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Comparison of the Effects of Different Drying Chemicals and Temperatures on Onion (*Allium cepa* L.) Seed Vigour

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Abstract Desiccant is a hygroscopic chemical that dries the surface of the seed. Silica is the most often used desiccant, and others include activated charcoal, bentonite, and zeolite. In addition, the relative humidity and temperature given to the environment by saturated salt solutions (NaCl, Silica gel, $CaCl_2$, NaOH, $MgCl_2$, KNO_3) used in controlled conditions during seed drying have different effects on this process. The aim of this study was to understand the change in viability with the drying of the seed and the quality change with the dehumidification process applied at room conditions. In this context, accelerated aging, controlled deterioration, and EC tests were carried out. The maximum germination rate was attained in the control group, and the results of the controlled deterioration and accelerated aging tests were significant for the Tan8 variety, but not for the Güntan variety. After aging and deteriorating for a while, seed germination decreased, especially in the Tan8 variety. According to the results, the Tan8 variety was significantly affected by the temperature and the type of the desiccant. In general, the drying media with $MgCl_2$ resulted in an earlier mean germination time for the controlled deterioration test after humidification. When the seedling emergence performance was evaluated, drying the seeds of the Tan8 variety more rapidly with $MgCl_2$ negatively affected the results. For both varieties, the humidification group's longest root length was measured after drying with silica gel.

Keywords Onion, Desiccant, Seed vigor, Seedling quality, Vigor tests

1. Introduction

Onion (*Allium cepa* L.) is one of the most important spices and commercial biennial vegetable crops on all continents. It is consumed as fresh onion and bulb onion mainly due to its high profitability in the cuisine, and antibacterial and curative values around the world [1]. The fundamental component of the production of agronomic and horticultural crops is using good quality and certified seeds to enhance productivity and to ensure a higher yield potential for achieving the desired goal. Many aspects determine seed quality, and one of the fundamental attributes is seed vigor which has been identified worldwide and perceived as the fast and uniform emergence of plants under a broad-ranging field conditions providing high plant performance for its association with field stand establishment and crop productivity and which has a pivotal role in the seed industry [2]. Onion seed quality is determined by environmental temperature and variation during seed production and development, seed position on the plant, timely and proper harvesting, procedures adopted for seed drying and storage, and seed priming techniques [3]. The main factors affecting storability are moisture content and storage temperature. Adverse conditions (high humidity at a high temperature) considerably result in seed deterioration during storage [4] and also accelerate the aging of the seed [2]. *Arabidopsis thaliana* [5], zinnia (*Zinnia elegans*), and lettuce (*Lactuca sativa* L.) [6] are susceptible to high humidity.

There are several methods to acquire information on seed vigor that directly or indirectly determines the tolerance of seeds to certain conditions or predicts metabolic changes or activities during seed germination, such as new knowledge gained through biotechnology, molecular biology, and seedling imaging analysis [2]. Among them, the commonly used procedures, such as accelerated aging and controlled deterioration tests, are useful for many species due to their more cost-effectiveness, speed, and simplicity of operation [7].

The term desiccation has received much attention worldwide in recent years, and is associated with low moisture contents. Although the moisture content of the seed after harvest varies according to the species, it is between 13-18% in most crops. The drying temperature needs to be lower as the seed's initial water content increases. After the water content is reduced to less than 10% by drying, the seed retains 50% or more of its original germination percentage, with some degree of tolerance. Therefore, metabolic

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activities occur during the seed desiccation phase. The permeability of cell membranes, seed viability, storage life, dormancy status and germination of dry seeds decrease as a result of oxidative stress or damage occurring in this process, and gene expression in enzyme synthesis [8]. Since warm air will negatively affect seeds' ability to germinate, seeds cannot be dried by being exposed to heated air. The alternative is to release the product's moisture into the surrounding air. The dryer can speed up the drying process by keeping the air's moisture content lower. Additionally, it eliminates weather unpredictability as a role in drying operations. Sun drying (natural drying), forced air drying (mechanical drying), and desiccants (chemical drying) are the ways used to dry seeds. The method to be applied varies according to the species. Especially chemical drying results in minimal mechanical or physiological damage to the seed. The desiccant that is used most frequently is silica, while additional options include activated charcoal, bentonite, and zeolite. Moreover, saturated salt solutions (NaCl, Silica gel, $CaCl_2$, NaOH, $MgCl_2$, KNO_3) applied under controlled conditions during seed drying have a varied impact on the relative humidity and temperature of the environment. Also, pre-germination treatments using inorganic salt solutions, such as $CaCl_2$ [9], $MgSO_4$ [10], NaCl [11], and $MgCl_2$ [12], have beneficial properties on limited seeds. The gravimetric method was used to calculate the sorption isotherm curves of a native cork at 25, 40, and 60℃. Six saturated salt solutions (KOH, $MgCl_2$, K_2CO_3, $NaNO_3$, KCl, and $BaCl_2$) were used in this approach, and it was shown that the $MgCl_2$ salt produced lower relative humidity than the others [13].

Onion seeds are difficult to store in the long term because their viability, germinability, and vigor quickly deteriorate. The goal of this study was to understand how the seed's viability changed as a result of drying and to articulate how the dehumidification procedure used in the seed's environment after drying affected germination and emergence quality. The effects of different drying chemicals on the seed viability of onion cultivars, which are widely used in Turkey, were investigated at different application temperatures.

2. Materials and Methods

This study was carried out in May/ June 2022 in the seed research laboratory of the Department of Horticulture, Agriculture Faculty, Uşak University, Turkey. The 'Tan8' and 'G*ü*ntan' varieties, the two commercial varieties of onion (*Allium cepa* L.), were purchased from Agraton seed company in Turkey and used in the experiments. The seeds (8–9% moisture content) were kept at 4 ± 1℃ in a refrigerator until starting the experiments. Moisture content (%), germination test (%), controlled deterioration, accelerated aging test, seedling emergence test (%) and electrical conductivity test (EC) (µscm-1g^{-1}) were performed for these two onion varieties. Also, we used different desiccants (silica gel and Magnesium chloride ($MgCl_2$)) at 5℃ and 30℃ for three days for allowing the seeds to dry either rapidly or slowly.

1. Seed Moisture Content (SMC) For measuring the moisture content of the seeds, 1 gram of 2 duplicated onion seeds were weighed, dried in an oven at 103℃ for 17 hours, and then placed in a desiccator for 20 minutes to cool the seeds. SMC was calculated as in Equation (1) [14]

$$\text{MC (\%)} = \frac{\text{First seed weight} - \text{Last seed weight}}{\text{First seed weight}} \times 100 \qquad (1)$$

Fsw: First seed weight

Lsw: Last seed weight

1. Germination test (%): Germination tests were performed in four replications for each of 50 seeds in both control and treated seeds. The seeds were placed in polystyrene petri dishes with a diameter of 150 ×15 mm containing a double-layer filter paper in the lower part and one layer in the upper, moistened with 3 ml of a fungicide called "Thiram", and kept in darkness at 20℃ for 12 days [15]. The seeds were considered germinated when their radicle length was 2 mm. The seeds were considered germinated when their radicle length was 2 mm.

2. Mean germination time (day): Mean germination time is calculated as in Equation (2) [16].

$$\text{MGT} = \frac{\Sigma\, \text{n.D}}{\Sigma\, \text{n}} \qquad (2)$$

MGT: Mean germination time

n: the number of germinated seeds on D. day

D: Days from the start of germination

3. Controlled deterioration: For the controlled deterioration test (CD), seed aging was conducted at 24% humidity at 45℃ for 24, 48, and 72 hours, and seed weight was calculated as in Equation (3) [17].

$$\text{Seed weight at desired moisture (g)} = \frac{\text{Frist seed weight x } (100 - \text{frist moisture content})}{(100 - \text{Desired Moisture})} \qquad (3)$$

After the aging period, germination tests were performed for each treatment in four replications of 50 seeds at 20℃ in the dark.

4. Accelerated aging test: Seeds with four replications of 50 seeds were aged at 41℃ for 24, 48, and 72 hours, at 100% relative humidity, and under dark condition [18]. After the aging period, germination tests were performed on the treated seeds at a constant 20℃ in the dark.

Figure 1. Seed germination and seedling emergence experiment process

5. Seedling emergence test (%): The test was carried out in peat medium for 21 days at 20℃ with three replications of 50 seeds in both control and treated seeds of the two onion varieties [19].

6. Electrical conductivity test (EC) ($\mu scm^{-1}g^{-1}$): In both control and aged groups, 1 g of seed with two replications was kept in 25 ml of distilled water at 20±1℃ after 24 hours, and the measurement was made in an EC meter at room temperature [20].

7. Post-imbibition drying seeds: In the drying process, the seeds were allowed to dry either rapidly or slowly at temperatures 5℃ and 30℃ over silica gel and Magnesium chloride ($MgCl_2$) for three days. During the drying process, the seeds were put in a small lace bag or mesh and laid down on 75 g of silica gel in an air-tight glass container sealed with parafilm at 5℃ and 30℃ for 72 h. For the slowing drying test, the seeds were wrapped in small mesh, and put on 75 g of $MgCl_2$ in an air-tight glass container at 5℃ and 30℃ for 72 h; then, the seeds were divided into two parts, and seed moisture content (%), germination test (%), controlled deterioration, accelerated aging test, seedling emergence test (%), and electrical conductivity test (EC) ($\mu scm\text{-}1g^{-1}$) were performed for the two onion varieties. The other part of the seeds were placed in 100% relative humidity at room temperature for one day, and then all of the above-mentioned experiments were performed.

8. Data analysis: All statistical analyses were carried out using SAS statistical software package version 9.4. The varieties were compared by the Duncan test ($P \leq 0.05$).

Abbreviations

GT	Germination Test
Cd	Controlled deterioration
AA	Accelerated aging test
$MgCl_2$	Magnesium chloride
SMC	Seed Moisture Content
h	Hour
EC	Electrical conductivity test

3. Results and Discussion

3.1. Effect of Controlled Deterioration and Accelerated Aging Tests on Germination in Onion Seeds Varieties

With the studies carried out, it was concluded that the high relative humidity between the seed coat and the surrounding air automatically increased the seed moisture. If the moisture condition of the seed is higher than the humidity in the air, the seed will lose water and become drier. If the humidity of the seed is less than the humidity of the air, the seed will receive moisture. The absorption or desorption of water continues until the water potential of the seed and the surrounding air are balanced. This condition in the seed is called equilibrium moisture content. Knowing the moisture status of seeds is very important for seed viability because seed moisture content is correlated with the rate at which seeds lose viability [21]. Vijay et al. investigated the effects of four drying methods using silica gel, lithium chloride-saturated salt solution, concentrated sulfuric acid, and desiccants on different physiological and biochemical properties of sorghum genotypes CSH 18 and CSV 18 [22], and concluded that while the faster drying rate was observed in acid and silica gel, the desiccant and saturated salt solution of lithium chloride showed slower drying rate than acid and silica gel. This study evaluated the effect of controlled deterioration and accelerated aging tests with different *duration* on the seed germination of two onion varieties. According to our results of ANOVA analysis, the effect of *different treatments and duration* on the germination percentage of the onion varieties was significant ($P \leq 0.01$) (Table 1). The seed moisture content of the onion varieties was between 8-9% (Table 2). The results of the present study showed that there was variation in responses to the controlled deterioration and accelerated aging tests between the onion varieties (Fig. 2). The controlled deterioration and accelerated aging tests were not significant on the G*ü*ntan variety, whereas they were significant on the Tan8 variety. The highest germination percentage was achieved in control conditions (Fig. 2). Seed germination decreased with aging and deteriorating duration, especially in the Tan8 variety (Fig. 2).

Table 1. The ANOVA results for final seed germination of onion varieties at different Varieties (V), Treatments (T), and their interactions

Treatment	Df	**value**P-
Varieties (V)	1	**
Treatments (T)	13	**
V×T	13	**

** Significant at $P \leq 0.01$.

Table 2. Seed moisture content and electrical conductivity value for onion varieties

Variety	Seed Moisture Content % (SMC)	EC after 24h	EC after 48h
Tan8	9.20%	0.766	0.370
G*ü*ntan	8.30%	0.365	0.370

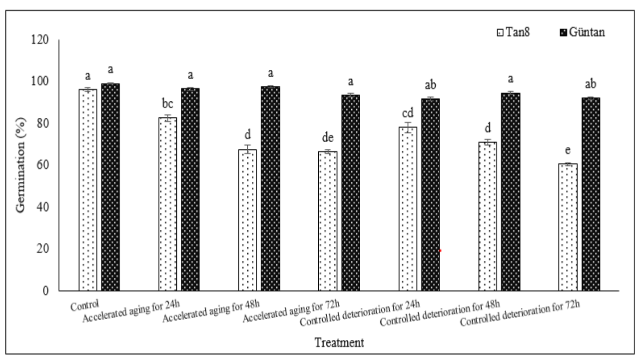

Figure 2. Tan8 and Güntan onion seed varieties germination percentage. Tan8 variety (white dotted bars), Güntan variety (black dotted bars), and different lowercase letters show means that are significantly different ($P \leq 0.05$). Error bars represent Mean ± SE

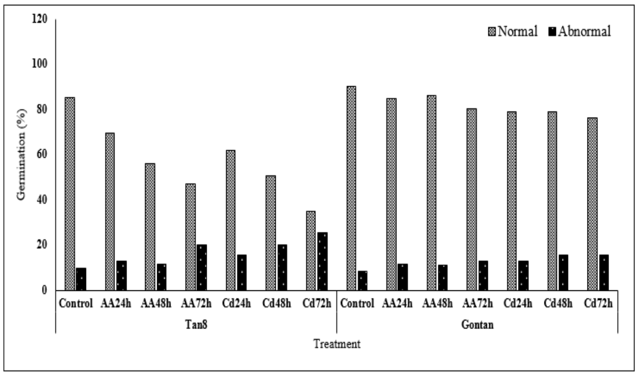

Figure 3. Normal and Abnormal seedling percentage (%)

Considering the germination results, the viability of the control groups of the varieties decreased gradually in the accelerated aging and controlled deterioration tests, especially in the Güntan variety. (Fig. 2). The abnormal seedling rates also increased as the application time of the vigor tests increased (Fig. 3).

3.2. Effect of Different Desiccants on Germination in Onion Seeds Varieties

The obtained results indicated that the effect of different desiccants and their treatment temperatures on germination was significant in the tan8 variety, that the highest germination percentage was achieved in control conditions, and that different desiccants and duration were not, however, significant in the G*ü*ntan variety (Fig. 3). The moisture of the control group decreased by 2-4% with dryers in the Tan 8 variety and by 1-3.5% in the Güntan variety (Table 3). Vodouhe (2008) [23] reported similar results using silica gel and found the lowest moisture content (3.6 to 4.6%) in *Citrullus lunatus*, (3.3 to 4.3%) in *Cucumeropsis edulis*, and (4.6 to 7%) in *Lagenaria siceraria* seeds by drying three species of Egusi seeds. The electrical conductivity test, which measures the quantity of electrolytes leached out of the seed during imbibition, is a significant indicator of seed quality that has a negative relationship with seed germination [24]. In our study, the EC values varied. The EC results of the Tan 8 variety decreased as a result of drying, while the values of the Güntan variety increased (Table 3). The electrical conductivity of the seed leachate was found to be negatively related to seed viability and vigor. In the current study, the onion seeds preserved with zeolite beads had considerably lower electrical conductivity (0.723 dSm-1) than those preserved with bentonite granules (0.778 dSm-1), charcoal granules (0.780 dSm-1) or the control [25]. Several studies evaluated the effect of seed ageing on electrolyte leakage, and found that as the ageing period increased, seed leachate of conductivity increased in muskmelon seeds [26] and tomato seeds [26]. According to [27] Penaloza and Eira (1993), this could be the outcome of membrane repair through the hydration stage in tomato seeds.

It is seen that different desiccants affect seed vigor at different levels. When the results of the accelerated aging and controlled deterioration tests of the seeds dried with these dryers were examined, it was determined that the vitality of the seeds dried with silica did not decrease much compared to the others as a result of the 72-hour test and that the vitality of the Tan 8 variety decreased the most. *Considering the results of the vigor tests applied to the Güntan seeds after drying, it was determined that the viability did not decrease, that is, drying preserved the viability under stress conditions (high temperature and humidity) (Table 4, 5). However, in general, the germination performance for both varieties was higher after drying with* $MgCl_2$.

Abnormal seedling rates are inversely proportional to the viability performance of the seed. In vigor tests, as the treatment time increases, the viability will decrease and the abnormal seedling rate will increase. In the Tan 8 variety, the seed moisture decreased after drying and in the accelerated aging test, where the proportional humidity increased uncontrollably, and the abnormal seedling rate was found to be higher as a result of the rapid increase in seed moisture. The results of Khan et al. (2004) [7] obviously demonstrated declining trends in final seed germination. The loss of germinability progressively with aging treatment was associated with incremented membrane disintegration and destruction which was a pivotal factor for seed deterioration leading to the abnormal development of the seedling [7].

While the mean germination time of the control seeds of the cultivars was between 1-1.5 days, germination was faster in the controlled deterioration test as a result of the vigor tests compared to the other test application due to the controlled decrease in viability. In general, the germination period of the seeds, whose viability decreased to a certain extent as a result of the vigor tests, was prolonged. Especially in the seeds of the Güntan variety, the moisture loss was more controlled in the groups dried with $MgCl_2$, and there was, thus, not much delay in germination (Table 6).

Table 3. Seed moisture content and electrical conductivity for onion varieties after 3 days at temperatures 5℃ and 30℃ over silica gel and Magnesium chloride ($MgCl_2$)

Variety	Treatment	Seed Moisture Content % (SMC)	EC after 24h
Tan8	Silica gel at 5℃	6.83%	0.71
	Magnesium chloride ($MgCl_2$) at 30℃	4.50%	0.53
G*ü*ntan	Silica gel at 30℃	5.56%	0.85
	Magnesium chloride ($MgCl_2$) at 5℃	8.04%	0.57

Table 4. Comparison of drying treatments effect on seed germination percentage (%) of varieties of onion after Cd test

Tan8	C	Silica gel (5℃- GT)	Silica gel (5℃- Cd 24h)	Silica gel (5℃- Cd 48h)	Silica gel (5℃- Cd 72h)
	96	86.67	76.00	61.33	54.67
	C	$MgCl_2$ (30℃- GT)	$MgCl_2$ (30℃- Cd 24h)	$MgCl_2$ (30℃- Cd 48h)	$MgCl_2$ (30℃- Cd 72h)
	96	85.33	84.00	78.67	66.67
Güntan	C	Silica gel (30℃- GT)	Silica gel (30℃- Cd 24h)	Silica gel (30℃- Cd 48h)	Silica gel (30℃- Cd 72h)
	99	100.00	90.70	96.00	90.67
	C	$MgCl_2$ (5℃- GT)	$MgCl_2$ (5℃- Cd 24h)	$MgCl_2$ (5℃- Cd 48h)	$MgCl_2$ (5℃- Cd 72h)
	99	100.00	93.33	90.67	92.00

Table 5. Comparison of drying treatments effect on seed germination percentage (%) of varieties of onion after AA test

Tan8	C	Silica gel (5℃- GT)	Silica gel (5℃- AA 24h)	Silica gel (5℃- AA 48h)	Silica gel (5℃- AA 72h)
	96	86.67	78.67	70.67	57.33
	C	$MgCl_2$ (30℃- GT)	$MgCl_2$ (30℃- AA 24h)	$MgCl_2$ (30℃- AA 48h)	$MgCl_2$ (30℃- AA 72h)
	96	85.33	77.33	70.67	18.67
Güntan	C	Silica gel (30℃- GT)	Silica gel (30℃- AA 24h)	Silica gel (30℃- AA 48h)	Silica gel (30℃- AA 72h)
	99	100.00	96.00	97.33	93.33
	C	$MgCl_2$ (5℃- GT)	$MgCl_2$ (5℃- AA 24h)	$MgCl_2$ (5℃- AA 48h)	$MgCl_2$ (5℃- AA 72h)
	99	100.00	97.33	92.00	94.67

Table 6. Comparison of drying treatments effect on mean germination time (day) of varieties of onion

Tan8	C	AA (24h)	AA (48h)	AA (72h)	Cd (24h)	Cd (48h)	Cd (72h)	
	1.1	1.33	1.86	1.78	1.37	1.12	1.00	
Güntan	C	AA (24h)	AA (48h)	AA (72h)	Cd (24h)	Cd (48h)	Cd (72h)	
	1.5	1.93	1.56	1.48	1.41	1.17	1.46	
Tan8	C	Silica gel (5℃- GT)	Silica gel (5℃- Cd 24h)	Silica gel (5℃- Cd 48h)	Silica gel (5℃- Cd 72h)	Silica gel (5℃- AA 24h)	Silica gel (5℃- AA 48h)	Silica gel (5℃- AA 72h)
	1.6	1.522	1.995	1.871	1.484	1.939	1.980	3.085
	C	$MgCl_2$ (30℃- GT)	$MgCl_2$ (30℃- Cd 24h)	$MgCl_2$ (30℃- Cd 48h)	$MgCl_2$ (30℃- Cd 72h)	$MgCl_2$ (30℃- AA 24h)	$MgCl_2$ (30℃- AA 48h)	$MgCl_2$ (30℃- AA 72h)
	1.6	1.727	1.652	1.406	2.149	2.002	1.228	2.800
Güntan	C	Silica gel (30℃- GT)	Silica gel (30℃- Cd 24h)	Silica gel (30℃- Cd 48h)	Silica gel (30℃- Cd 72h)	Silica gel (30℃- AA 24h)	Silica gel (30℃- AA 48h)	Silica gel (30℃- AA 72h)
	1.5	1.293	1.387	2.054	1.884	1.937	1.922	2.030
	C	$MgCl_2$ (5℃- GT)	$MgCl_2$ (5℃- Cd 24h)	$MgCl_2$ (5℃- Cd 48h)	$MgCl_2$ (5℃- Cd 72h)	$MgCl_2$ (5℃- AA 24h)	$MgCl_2$ (5℃- AA 48h)	$MgCl_2$ (5℃- AA 72h)
	1.5	1.613	1.806	1.589	1.520	1.872	1.689	2.876

3.3. Effect of Different Desiccants on Germination in Onion Seeds Varieties under One Day in 100% Relative Humidity at Room Temperature (RT)

After drying the seeds of the cultivars at different temperatures with different dryers, they were kept at room temperature for 1 day in 100% relative humidity for moisture balance. According to their initial moisture, the seeds were dried at a rate of 1-4%, and there was an increase in moisture of approximately 10%. However, the EC values increased due to the mobility in the seed membrane (Table 7).

According to the germination results after humidification, the condition in which the germination performance of the Tan8 variety gave better results under stress conditions was drying with silica gel (Table 8). Although the initial (control) germination rates were close to each other, some differences were determined in the performance obtained with the vigor tests after drying. [28] Nassari et al. (2014) evaluated the effects of postharvest drying of tomato (*Lycopersicon esculentum*) seeds on seed quality using desiccant zeolite. Seeds were dried under ambient conditions using zeolite beads and silica gel. In the study, seeds were dried for 96 hours with zeolite beads at 1:1 and 0.5:1 bead/seed ratios to the lowest moisture content of 4.4% and 7%. Likewise, after drying seeds for 96 hours with a 1:1 and 0.5:1 silica gel/seed ratio, the seed moisture was reduced to 7.2% and 8.4%, respectively. They concluded that the germination percentage was not significantly affected by the extent and rate of seed drying for 96 hours with the drying zeolite beads and silica gel and remained the same as that of the control [28].

Table 7. Seed moisture content and electrical conductivity for onion varieties after 3 days at temperatures 5℃ and 30℃ over silica gel desiccant and Magnesium chloride ($MgCl_2$) and then for one day in 100% relative humidity at room temperature (RT)

Variety	Treatment	Seed Moisture Content % (SMC)	EC after 24h
Tan8	Silica gel at 5℃	18.00%	0.69
	Magnesium chloride ($MgCl_2$) at 30℃	18.50%	0.71
Güntan	Silica gel at 30℃	19.50%	0.69
	Magnesium chloride ($MgCl_2$) at 5℃	16.00%	0.65

Table 8. Comparison of humidification (one day under 100% RH at RT) treatments effect on seed germination percentage (%) of varieties of onion

Tan8	C	Silica gel (5℃- GT)	Silica gel (5℃- Cd 24h)	Silica gel (5℃- Cd 48h)	Silica gel (5℃- Cd 72h)	Silica gel (5℃- AA 24h)	Silica gel (5℃- AA 48h)	Silica gel (5℃- AA 72h)
	96	90.7	92.0	88.0	74.7	86.7	70.7	61.3
	C	$MgCl_2$ (30℃- GT)	$MgCl_2$ (30℃- Cd 24h)	$MgCl_2$ (30℃- Cd 48h)	$MgCl_2$ (30℃- Cd 72h)	$MgCl_2$ (30℃- AA 24h)	$MgCl_2$ (30℃- AA 48h)	$MgCl_2$ (30℃- AA 72h)
	96	82.7	70.7	58.7	26.7	80.0	84.0	80.0
Güntan	C	Silica gel (30℃- GT)	Silica gel (30℃- Cd 24h)	Silica gel (30℃- Cd 48h)	Silica gel (30℃- Cd 72h)	Silica gel (30℃- AA 24h)	Silica gel (30℃- AA 48h)	Silica gel (30℃- AA 72h)
	99	96.0	94.7	94.7	90.7	97.3	93.3	90.7
	C	$MgCl_2$ (5℃- GT)	$MgCl_2$ (5℃- Cd 24h)	$MgCl_2$ (5℃- Cd 48h)	$MgCl_2$ (5℃- Cd 72h)	$MgCl_2$ (5℃- AA 24h)	$MgCl_2$ (5℃- AA 48h)	$MgCl_2$ (5℃- AA 72h)
	99	98.7	96.0	89.3	93.3	97.3	93.3	89.3

Table 9. Comparison of different treatment's effect on mean germination time (day) of varieties of onion

Tan8	C	AA (24h)	AA (48h)	AA (72h)	CD (24h)	CD (48h)	CD (72h)	
	1.1	1.33	1.86	1.78	1.37	1.12	1.00	
Güntan	C	AA (24h)	AA (48h)	AA (72h)	CD (24h)	CD (48h)	CD (72h)	
	1.5	1.93	1.56	1.48	1.41	1.17	1.46	
Tan8 (one day under 100% RH at RT)	C	Silica gel (5℃- GT)	Silica gel (5℃- Cd 24h)	Silica gel (5℃- Cd 48h)	Silica gel (5℃- Cd 72h)	Silica gel (5℃- AA 24h)	Silica gel (5℃- AA 48h)	Silica gel (5℃- AA 72h)
	1.4	1.281	1.950	3.324	1.900	3.556	2.776	3.186
	C	$MgCl_2$ (30℃- GT)	$MgCl_2$ (30℃- Cd 24h)	$MgCl_2$ (30℃- Cd 48h)	$MgCl_2$ (30℃- Cd 72h)	$MgCl_2$ (30℃- AA 24h)	$MgCl_2$ (30℃- AA 48h)	$MgCl_2$ (30℃- AA 72h)
	1.4	1.116	1.821	3.680	1.859	2.186	2.778	3.500
Güntan (one day under 100% RH at RT)	C	Silica gel (30℃- GT)	Silica gel (30℃- Cd 24h)	Silica gel (30℃- Cd 48h)	Silica gel (30℃- Cd 72h)	Silica gel (30℃- AA 24h)	Silica gel (30℃- AA 48h)	Silica gel (30℃- AA 72h)
	1.5	1.888	2.307	4.495	1.943	2.191	3.394	3.942
	C	$MgCl_2$ (5℃- GT)	$MgCl_2$ (5℃- Cd 24h)	$MgCl_2$ (5℃- Cd 48h)	$MgCl_2$ (5℃- Cd 72h)	$MgCl_2$ (5℃- AA 24h)	$MgCl_2$ (5℃- AA 48h)	$MgCl_2$ (5℃- AA 72h)
	1.5	1.606	2.107	4.397	2.501	1.882	3.939	3.982

In general, the mean germination time of the controlled deterioration test after humidification was earlier, which was achieved in the drying media with MgCl (Table 9). The latest germination was 48 hours in the CD test, while it differed in the AA test.

When the results were evaluated in terms of seedling emergence performance, since the seeds of the Tan8 variety were dried more with $MgCl_2$, this situation negatively affected the seedling emergence performance. On the other hand, in the Güntan variety, a higher emergence rate was determined because the seeds lost less moisture after drying (Table 10).

When the mean emergence times were compared, the best results were determined in the humidification process after drying with $MgCl_2$ in the Tan 8 variety, while all groups showed earlier emergence in the Güntan variety. However, silica gel gave good results in both uses (Table 11).

Considering the seedling length in terms of seedling quality, in the Tan8 variety, after the control group, the longest seedling was determined in the seeds that were dried with silica gel, while a longer seedling in the Güntan variety was observed in the same application compared to that of the control (16.58) (Table 12). In the study, in which the effect of drying methods on sorghum seed quality was investigated, 7-10 days of fast drying with sulfuric acid and silica gel and 19-24 days of slow drying methods with Lithium chloride and room conditions were applied. Maximum root value, shoot, seedling height and viability index were determined in seed lots dried using silica gel, a seed dryer. However, lithium chloride also functioned the same as silica gel. Acid drying is harmful and can cause physical and physiological changes in the seed by reducing the moisture content suddenly and significantly. This can ultimately lead to poor germination and higher numbers of abnormal seed production [29].

Another seedling quality criterion is root length. In this criterion, the longest value was measured in the humidification group after drying with silica gel for both varieties (Table 13).

Table 10. Comparison of different treatments effect on emergence percentage (%) of varieties of onion

Tan8		Güntan	
Control	88	Control	78.7
Silica gel (5℃)	81.33	Silica gel (30℃)	96
$MgCl_2$ (30℃)	72	$MgCl_2$ (5℃)	92
Silica gel (5℃- GT) (one day under 100% RH at RT)	80	Silica gel (30℃- GT) (one day under 100% RH at RT)	88.33
$MgCl_2$ (30℃- GT) (one day under 100% RH at RT)	70	$MgCl_2$ (5℃- GT) (one day under 100% RH at RT)	88.33

Table 11. Comparison of different treatments effect on mean emergence time (day) of varieties of onion

Tan8		Güntan	
Control	3.83	Control	2.9
Silica gel (5℃)	3.76	Silica gel (30℃)	1.43
$MgCl_2$ (30℃)	3.39	$MgCl_2$ (5℃)	2.57
Silica gel (5℃- GT) (one day under 100% RH at RT)	3.35	Silica gel (30℃- GT) (one day under 100% RH at RT)	1.78
$MgCl_2$ (30℃- GT) (one day under 100% RH at RT)	1.89	$MgCl_2$ (5℃- GT) (one day under 100% RH at RT)	3.54

Table 12. Comparison of different treatments effect on seedling length (cm) of varieties of onion

Tan8		Güntan	
Control	17.31	Control	14.43
Silica gel (5℃)	16.22	Silica gel (30℃)	16.58
$MgCl_2$ (30℃)	15.65	$MgCl_2$ (5℃)	15.68
Silica gel (5℃- GT) (one day under 100% RH at RT)	15.78	Silica gel (30℃- GT) (one day under 100% RH at RT)	16.24
$MgCl_2$ (30℃- GT) (one day under 100% RH at RT)	14.25	$MgCl_2$ (5℃- GT) (one day under 100% RH at RT)	14.89

Table 13. Comparison of different treatments effect on root length (cm) of varieties of onion

Tan8		Güntan	
Control	4.22	Control	3.29
Silica gel (5℃)	3.91	Silica gel (30℃)	4.36
$MgCl_2$ (30℃)	3.47	$MgCl_2$ (5℃)	4
Silica gel (5℃- GT) (one day under 100% RH at RT)	4.06	Silica gel (30℃- GT) (one day under 100% RH at RT)	4.6
$MgCl_2$ (30℃- GT) (one day under 100% RH at RT)	2.97	$MgCl_2$ (5℃- GT) (one day under 100% RH at RT)	3.48

4. Conclusions

There are various forms of drying methods, such as sun drying, forced air drying, modified solar drying [30], and desiccant drying [31], which have been used for drying seeds to reduce seed moisture content. Since seed is a material used for regeneration purposes, it must be dried in a manner that does not affect its germination and viability during storage. Desiccant drying in a closed container is often suggested as a low-technology method to reduce the moisture content of seed germplasm. Suitable desiccants include silica gel (sodium silicate), lithium chloride, calcium chloride, molecular sieve, charcoal, and rice that have been widely used on agricultural seeds with an appreciable success [32]. The EC value was measured to be lower in the seeds dried with magnesium; therefore, the highest germination and emergence performance was obtained from the seeds in this group in general. In the vigor tests, the effects of the drying chemicals on the seed varied according to the moisture difference to which the seed was exposed. According to the results obtained in general, magnesium chloride provided a controlled moisture reduction, which showed differences in seed viability according to the variety. However, seedling quality of seed groups dried with silica gel, which is one of the most common dryers, was better. In this respect, magnesium salt, which has a feature close to the drying efficiency of silica gel, can also be used.

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