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Impact of storage environment and packaging materials on seed quality parameters during storage in onion seed (*Allium cepa* L.)

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ABSTRACT

A lab experiment was conducted from April 2021-Sep 2022 at NSP, Seed unit, UAS, Dharwad. The seed quality parameters such as germination, shoot length, root length, seedling dry weight, and seedling vigor index were calculated. Onion seeds were evaluated at bimonthly intervals, and the experimental design followed was a Factorial completely randomized design (FCRD) with 3 replications and 2 factors, namely storage conditions such as ambient and cold storage,and storage containers (cloth bag, high-density polythene bag (HDPE), polythene bag (700 gauge), aluminum laminated bag, vacuum packed bag), the results revealed that the seeds stored with the treatment with vacuum packed bag and stored in cold storage gave good results at the end of 18 months of storage period i.e., seed germination (82.83 %), Shoot length (8.97 cm), root length (7.61 cm), seedling dry weight (21.95 mg) and seedling vigor index (1818) respectively compared to other treatments. Next to the vacuum-packed bag with cold storage, the best results were seen in the seeds stored in cold storage with the aluminum laminated bag.

Keywords:*Vacuum packed bag, cold storage, Ambient storage, seed germination, shoot length, root length, seedling dry weight, seedling vigor index*

1. Introduction

Onion (*Allium cepa* L.) is one of the major bulb crops grown in the world which belongs to the Amaryllidaceae family. It holds a significant place in the world due to its widespread cultivation and high demand for its consumption. Most of the onion produced in India comes from Maharastra, Orissa, Gujarath, Karnataka and Uttar Pradesh (Barakade *et al.,* 2011). It is generally known that Onion seed is one of the shortest-lived seeds of the vegetable crops, rapidly losing its viability after harvest unless special precautions are taken in its storage. The seed possesses the highest vigor at the time of physiological maturity and gradually decreases as the storage period increases (Goel *et al.,* 2003). The percentage and rate of germination of onion seeds also vary considerably among seed lots and this leads to difficulties in establishing optimum plant populations in the field. It has long been known that the factors, that have the greatest influence on the longevity of seeds in storage, are moisture, temperature and oxygen partial pressure (Amjad and Anjum 2002). Maintaining seed viability for a longer period is very essential to preserve the genetic integrity in stored samples. The principal purpose of seed storage is to preserve economic crops from one season to another. Storage temperature and moisture content are the most important factors affecting seed longevity, with seed moisture content usually being more influential than temperature. Majorly the initial quality of seeds, moisture level, relative humidity (RH %), and storage conditions have considerable influence on seed storage. However, if the seeds are stored in controlled conditions, it is suitable for the maintenance of the seed quality for a longer duration. Prolong the storage period, especially in natural environments under tropical and subtropical areas, seed deterioration will be higher.

Usually, as seed moisture levels and storage space temperatures rise, the degree of degradation increases. Seeds are harmed by moist seeds and higher storage temperatures. (Ellis *et al*., 1981). The present investigation has been carried to find out the effect of different storage containers and storage environments on the seed quality parameters of onion seeds.

2. Material and Methods

At the NSP, Seed unit, UAS, Dharwad, a lab experiment was conducted from April 2021 to September 2022. The seed quality parameters such as Germination, shoot length, root length, seedling dry weight, and seedling vigor index were assessed, and the experiment design used was Factorial Completely Randomised Design (FCRD) with 3 replications and 2 factors, namely storage conditions such as ambient and cold storage and storage containers such as cloth bags, high-density polythene bags (HDPE), polythene bags, aluminum laminated bags and vacuum packed bags. The seeds were stored for 18 months. Arka Kalyan variety was used for the study. The seed is purchased from the University of Horticultural Sciences, Bagalkot. Every bimonthly, readings were taken.

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2.1 Germination (%)
The germination test was conducted in four replicates of 100 seeds in onion by following between paper method and was incubated in the walk-in seed germination room maintained at 25 ± 5 °C temperature and 90 ± 5 percent relative humidity. The number of normal seedlings in each replication was counted on the 12th day. The germination was calculated based on the number of seedlings and expressed in percentage (Anon, 2013).

2.2 Shoot length (cm)
From the germination test, ten normal seedlings were randomly selected from each treatment on the final day of the germination test, and the shoot length was measured. The mean length was calculated and expressed in centimeters.

2.3 Root length (cm)
From the germination test, the same ten normal seedlings that were randomly selected for measuring the shoot length were also used for measuring the root length. The mean length was calculated and expressed in centimeters.

2.4 Seedling dry weight (mg/ 10 seedlings)
The ten normal seedlings used for measuring total seedling length were taken in butter paper and dried in a hot-air oven at 70 ºC temperature until they attained constant dry weight and then weighed. The average is expressed in milligrams.

2.5 Seedling vigour index (SVII)
The seedling vigour index was worked out by multiplying the percent germination with the total seedling dry weight (Abdul-Baki and Anderson, 1973).
Seedling Vigour Index II = Germination % × Mean seedling dry weight (mg)

3. Results and Discussion
There was a significant effect of storage containers and duration under ambient and cold temperatures on germination, root length, shoot length, seedling dry weight, and seedling vigour index were given in tables 1 to 5.

3.1 Germination
The results on seed germination as influenced by storage conditions, packaging materials, and their interactions during the storage period are given in Table 1 and Fig: 1,2. As the storage period progressed general trend of gradual decrease in seed germination was observed from 87.93 percent at 2nd month to 67.95 percent at the end of the 18th months of storage period in cold condition and vacuum packaging, irrespective of storage conditions and packaging materials. Germination per cent was influenced by the factors like storage condition in which it is stored and packaging material in which it is packed. There was a decrease in germination per cent from the 2nd month to the 18th month which was influenced by different factors.

Storage conditions (S)
Regardless of initial storage conditions and their packaging material, the germination was lower in ambient storage compared to cold storage throughout the storage period. The germination reduced from 87.56 percent to 57.13 percent and 88.30 to 78.76 percent in ambient and cold storage respectively.

Packaging material (P)
Among all the packaging material, higher germination reduction was noticed in cloth bag followed by HDPE bags, polythene bag, aluminum laminated pouch and vacuum packed bag. Mean germination reduced from 84.66 to 38.08 per cent in cloth bag, whereas in vacuum bag it decreased from 93 to 81.5 per cent.

Interaction (S x P)
Interaction effect between storage conditions and packaging material on germination was found to be significant throughout the storage period. Among all the treatment combinations S_2P_5 (82.83) had showed highest germination percentage followed by S_1P_5 (80.17) at the end of the storage period and S_1P_1 recorded the 0 per cent germination at the end of the 18 month of storage period. There was a 100 percent decrease in germination in S_1P_1 followed by S_1P_2 40 percent decrease and 9 percent decrease was seen in S_2P_5.

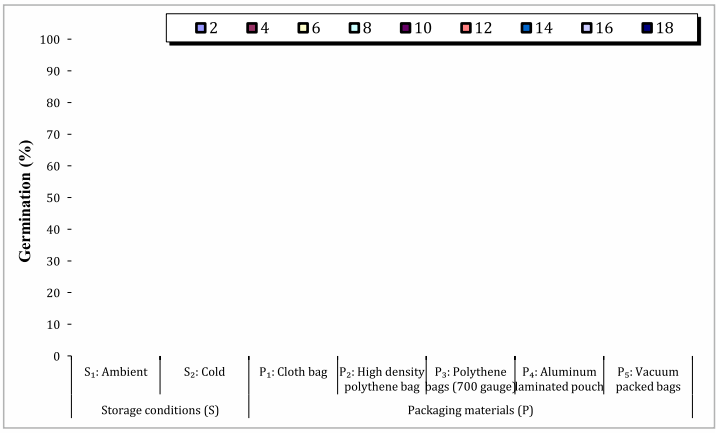

Fig. 1. Effect of packaging and storage conditions on germination during storage in Onion seeds onion seeds

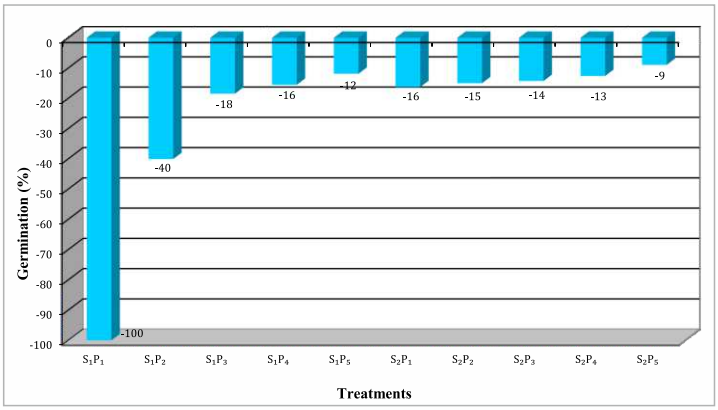

Fig. 2. Percent reduction in the germination of treatment interactions after 18 months of storage

3.2 Shoot length
The results of shoot length as influenced by storage conditions, packaging materials, and their interactions during the storage period are given in Table 2. With the increase in storage period, a reduction in shoot length from 10.46 at 2nd month to 7.97 cm at the end of the 18th month of the storage period was observed irrespective of storage conditions and packaging materials.

Storage conditions (S)
Regardless of initial storage conditions and their packaging material lower shoot length was observed in ambient storage compared to cold storage throughout the storage period (18 months). The reduction in mean shoot length was from 10.45 to 7.09 cm and from 10.47 to 8.84 in ambient storage and cold storage respectively.

Packaging material (P)
Among all the packaging material, higher shoot length reduction was noticed in cloth bags followed by HDPE bag, polythene bag, aluminum laminated pouches and vacuum packed bag. Mean shoot length reduced from 10.34 to 4.34 cm in cloth bag and from 10.56 to 8.95 cm in vacuum packed bags through the storage period.

Interaction (S x P)
Interaction effect of storage conditions and packaging material on shoot length was found to be significant throughout the storage period. Among all the treatment, combinations S_1P_5 and S_2P_5 were on par to each other and recorded significantly highest shoot lengths of 8.93 and 8.97 cm, respectively at the end of the storage period. S_1P_1 recorded the 0 cm of shoot length at the end of 18 months of storage period.

3.3 Root length
The results of root length as influenced by storage conditions, packaging materials and their interactions during the storage period are given in table 3. With the increase in storage period, a reduction in root length from 9.11 at 2nd month to 6.73 cm at the end of 18 th month of the storage period was recorded irrespective of storage conditions and packaging materials.

Storage conditions (S)
Regardless of initial storage conditions and their packaging material lower root length was noticed in ambient storage compared to cold storage throughout the storage period (18 months). The reduction in mean root length was from 9.06 to 5.98 cm and from 9.14 to 7.48 in ambient storage and cold storage respectively.

Packaging material (P)
Among all the packaging material, higher root length reduction was noticed in cloth bag followed by HDPE bag, polythene bags, aluminum laminated pouch and vacuum-packed bags. Mean root length reduced from 8.72 to 3.67 cm in cloth bag and from 9.31 to 7.59 cm in vacuum-packed bags throughout the storage period.

Interaction (S x P)
The interaction effect of storage conditions and packaging material on root length was found to be significant throughout the storage period. Among all the treatment, combinations S_2P_5 recorded significantly highest root length of 7.61 cm at the end of the storage period. S_1P_1 recorded the 0 cm of root length at the end of the 18-months storage period.

3.4 Seedling dry weight (mg/ 10 seedlings)
The results of seedling dry weight as influenced by storage conditions, packaging materials and their interactions during the storage period is given in Table 4. With the increase in storage period, reduction in seedling dry weight from 24.39 at 2nd month to 19.25 mg at the end of 18th month of the storage period irrespective of storage conditions and packaging materials.

Storage conditions (S)
Regardless of initial storage conditions and their packaging material lower seedling dry weight was noticed in ambient storage compared to cold storage throughout the storage period (18 months).
The reduction in seedling dry weight was from 24.26 to 17.16 mg and from 24.51 to 21.34 in ambient storage and cold storage respectively.

Packaging material (P)
Among all the packaging material, higher seedling dry weight reduction was noticed in cloth bags followed by HDPE bag, polythene bag, aluminum laminated pouches and vacuum packed bag. Mean seedling dry weight reduced from 23.40 to 10.16 mg in cloth bag and from 25.13 to 21. 86 cm in vacuum packed bags throughout the storage period.

Interaction (S x P)
Interaction effect of storage conditions and packaging material on seedling dry weight was found to be significant throughout the storage period. Among all the treatment, combinations S_1P_5 and S_2P_5 which were on par to each other recorded significantly highest seedling dry wright of 21.77 and 21.95 mg, respectively at the end of the storage period. S_1P_1 recorded the 0 mg of root length at the end of 18 months storage period.

3.5 Seedling vigour index
The results of seedling vigour index-II as influenced by storage conditions, packaging materials and their interactions during the storage period are given in table 6. With the increase in storage period, reduction in seedling vigour index II from 2146 at 2nd to 1455 at the end of 18th month of storage period irrespective of storage conditions and packaging materials.

Storage conditions (S)
Regardless of initial storage conditions and their packaging material lower seedling vigour index-II was noticed in ambient storage compared to cold storage throughout the storage period (18 months). The reduction in seedling vigour index-II was from 2125 to 1227 and from 2165 to 1682 in ambient storage and cold storage respectively.

Packaging material (P)
Among all the packaging material, higher seedling vigour index-II reduction was noticed in cloth bag followed by HDPE bags, polythene bag, aluminum laminated pouches and vacuum packed bag. Mean seedling vigour index-II reduced from 1981 to 774 mg in cloth bag and from 2278 to 1781 in vacuum packed bags throughout the storage period.

Interaction (S x P)
Interaction effect of storage conditions and packaging material on seedling vigor index-II was found to be significant throughout the storage period. Among all the treatment, S_2P_5 which were reported significantly highest seedling vigour index-II of 1818 at the end of the storage period. S_1P_1 recorded the zero-seedling vigour index-II at the end of 18 months storage period. There was 100 percent decrease in seedling vigour index-II in S_1P_1 followed by S_1P_2 53 per cent decrease and 26 per cent decrease was seen in S_2P_5.
Seed germination and seedling vigour index are a better criterion for the determination of seed storage. Seeds stored in ambient conditions have declined germination per cent at faster rate than those seeds stored in cold conditions, because of uncontrolled environmental conditions. Next is the proper packaging material, seeds deteriorate faster because of higher rate of respiration as they are stored in pervious packaging materials and ambient storage conditions, and in impervious

containers the deterioration is very less compared to pervious containers.

As the storage period increased, the germination percentage were decreased more in case of cloth bag as compared to other packaging material, because of the pervious nature of cloth bag and the ambient oxygen, temperature and RH together lead to reduction of germination over a storage period. Irrespective of the packaging material the germination per cent was reduced less in case of seeds stored in cold conditions, because the cold conditions slow down the rate of respiration and metabolic activity results in less deterioration compared to ambient storage. Among all the packaging materials the vacuum packed bag showed highest germination per cent at the end of the storage period in the present study. These results in the present study are in accordance with Kamara *et al*. (2014) in cowpea, Thumar *et al*. (2017) in cumin, Biradar and Jirali (2017) in soybean, Rai *et al*. (2017) in lentil, Siddarudh *et al*. (2019) in rice, Bhattacharya and Raha (2002) in maize, Vadivellu *et al*. (1985) in bengal gram, Baskin *et al*. (1987) in soybean, Tammanagouda (2002) in greengram, Rao *et al*., 2006 in onion and Raikar *et al*., 2012 in onion.

Seedling length and its dry weight were considerably decreased in cloth, HDPE bags, polythene bags, very less in aluminum laminated bags and vacuum packed bags irrespective of storage conditions and seeds. Due to the decrease in the seedling length, dry weight of seedlings decreased, mobilization efficiency has also decreased throughout the storage period, as they were associated with each other.

With the progress in the storage period, decrease in seedling length, seedling dry weight, and mobilization efficiency was more in cloth bags. There was decrease in seedling length and seedling dry weight in all types of packaging materials but with very minimal difference especially in cold conditions, and it was due to the differential rate of seed deterioration in which seeds are stored. This decreasing trend in seedling dry weight might be due to oxidative stress which induced the production of reactive oxygen species (ROS) that cause lipid peroxidation production of reactive aldehydes, such as malondialdehyde (MDA) and 4-hydroxynonenal (HNE) as a final product which hinders the cellular metabolism resulting in lower ATP production required for growth and development of the seedling.

As the storage progressed the seedling length, seedling dry weight and mobilization efficiency reduced at minimal significant difference in seeds stored in cold storage than seeds stored in ambient storage conditions. These results are in accordance with the findings of the investigation with findings of Ashok *et al.* (2019) in onion, Ramya *et al.* (2018) in sesame, Rai and Mishra (2017) in lentils, as they reported that, a lesser rate of decrease in seedling length, seedling dry weight and mobilization efficiency due to vacuum package of seeds. In addition to this, similar results of a decrease in seedling parameters by storing seeds in conventional packaging's were reported by Amruta *et al.* (2015), Veraja and Rai (2015) in Blackgram and Akter *et al.* (2014) in soybean.

Conclusion

It was concluded that storage conditions and storage container play a significant role in the seed quality parameters like germinability of onion seeds, root length, shoot length, and seedling dry weight of the onion seeds were significantly reduced during the aging process in the ambient storage than cold storage. This is due to the environmental factors and packaging materials have played a major role in deterioration of the onion seed during the storage period.

Future scope of study

As the study was conducted for only 18 months of period it can be extended still further. The Arka kalyan variety was used for the study so there is scope to study with different varieties available. The seed vigour and viability lost was reduced by different seed enhancement techniques like magneto priming and plasma seed treatment before going for sowing.

Acknowledgement

I would like to express my deep sense of gratitude to my major advisor Dr.J.S. Hilli and my members of advisory committee and department HOD for constant support during my study.

Table 1 Influence of packaging material and storage conditions on germination (%) during storage in onion seeds

Treatments	Storage (Months)								
	2	4	6	8	10	12	14	16	18
Storage conditions (S)									
S_1: Ambient	87.56	85.13	83.06	81.66	78.93	73.36	68.03	61.96	57.13
S_2: Cold	88.30	86.43	85.40	84.22	83.40	82.56	81.50	79.43	78.76
S. Em (±)	0.24	0.33	0.40	0.30	0.26	0.18	0.26	0.18	0.15
C. D. (1%)	1.02	1.37	1.69	1.28	1.09	0.76	1.08	0.76	0.65
Packaging materials (P)									
P_1: Cloth bag	84.66	82.16	78.75	76.75	73.33	65.16	58.50	46.83	38.08
P_2: High-density polythene bag	87.00	84.75	83.50	82.00	78.66	75.50	71.66	69.00	65.91
P_3: Polythene bags (700 gauge)	88.41	86.41	85.58	84.66	83.58	81.58	79.58	77.00	76.08
P_4: Aluminum laminated pouch	88.91	87.25	86.33	85.48	84.83	83.16	81.00	78.50	78.16
P_5: Vacuum packed bags	90.66	88.33	87.00	85.83	85.41	84.41	83.08	82.16	81.5
S. Em (±)	0.38	0.52	0.64	0.48	0.41	0.28	0.41	0.28	0.24

C. D. (1%)	1.62	2.17	2.68	2.02	1.72	1.20	1.71	1.20	1.03
Interaction (S x P)									
S_1P_1	84.17 (66.60)	80.83 (64.04)	75.00 (60.00)	71.67 (57.84)	66.33 (54.53)	50.67 (45.38)	38.67 (38.45)	16.70 (24.09)	0.00 (0.00)
S_1P_2	86.83 (68.70)	83.83 (66.29)	82.17 (65.02)	81.33 (64.40	75.67 (60.44)	70.33 (57.00)	63.33 (52.73)	59.80 (50.67)	54.50 (47.58)
S_1P_3	88.33 (70.00)	86.17 (68.17)	85.17 (67.35)	84.33 (66.68)	83.17 (65.78)	80.00 (63.43)	77.67 (61.80)	75.30 (60.22)	74.17 (59.45)

Treatments	**Storage (Months)**								
	2	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**
S_1P_4	88.83 (70.50)	87.00 (68.87)	86.17 (68.17)	85.33 (67.48)	84.50 (66.82)	82.00 (64.90)	79.17 (62.84)	77.00 (61.34)	76.83 (61.23)
S_1P_5	89.67 (71.20)	87.83 (69.59)	86.83 (68.72)	85.67 (67.75)	85.00 (67.21)	83.83 (66.29)	81.33 (64.40)	81.00 (64.16)	80.17 (63.55)
S_2P_1	85.17 (67.30)	83.50 (66.03)	82.50 (65.27)	81.83 (64.77)	80.33 (63.67)	79.67 (63.20)	78.33 (62.26)	77.00 (61.34)	76.17 (60.78)
S_2P_2	87.17 (69.00	85.67 (67.75)	84.83 (67.08)	82.67 (65.40)	81.67 (64.65)	80.67 (63.92)	80.00 (63.43)	78.20 (62.14)	77.33 (61.57)
S_2P_3	88.50 (70.20)	86.67 (68.58)	86.00 (68.03)	85.00 (67.21)	84.00 (66.42)	83.17 (65.78)	81.50 (64.53)	78.70 (62.49)	78.00 (62.03)
S_2P_4	89.00 (70.60)	87.50 (69.30)	86.50 (68.44)	85.63 (67.73)	85.17 (67.35)	84.33 (66.68)	82.83 (65.52)	80.00 (63.43)	79.50 (63.08)
S_2P_5	91.67 (73.2)	88.83 (70.48)	87.17 (69.01)	86.00 (68.03)	85.83 (67.89)	85.00 (67.21)	84.83 (67.08)	83.33 (65.91)	82.83 (65.52)
Mean	**87.93**	**85.78**	**84.23**	**82.95**	**81.17**	**77.97**	**74.77**	**70.70**	**67.95**
S. Em (±)	**0.55**	**0.73**	**0.90**	**0.68**	**0.58**	**0.40**	**0.58**	**0.40**	**0.35**
C. D. (1%)	**2.29**	**3.08**	**3.79**	**2.86**	**2.44**	**1.70**	**2.42**	**1.70**	**1.46**
C.V (%)	**1.08**	**1.49**	**1.87**	**1.44**	**1.25**	**0.91**	**1.35**	**1.00**	**0.90**

Storage conditions (S) : S1: *Ambient storage,* ***S2:*** *Cold storage,*
Packaging materials (P) : P1: *Cloth bag,* ***P2:*** *High density polythene bag,* ***P3:*** *Polythene bags (700 gauge),* ***P4:*** *Aluminum laminated pouch,*
P5: *Vacuum packed bags*
**Figures in the parenthesis are arcsine transformed value (Initial=93%)*

Table 2. Influence of packaging material and storage conditions on shoot length (cm) during storage in onion seeds

Treatments	Storage (Months)								
	2	4	6	8	10	12	14	16	18
Storage conditions (S)									
S_1: Ambient	10.45	10.36	9.91	9.46	9.32	9.18	9.07	8.90	7.09
S_2: Cold	10.47	10.41	9.96	9.53	9.42	9.26	9.14	8.98	8.84
S. Em (±)	0.06	0.05	0.16	0.15	0.13	0.13	0.13	0.01	0.006
C. D. (1%)	0.25	0.22	0.67	0.63	0.54	0.57	0.55	0.06	0.02
Packaging materials (P)									
P_1: Cloth bag	10.34	10.24	9.77	9.25	9.09	8.95	8.85	8.68	4.34
P_2: High-density polythene bag	10.40	10.35	9.89	9.44	9.30	9.15	9.06	8.90	8.82
P_3: Polythene bags (700 gauge)	10.48	10.40	9.93	9.51	9.41	9.25	9.13	8.94	8.84
P_4: Aluminum laminated pouch	10.52	10.44	10.02	9.59	9.48	9.33	9.19	9.05	8.89
P_5: Vacuum packed bags	10.56	10.49	10.09	9.68	9.56	9.43	9.30	9.14	8.95
S. Em (±)	0.09	0.08	0.025	0.24	0.20	0.21	0.21	0.02	0.01
C. D. (1%)	0.40	0.36	1.06	1.00	0.86	0.90	0.88	0.09	0.04
Interaction (S x P)									
S_1P_1	10.33	10.17	9.73	9.18	8.97	8.85	8.75	8.57	0.00
S_1P_2	10.40	10.34	9.87	9.41	9.25	9.13	9.05	8.90	8.82
S_1P_3	10.46	10.38	9.92	9.50	9.40	9.20	9.08	8.92	8.84
S_1P_4	10.52	10.43	10.00	9.58	9.47	9.33	9.22	9.03	8.89
S_1P_5	10.55	10.48	10.07	9.64	9.55	9.40	9.25	9.10	8.93
S_2P_1	10.35	10.31	9.81	9.33	9.22	9.05	8.95	8.80	8.68
S_2P_2	10.42	10.37	9.91	9.47	9.37	9.17	9.08	8.90	8.83
S_2P_3	10.50	10.42	9.94	9.53	9.43	9.30	9.18	8.97	8.85
S_2P_4	10.53	10.45	10.05	9.61	9.50	9.33	9.17	9.07	8.90
S_2P_5	10.58	10.51	10.12	9.72	9.58	9.47	9.35	9.18	8.97
Mean	**10.46**	**10.39**	**9.94**	**9.50**	**9.37**	**9.22**	**9.11**	**8.94**	**7.97**
S. Em (±)	**0.13**	**0.12**	**0.36**	**0.34**	**0.29**	**0.30**	**0.29**	**0.03**	**0.01**
C. D. (1%)	**0.56**	**0.51**	**1.50**	**1.41**	**1.21**	**1.28**	**1.24**	**0.13**	**0.06**
C.V (%)	**2.25**	**2.05**	**6.30**	**6.21**	**5.41**	**5.77**	**5.69**	**0.65**	**0.33**

NS: Non-significant, Storage conditions (S): S1: *Ambient storage,* ***S2:*** *Cold storage,* ***Packaging materials (P): P1:*** *Cloth bag,* ***P2:*** *High density polythene bag,* ***P3:*** *Polythene bags (700 gauge),* ***P4:*** *Aluminum laminated pouch,* ***P5:*** *Vacuum packed bags (Initial=10.62 cm)*

Table 3. Influence of packaging material and storage conditions on root length (cm) during storage in onion seeds

Treatments	Storage (Months)								
	2	4	6	8	10	12	14	16	18
Storage conditions (S)									
S_1: Ambient	9.06	8.80	8.41	8.19	8.10	7.82	7.54	7.40	5.98
S_2: Cold	9.14	8.90	8.52	8.25	8.20	7.90	7.66	7.58	7.48
S. Em (±)	0.09	0.08	0.04	0.05	0.06	0.05	0.002	0.008	0.003
C. D. (1%)	0.41	0.33	0.19	0.24	0.26	0.21	0.008	0.03	0.01
Packaging materials (P)									
P_1: Cloth bag	8.72	8.52	8.18	7.95	7.81	7.61	7.31	7.05	3.67
P_2: High-density polythene bag	8.99	8.83	8.45	8.16	8.14	7.80	7.57	7.50	7.39
P_3: Polythene bags (700 gauge)	9.23	8.90	8.51	8.26	8.20	7.90	7.64	7.58	7.46
P_4: Aluminum laminated pouch	9.27	8.95	8.55	8.34	8.28	7.95	7.70	7.64	7.52
P_5: Vacuum packed bags	9.31	9.05	8.63	8.40	8.33	8.04	7.77	7.68	7.59

S. Em (±)	0.15	0.12	0.07	0.09	0.10	0.08	0.003	0.01	0.005
C. D. (1%)	0.65	0.52	0.30	0.39	0.42	0.33	0.01	0.05	0.02
Interaction (S x P)									
S_1P_1	8.57	8.35	7.99	7.88	7.65	7.51	7.12	6.68	0.00
S_1P_2	8.98	8.82	8.44	8.12	8.12	7.77	7.55	7.47	7.38
S_1P_3	9.21	8.88	8.49	8.25	8.18	7.88	7.61	7.56	7.45
S_1P_4	9.27	8.95	8.54	8.33	8.28	7.94	7.69	7.63	7.51
S_1P_5	9.30	9.05	8.59	8.40	8.32	8.02	7.75	7.67	7.58
S_2P_1	8.88	8.70	8.38	8.03	7.97	7.72	7.52	7.42	7.35
S_2P_2	9.00	8.85	8.46	8.22	8.17	7.85	7.60	7.53	7.41
S_2P_3	9.25	8.93	8.53	8.28	8.23	7.92	7.67	7.61	7.49
S_2P_4	9.28	8.96	8.57	8.35	8.30	7.97	7.72	7.65	7.54
S_2P_5	9.33	9.07	8.68	8.41	8.35	8.08	7.80	7.70	7.61
Mean	**9.11**	**8.85**	**8.47**	**8.23**	**8.16**	**7.86**	**7.60**	**7.49**	**6.73**
S. Em (±)	**0.22**	**0.17**	**0.10**	**0.13**	**0.14**	**0.11**	**0.004**	**0.01**	**0.07**
C. D. (1%)	**0.92**	**0.74**	**0.43**	**0.55**	**0.60**	**0.47**	**0.020**	**0.07**	**0.03**
C.V (%)	**4.23**	**3.51**	**2.12**	**2.80**	**3.08**	**2.50**	**0.11**	**0.42**	**0.19**

NS: Non-significant, Storage conditions (S): S1: *Ambient storage,* ***S2:*** *Cold storage,* ***Packaging materials (P): P1:*** *Cloth bag,* ***P2:*** *High density polythene bag,* ***P3:*** *Polythene bags (700 gauge),* ***P4:*** *Aluminum laminated pouch,* ***P5:*** *Vacuum packed bags (Initial=9.45 cm)*

Table 4. Influence of packaging material and storage conditions on seedling dry weight (mg/10 seedlings) during storage in onion seeds

Treatments	**Storage (Months)**								
	2	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**
Storage conditions (S)									
S_1: Ambient	24.26	24.02	23.83	23.70	23.23	22.92	22.60	21.90	17.16
S_2: Cold	24.51	24.26	24.05	23.88	23.38	23.08	22.93	22.19	21.34
S. Em (±)	0.08	0.09	0.08	0.11	0.13	0.12	0.13	0.06	0.03
C. D. (1%)	0.35	0.38	0.36	0.45	0.55	0.52	0.55	0.26	0.13
Packaging materials (P)									
P_1: Cloth bag	23.40	23.13	22.91	22.81	22.11	21.55	21.35	20.63	10.16
P_2: High-density polythene bag	24.03	23.81	23.65	23.60	23.13	23.01	22.68	22.05	21.19
P_3: Polythene bags (700 gauge)	24.48	24.23	24.00	23.84	23.15	23.00	22.85	22.24	21.45
P_4: Aluminum laminated pouch	24.88	24.66	24.45	24.15	23.83	23.52	23.25	22.45	21.60
P_5: Vacuum packed bags	25.13	24.86	24.65	24.55	24.28	23.90	23.68	22.85	21.86
S. Em (±)	0.13	0.14	0.13	0.017	0.20	0.19	0.20	0.09	0.05
C. D. (1%)	0.56	0.60	0.57	0.72	0.87	0.82	0.87	0.41	0.20
Interaction (PXS)									
S_1P_1	23.14	22.93	22.73	22.57	21.80	21.25	20.98	20.25	0.00
S_1P_2	23.90	23.73	23.60	23.57	23.03	22.92	22.62	22.03	21.08
S_1P_3	24.30	24.07	23.85	23.74	23.33	23.15	22.82	22.22	21.42
S_1P_4	24.87	24.60	24.37	24.12	23.78	23.47	23.17	22.33	21.55
S_1P_5	25.10	24.78	24.60	24.53	24.20	23.82	23.42	22.70	21.77
S_2P_1	23.67	23.33	23.10	23.07	22.43	21.85	21.72	21.02	20.33
S_2P_2	24.17	23.90	23.72	23.65	23.23	23.12	22.75	22.08	21.30
S_2P_3	24.67	24.40	24.17	23.95	22.98	22.85	22.90	22.27	21.48
S_2P_4	24.90	24.73	24.55	24.20	23.88	23.58	23.35	22.58	21.65
S_2P_5	25.17	24.95	24.72	24.57	24.37	24.00	23.95	23.02	21.95
Mean	**24.39**	**24.14**	**23.94**	**23.80**	**23.35**	**23.06**	**22.77**	**22.05**	**19.25**
S. Em (±)	**0.19**	**0.20**	**0.19**	**0.24**	**0.29**	**0.28**	**0.29**	**0.14**	**0.07**
C. D. (1%)	**0.80**	**0.85**	**0.80**	**1.02**	**1.23**	**1.16**	**1.23**	**0.58**	**0.29**
C.V (%)	**1.36**	**1.48**	**1.40**	**1.79**	**2.20**	**2.11**	**2.25**	**1.10**	**0.64**

Storage conditions (S): S1: *Ambient storage,* ***S2:*** *Cold storage,* ***Packaging materials (P): P1:*** *Cloth bag,* ***P2:*** *High density polythene bag,* ***P3:*** *Polythene bags (700 gauge),* ***P4:*** *Aluminum laminated pouch,* ***P5:*** *Vacuum packed bags (Initial=26.50 mg)*

Table 5. Influence of packaging material and storage conditions on seedling vigour index-II during storage in onion seeds

Treatments	Storage (Months)								
	2	4	6	8	10	12	14	16	18
Storage conditions (S)									
S_1: Ambient	2125	2046	1982	1935	1832	1678	1542	1362	1227
S_2: Cold	2165	2093	2033	1979	1906	1899	1865	1753	1682
S. Em (±)	7.68	11.08	12.56	11.03	12.36	10.90	10.35	7.34	4.19
C. D. (1%)	32.00	46.19	52.36	45.97	51.52	45.46	43.15	30.59	17.46
Packaging materials (P)									
P_1: Cloth bag	1981	1889	1753	1675	1511	1408	1256	978	774
P_2: High-density polythene bag	2090	2018	1975	1935	1820	1826	1625	1496	1398
P_3: Polythene bags (700 gauge)	2164	2094	2054	2004	1919	1852	1787	1675	1632
P_4: Aluminum laminated pouch	2212	2152	2111	2065	2021	1938	1884	1763	1688
P_5: Vacuum packed bags	2278	2196	2145	2107	2074	2018	1968	1878	1781
S. Em (±)	12.14	17.52	19.86	17.44	19.55	17.24	16.37	11.60	6.62
C. D. (1%)	50.60	73.04	82.79	72.69	81.47	71.88	68.23	48.37	27.61
Interaction (S x P)									
S_1P_1	1947	1854	1705	1617	1446	1077	811	338	0
S_1P_2	2075	1989	1939	1917	1743	1588	1431	1318	1149
S_1P_3	2147	2074	2031	1984	1909	1805	1733	1600	1588
S_1P_4	2209	2140	2100	2058	2010	1924	1834	1720	1656
S_1P_5	2250	2177	2136	2102	2057	1996	1905	1839	1746
S_2P_1	2016	1925	1802	1734	1578	1741	1701	1618	1549
S_2P_2	2106	2047	2012	1955	1897	1865	1820	1675	1647
S_2P_3	2183	2115	2078	2024	1931	1900	1842	1752	1676
S_2P_4	2216	2164	2124	2072	2034	1953	1934	1807	1721
S_2P_5	2307	2216	2154	2113	2091	2040	2032	1918	1818
Mean	**2146**	**2070**	**2008**	**1958**	**1870**	**1789**	**1704**	**1558**	**1455**
S. Em (±)	**17.17**	**24.78**	**28.09**	**24.67**	**27.64**	**24.39**	**23.15**	**16.41**	**9.37**
C. D. (1%)	**71.57**	**103.29**	**117.08**	**102.80**	**115.52**	**101.66**	**96.49**	**68.41**	**39.04**
C.V (%)	**1.39**	**2.07**	**2.42**	**2.18**	**2.56**	**2.36**	**2.35**	**1.82**	**1.12**

Storage conditions (S): S1: *Ambient storage,* ***S2:*** *Cold storage,* ***Packaging materials (P): P1:*** *Cloth bag,* ***P2:*** *High density polythene bag,* ***P3:*** *Polythene bags (700 gauge),* ***P4:*** *Aluminum laminated pouch,* ***P5:*** *Vacuum packed bags (Initial=2465)*

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