded in S_2T_3 (seeds treated with sweet flag rhizome powder @ 5g/kg and stored in cold storage condition), while significantly the minimum seedling length (8.60 cm) was observed in S_1T_1 (untreated seeds stored in ambient storage condition). After fourteen months of storage period, significantly the maximum seedling vigour index I (595.02) was recorded in S_2T_3 (seeds treated with sweet flag rhizome powder @ 5g/kg and stored in cold storage condition) and the minimum seedling vigour index I (224.43) was observed in S_1T_1 (untreated seeds stored in ambient storage condition).

Interaction effects of packaging materials and seed treatments

Interaction effect of packaging materials and seed treatments (P x T) was found non-significant for all the seed quality parameters studied during all the storage period except for seedling length after 8, 12 and 14 months of storage period and for seedling vigour index I after 10, 12 and 14 months of storage (Table 1-6). After fourteen months of storage period, significantly the maximum seedling length (7.00 cm) and seedling vigour index I (556.54) were recorded in P_4T_3 (seeds treated with sweet flag rhizome powder @ 5g/kg and packed in Aluminium foil bag with vacuum packing). Significantly the minimum seedling length (4.18 cm) and seedling vigour index I (281.64) were recorded in P_2T_1 (untreated seeds packed in air tight plastic container)

Interaction effect of storage conditions, packaging materials and seed treatments

Interaction effect of storage condition, packing material and seed treatments on seed quality parameters was non-significant after 14 months of storage (Table 1-6). However, germination and vigour index were recorded

comparatively higher in $S_2P_4T_4$ (seeds packed in Aluminium foil bag with vacuum packing after seed treatment with black pepper powder @ 5g/kg and stored in cold storage condition) and it was followed by $S_2P_4T_3$ (seeds packed in Aluminium foil bag with vacuum packing after seed treatment with sweet flag rhizome powder @ 5g/kg and stored in cold storage condition) and $S_2P_4T_2$ (seeds packed in Aluminium foil bag with vacuum packing after seed treatment with neem seed Kernel powder @ 5g/kg and stored in cold storage condition). This was mainly due to treating the seeds with compatible organics and it played an effectively role in inhibiting the storage microflora with packing materials like Aluminium foil bag with vacuum packing acted as moisture entry barriers and also maintained the lower moisture content in the seeds. The results obtained under the present study are supported by the findings of [9] and [12] in onion.

In the present study, onion seeds packed in aluminum foil bag with vacuum packing after seed treatment with sweet flag rhizome powder @ 5g/kg seed and stored in cold storage condition was found to be the best treatment combination resulting in high germination along with other seed quality parameters even after fourteen months of ambient storage.

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