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Influence of Storage Conditions on Seed Quality and Longevity of Four Vegetable Crops

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Abstract: Seeds of four vegetable crops; carrot (*Daucus carota* L**.** cv Nantes 2-Tito), cucumber (*Cuucumis sativus* L. cv Special), onion (*Alium cepa* L. cv Red Creole) and tomato (*Lycopersicon esculentum* Mill. cv Tanshet Star) were stored under a wide range of temperature (5, 15, 25 and 35°C) and relative humidity (RH) (11.3, 22.5, 32.5, 43.2, 58.4, 75.3 and 84.3%) conditions for various storage periods (1, 3, 6, 9 and 12 months). The quality of stored seeds was tested by measuring seed germination percentage (SGP), mean germination time (MGT) and germination coefficient of velocity (GCV). Significant differences were found in (SGP), (MGT) and (GCV) in response to storage temperature, RH and among crops. Seeds stored at 5°C had the highest SGP and GCV but had the shortest MGT. However, seeds stored at 35°C had the lowest SGP and GCV and the longest MGT. RH up to 58.4% had no significant effect on SGP while higher levels of RH significantly lowered SGP and MGT. The highest RH levels (75 and 84%) showed an obvious decrease in seed quality by lowering SGP and increasing MGT. Tomato and cucumber SGP were significantly higher than that of onion and carrot seeds. Cucumber seeds had significantly the shortest MGT and highest GCV while carrot seeds had the longest MGT and lowest GCV than the other vegetable crops. These results emphasize the importance of storage temperature, relative humidity, choice of seed crop and storage period on the quality and germplasm conservation of vegetable seeds.

Key words: Storage % Temperature % Relative humidity % Vegetable seeds % Germination % Longevity % Quality

INTRODUCTION

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 [1]. Many investigators reported that the speed of decline in seed quality is largely dependent on storage temperature, relative humidity, seed moisture content, length of storage, type of seed and seed quality [2-5]. The relation between seed deterioration and moisture thermodynamic properties of seeds were examined [6]. The thermodynamic properties lead to the loss of viability and to an increase in seed leachate conductivity. Stumof *et al*. [7] tested 154 commercial seed lots of onion, stored for 1 – 10 years. They concluded that as moisture content and storage period increases, the viability equation becomes less accurate, being particularly useful up to three years. Yanping *et al*. [8] investigated the effect of storage temperature and moisture content on the vigor of Welsh onion seeds. After two years storage, the seed quality declined as storage temperature and seed moisture content increased. The effects of storage conditions on viability and vigor of onion seeds were studied [9]. They reported that a complete pattern of loss in viability could be understood on the basis of seed moisture and storage temperature and concluded that adoption of appropriate storage temperature and moisture control technique would significantly affect onion seed quality. Khaldun and Haque [10] studied the effect of temporal variation on the cucumber (*Cucumis sativus*) seed quality. They reported that the maximum germination parentage was observed when moisture contents was 10.66 and 10.95 but slightly decreased when the moisture content attained at 11.03 and 11.08, respectively. The declination

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of germinability with high moisture content is related to the hygroscopic nature of seeds, especially under worm temperatures, which in turn is associated with the relative humidity of the surrounding air [10]. After ten monthes of storage period, maximum decrease in all the seed quality parameters with higher moisture content was noticed in tomato seeds [11]. Normal carrot production required uniform and quick germination. Carrot seeds soaking in PRG increases germination percentage and decreases germination time [12].

Vegetables are widely grown in Saudi Arabia. Among the common crops are carrot, cucumber, onion and tomato. Vegetable seeds are mostly imported by agricultural companies and sold to farmers. Some farmers may use part of the seeds to grow their crops and keep the remaining for the following season. Seeds may be stored in farm storage houses in an environment that might not be suitable to preserve seed viability. There is a limited scientific data about optimal storage condition to preserve seed quality that can be used for crop production under farm condition. The average maximum and minimum relative humidity in the coastal areas of Saudi Arabia is 81 and 40%, respectively [13]. In the Central region, average RH can be as high as 48% and as low as 22%. The humid environment in the coastal areas and the dry environment in the central region along with higher temperature all have major influence on seed longevity.

The aim of this study was to determine seed quality response of four vegetable crops (tomato, cucumber, carrot and onion) stored under a wide range of temperature and relative humidity conditions for various periods. Quality parameters used in this study include seed germination percentage (SGP), mean germination time (MGT) and germination coefficient of velocity (GCV).

MATERIALS AND METHODS

Seeds of four vegetable crops; carrot (*Daucus carota* L. cv Nantes 2-Tito), cucumbe (*Cuucumis sativus* L. cv Special), onion (*Alium cepa* L. cv Red Creole) and tomato (*Lycopersicon esculentum* Mill. cv Tanshet Star); were used in this study (Table 1). Seven saturated salt solutions were prepared corresponding to a range of equilibrium relative humidity from 0.113 to 0.843. The values of the binary saturated aqueous solutions at the four storage temperatures were reported [14]. Glass desiccators containing the salt solutions were kept in controlled chambers at 5°, 15°, 25°and 35°(±0.5°C). The desiccators were tightly sealed from the outside atmosphere using high vacuum silicone grease (BDH Laboratory Supplies, England). Seeds were stored inside desiccators under combination of temperatures (5°, 15°,25°and 35°C) and relative humidity, (11.3, 22.5, 32.5, 43.2, 58.4, 75.3 and 84.3%) conditions. Seed samples were collected at 1.3.6.9 and 12 months of storage to evaluate seed quality and longevity.

Determination of Seed Quality: Prior to the initiation of seed quality laboratory tests, the initial seed status was tested (Table 1).

The extent and progress of seed deterioration were evaluated for each treatment using the following laboratory tests:

Seed Germination Percentage (SGP): Seed germination was tested on four 25 seed replicates from the 28 storage treatments of each crop. Each replicate was set to germinate at 24°C in a Petri dish (9 cm diameter) containing a germination paper to which 5 ml water had been added. Germination, judged by the appearance of the radicle, was counted daily up to 7 days. At the final count, the number of normal and abnormal seedlings produced was assessed [15]. The SGP was calculated as follows:

$$\text{SGP}(\%) = \frac{\text{number of germinated seeds}}{\text{Total seed number}} \times 100$$

Mean Germination Time (MGT): The rate of germination was calculated [16]:

$$\text{MGT} = \frac{\sum fx}{\sum x}$$

Where,

f = Number of days from the beginning of the germination test.

x = Number of seeds newly germinated on that day.

Table 1: Seeds sources, initial water activity (a_w) and initial moisture content (MC) for the four vegetable species

Species	Source Company	Initial germ. (%)	Initial a_w	Initial MC% (db)
Carrot	Nickerson - Zwaan, Barendrecht, Holland	80	0.378	4.54
Cucumber	California - Ventura, CA, USA.	95	0.383	4.38
Onion	SunSeeds, Porma, ID, USA.	84	0.274	3.21
Tomato	Genetics Int. Inc., Modesto, CA, USA.	85	0.298	2.99

a_w = water activity = *RH*/100

M.C.(db): (g H2O/g dry weight).

Germination Coefficient of Velocity (GCV): The GCV, mentioned by [17]:

$$GCV = \frac{\sum G_n}{\sum (G_n \cdot D_n)}$$

Where

G_n = Number of seeds germinated on day n.

$\sum G_n$ = Total number of germinated seed.

D_n = Days from initial planting.

Experimental Design: A randomized complete block design in split split plot system with four replications was used for germination tests. Storage temperature treatments were considered as a main plot, whereas the storage RH treatments were assigned as a sub plots. Vegetable crops were applied as a sub sub plot.

Analysis of variance and least significant differences at 5% [18] were utilized to analyze the data using SAS program [19].

RESULTS AND DISCUTION

Effect of Temperature: Seeds stored at 5°C had higher SGP and GCV values while they maintained the shortest MGT values (Table 2). On the other hand, seeds stored at 35°C had the lowest SGP (65.3) and GCV (0.233) values while they maintained the highest MGT value (4.81). The rate of seed deterioration is influenced by confounding environmental and biological factors. High temperatures during storage enhance seed deterioration as does high seed moisture content. Rao *et al*. [9] reported that medium term storage of onion seeds under tropical and sub-tropical conditions could be achieved upon desiccation of seeds to 6 ±1% seed moisture, hermetically sealed in moisture impervious containers and stored at 20–25°C. Elias and Copeland [20] reported that storage temperature of 5°C was low enough to slow down the biochemical and physiological processes which lead to seed deterioration. Lowering storage temperature progressively increased longevity of lettuce seeds [6].

Effect of Relative Humidity: There is a trend of decrease in SGP with the increase in RH (Table 3). Seeds stored at the highest RH levels (75.3% and 84.3%) had significantly the slowest MGT response (>4 days) and the lowest GCV values compared with those stored at lowest RH levels (11.3% and 22.5%). Equilibrium RH is an important factor influencing seed moisture content as indicated by their sorption isotherms [21, 22]. Rapid and uniform emergence is an important component of the definition of seed vigor. The complete loss of ability to germinate is the ultimate result of seed deterioration. However, before that state is reached, various seeds in a population lose vigor at different rates. The majority of seeds come into equilibrium between their internal moisture content and the relative humidity of the atmosphere in which they are stored. As a general rule, the life of the seed is halved for each 1% increase in moisture content of the seed [23]. The results obtained in this study agreed with other studies which reported that moisture content is the most important factor effecting seed deterioration. Ellis *et al*. [24] studied in detail the moisture contents of various seeds and their atmospheric storage humidities. When orthodox seed tissues become dried, physiological activity is reduced and resumes as the tissue is rehydrated. Low moisture content is beneficial for the storage of the seeds of most agricultural crops.

Generally, the rate of deterioration will be slow if the seeds are stored at lower relative humidity and temperature, but even so, it is almost hard to predict the accurate longevity of any particular batch of seeds when placed in storage. More moisture allows them to respire, subsequently shortening their storage life, causes spoilage through extraneous water and also by the metabolic water produced in respiration. This applies also to the great majority of seeds from dry-climate plants.

Table 2: Main effect of storage temperature on seed germination percentage, mean germination time and germination coefficient of velocity

Storage temperature (°C)	SGP (%)	MGT (day)	GCV
5	86.143 a	3.364 c	0.329 a
15	83.607 b	3.909 b	0.304 b
25	88.357 a	3.835 b	0.286 c
35	65.387 c	4.814 a	0.233 d
L.S.D. $_{0.05}$	2.347	0.0667	0.006

Means not sharing the same letter(s) within each column are significantly different at 0.05 level

Table 3: Main effect of storage humidity on Seed germination percentage, mean germination time and germination coefficient of velocity

Storage humidity (%)	SGP (%)	MGT (day)	GCV
11.3	86.81 a	3.874 c	0.290 c
22.5	88.00 a	3.886 c	0.290 c
32.8	85.75 a	3.781 d	0.299 ab
43.2	86.81 a	3.828 cd	0.295 bc
58.4	86.81 a	3.687 e	0.304 a
75.3	75.08 b	4.087 b	0.282 d
84.3	56.85 c	4.709 a	0.254 e
L.S.D $_{0.05}$	2.852	0.082	0.008

Means not sharing the same letter(s) within each column are significantly different at 0.05 level

Response of Vegetable Seeds: The SGP of tomato and cucumber seeds was significantly higher than that of onion and carrot seeds (Table 4). Cucumber seeds had significantly the shortest MGT (2.5 d) and the highest GCV among studied vegetable crops. The MGT of carrots seeds was the longest (4.8 d) followed by onion and tomato seeds.

It is apparent that, tomato and cucumber seeds were more tolerant to high temperature than onion and carrot seeds. Increasing temperature up to 35°C significantly delayed MGT and slowed GCV for all tested crops. Under any storage temperature used in this study, cucumber seeds had the shortest MGT and fastest GCV, while carrot seeds had the longest MGT and the slowest GCV (Table 5). The interaction effect of RH and type of vegetable seeds was only significant at SGP of tomato seeds (Table 6). However, the interaction was significant on MGT and CGV of all crops. For all crop seeds, the longest MGT was noticed at the highest level of RH (84.3%) which in turn delayed germination and decreased seed quality. The results of this study agreed with other results in which significant differences were found between carrot and onion seeds in germination test under different levels of storage temperature and RH [25].

Table 4: Seed germination percentage, mean germination time and germination coefficient of velocity of vegetable crops as influenced by storage conditions

Vegetable Crop	SGP (%)	MGT (day)	GCV
Tomato	85.34 a	4.223 c	0.247 b
Onion	77.80 b	4.362 b	0.237 c
Cucumber	83.84 a	2.501 d	0.432 a
Carrot	76.52 b	4.818 a	0.235 c
$L.S.D._{0.05}$	1.799	0.072	0.007

*Means not sharing the same letter(s) within each column are significantly different at 0.05 level

Table 5: Interaction effects of different storage temperatures and vegetable crops on seed germination%, mean germination time and germination coefficient of velocity

Storage temperature (°C)	Vegetable crops	SGP	MGT (day)	GCV
5	Carrot	81.86 bcd	4.63 b	0.22 gh
	Cucumber	87.14 abc	2.01 h	0.50 a
	Onion	87.29 abc	3.63 e	0.28 f
	Tomato	88.29 abc	3.20 f	0.32 e
15	Carrot	83.00 bcd	4.60 bc	0.32 e
	Cucumber	85.86 a-d	2.50 g	0.42 c
	Onion	79.86 cd	4.21 d	0.24 g
	Tomato	85.71 a-d	4.26 cd	0.24 g
25	Carrot	82.14 bcd	4.64 b	0.22 gh
	Cucumber	94.14 a	2.24 gh	0.45 b
	Onion	86.29 abc	4.21 d	0.24 g
	Tomato	90.86 ab	4.25 d	0.24 g
35	Carrot	59.09 fg	5.41 a	0.19 i
	Cucumber	68.20 ef	3.26 f	0.36 d
	Onion	57.77 g	5.40 a	0.19 i
	Tomato	76.49 de	5.18 a	0.20 hi
$L.S.D._{0.05}$		9.43	0.35	0.03

Means not sharing the same letter(s) within each column are significantly different at 0.05 level.

Table 6: Interaction effects of different vegetable crops and storage humidity on seed germination percentage, mean germination time and germination coefficient of velocity

Vegetable crops	Storage humidity (%)	SGP (%)	MGT (day)	GCV
Carrot	11.3	84.25 a	4.52 c-f	0.24 def
	22.5	89.00 a	4.64 cd	0.23 efg
	32.8	85.00 a	4.55 cde	0.25 de
	43.2	89.00 a	4.68 bc	0.25 de
	58.4	85.25 a	4.56 cde	0.24 def
	75.3	91.25 a	5.23 a	0.23 efg
	84.3	86.25 a	5.45 a	0.21 g
Cucumber	11.3	89.25 a	2.23 h	0.46 a
	22.5	84.25 a	2.23 h	0.45 a
	32.8	90.50 a	2.19 h	0.46 a
	43.2	84.50 a	2.27 h	0.45 a
	58.4	83.75 a	2.22 h	0.46 a
	75.3	81.75 a	2.59 h	0.42 b
	84.3	90.00 a	3.82 g	0.34 c
Onion	11.3	85.75 a	4.23 c-g	0.24 def
	22.5	89.75 a	4.17 efg	0.24 def
	32.8	81.75 a	4.17 efg	0.24 def
	43.2	90.50 a	4.17 efg	0.24def
	58.4	85.00 a	4.15 efg	0.25 de
	75.3	90.00 a	4.51 c-f	0.23 efg
	84.3	62.56 bc	5.13 ab	0.21 fg
Tomato	11.3	80.75 a	4.52 c-f	0.23 efg
	22.5	67.00 b	4.43 c-f	0.23 efg
	32.8	90.00 a	4.21 d-g	0.24 def
	43.2	55.85 bc	4.20 d-g	0.24 def
	58.4	54.85 bc	3.82 g	0.27 d
	75.3	51.00 c	4.05 fg	0.26 de
	84.3	65.60 b	4.34 c-f	0.26 de
$L.S.D._{0.05}$		12.47	0.46	0.04

Means not sharing the same letter(s) within each column are significantly different at 0.05 level.

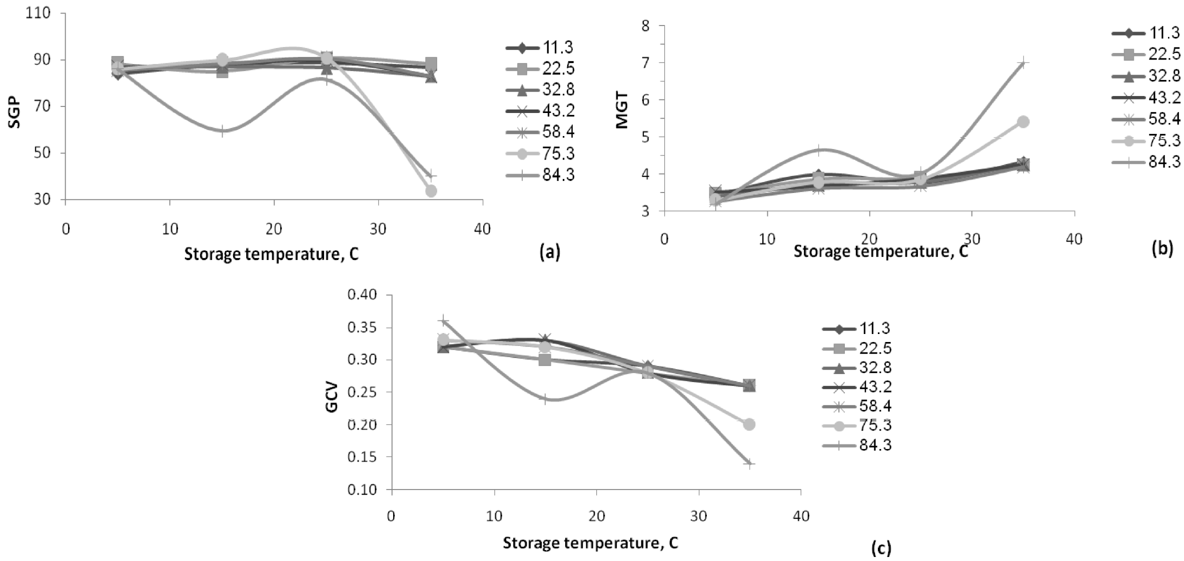

Fig. 1: Interaction effect of storage temperature and RH on (a) seed germination percentage, (b) mean germination time and (c) germination coefficient of velocity for vegetable crops stored for one month.

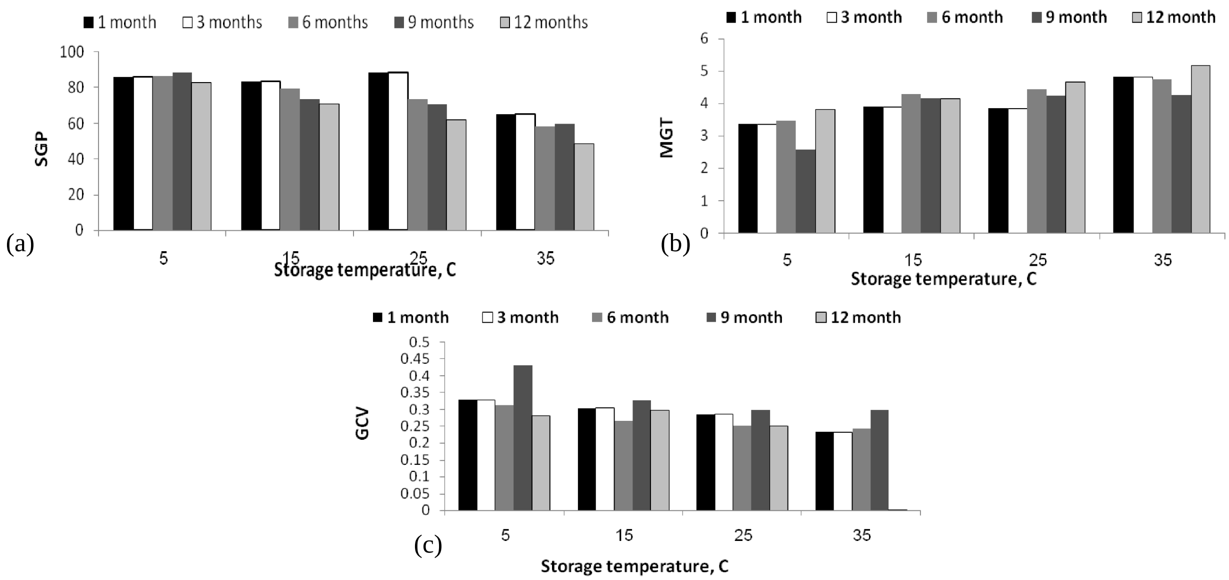

Fig. 2: Effect of storage temperature on (a) seed germination%, (b) mean germination time and (c) germination coefficient of velocity during various storage periods.ab

These variations of seed crop responses might be attributed to the differences in their chemical composition. Genes are important in determining predictable seed germination and seedling establishment in some cultivars of *Brassica oleracea* crop. Seed vigor is a quantitative character controlled by multi genes [26]. Relative effects of temperature and seed moisture content on seed longevity differ with species and the structural and biochemical composition of seeds. [9].

Influence of Storage Period: At all storage temperatures, SGP decreased with increased storage period. However, this trend was more pronounced when seeds were stored at 15°, 25°and 35°C compared to that of 5°C. The MGT was longer when seeds were stored for 12 months compared to other storage periods especially at higher temperatures (Fig. 1). Four levels of RH (11 to 43%) had no distinct influence on SGP throughout storage periods (Fig. 2). However, the highest RH level (84.3%) showed a decrease in SGP with longer storage periods.

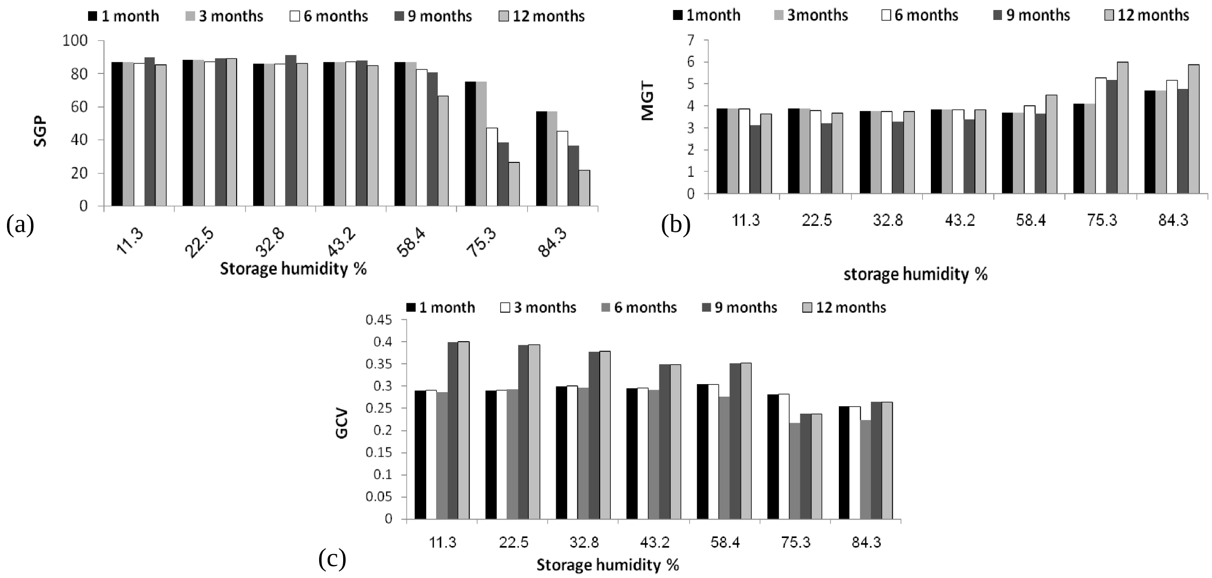

Fig. 3: Effect of storage relative humidity on (a) seed germination %, (b) mean germination time, and (c) germination coefficient of velocity during various storage periods.

Seeds stored at high RH levels (58.4% to 84.3%) revealed a clear reduction in MGT or GCV under all storage periods. There was a general decrease in SGP for all vegetable seeds when storage period was prolonged (Fig. 3). Storing vegetable seeds for one year clearly delayed MGT and slowed GCV. Similar results were reported [11], who found that, tomato seeds stored at 5°C showed high germinability throughout the entire storage period and humidity (40,60 and 80% RH) and showed a decline in germinability after 6 months at 60% RH and after 3 months at 80% RH and 25°C.

Generally, storage temperature and relative humidity are regarded as the two most important factors governing seed longevity. Cucumber seed with 12% initial moisture content were stored at 70% RH and 20°C for up to 12 months and germination percentage remained high throughout the storage period, while vigor decreased and electrolyte leakage increased from 6 months of storage [27]. Amjad and Anium [6] reported that germination percentage and rate of germination were higher in seed lots stored for one or two years compared with those stored for three or four years. Although RH of 75% is comparatively high temperature of 5°C was low enough to slow down the biochemical and physiological processes, which lead to seed deterioration [20].

CONCLUSION

Based on the results of the current study, it appears that storage temperature and RH are generally regarded as the two most important factors governing seed longevity. Storage relative humidity controls seed moisture content, thus influence their quality. Improving storage conditions could prolong seed longevity. The results emphasize the importance of storage temperature, relative humidity, seed crops and storage period on the quality and germplasm conservation of vegetable seeds.

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