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Changes in Germination and Quality Characteristics of Mung Bean Seeds Stored for Different Times

Farklı Sürelerde Depolanan Maş Fasulyesi Tohumlarında Çimlenme ve Kalite Özelliklerindeki Değişim

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CHANGES IN GERMINATION AND QUALITY CHARACTERISTICS OF MUNG BEAN SEEDS STORED FOR DIFFERENT TIMES

ABSTRACT

Maintaining seed quality during long-term storage of plant genetic resources is crucial to avert projected food crises linked to a changing climate and a growing world population. However, seed viability caused by senescence during storage remains an unavoidable process that jeopardizes productivity in some traditional seed crop species. Therefore, this study aimed to determine the change in germination and quality characteristics of mung bean seeds stored under the same storage conditions for different periods of time. In the study, mung bean seeds numbered 02G05, 07A05 and 07G04 were used as seed material and stored under the same temperature and humidity conditions for 36, 48, 60, 72 and 96 months. In the study, germination rate, germination index, moisture content, water absorption capacity and water absorption index of mung bean seeds decreased as the storage period increased, while mean germination time, electrical conductivity, cooking time and dry matter loss during cooking increased. In the study, seeds of mung bean genotypes stored for 36 months showed better germination rate and germination index, followed by seeds stored for 48 and 60 months and significant decreases were determined in the following months. 02G05 genotype stood out in terms of germination characteristics and some quality characteristics and was the least affected by the prolonged storage period. In the study, the highest and positive correlation was determined between cooking time and dry matter loss during cooking, while the lowest negative correlation was determined between moisture content and electrical conductivity and between water absorption capacity and cooking time. As a result, it can be suggested that mung bean seeds can be stored for 60 months for germination characteristics and 36 months for quality characteristics without causing any negativity, but after these months, storage can be terminated as negativity in germination and quality characteristics will begin.

Keywords: Mung Bean, Storage, Germination, Cooking Time, Water Absorption Capacity.

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FARKLI SÜRELERDE DEPOLANAN MAŞ FASULYESİ TOHUMLARINDA ÇİMLENME VE KALİTE ÖZELLİKLERİNDEKİ DEĞİŞİM

ÖZ

Bitki genetik kaynaklarının uzun süreli depolanması sırasında tohum kalitesinin korunması, değişen iklim ve artan dünya nüfusu ile bağlantılı öngörülen gıda krizlerini önlemek için çok önemlidir. Bununla birlikte, depolama sırasında yaşlanmanın neden olduğu tohum canlılığı, bazı geleneksel tohumlu mahsul türlerinde üretkenliği tehlikeye atan kaçınılmaz bir süreç olmaya devam etmektedir. Bu nedenle çalışmada farklı sürelerde aynı depo şartlarında depolanmış maş fasulyesi tohumlarının çimlenme ve kalite özelliklerindeki değişim belirlenmesi amaçlanmıştır. Çalışmada 02G05, 07A05 ve 07G04 nolu maş fasulyesi tohumları tohum materyali olarak kullanılarak, 36, 48, 60, 72 ve 96 ay boyunca aynı sıcaklık ve nem şartlarında depolanmıştır. Çalışmada depolama süresi artıkça maş fasulyesi tohumlarının çimlenme oranı, çimlenme indeksi, nem oranı, su alma kapasitesi ve su alma indeksi azalmış, ortalama çimlenme süresi, elektriksel iletkenlik, pişme süresi ve pişmede kuru madde kaybı artmıştır. Çalışmada 36 ay depolanan maş fasulyesi genotiplerinin tohumları daha iyi çimlenme oranı ve çimlenme indeksi göstermiş bunu 48 ve 60 ay depolanan tohumlar takip etmiş ve daha sonraki aylarda önemli azalmalar belirlenmiştir. 02G05 genotipi çimlenme özellikleri ve bazı kalite özellikleri yönünden ön plana çıkmış, depolama süresinin uzamasından en az etkilenen maş fasulyesi genotipi olmuştur. Çalışmada özellikler arasında en yüksek ve pozitif korelasyon pişme süresi ile pişmede kuru madde kaybında; en düşük negatif korelasyon ise nem oranı ile elektriksel iletkenlik arasında ve su alma kapasitesi ile pişme süresi arasında belirlenmiştir. Sonuç olarak maş fasulyesi tohumlarını çimlenme özelliklerinde 60 ay; kalite özelliklerinde 36 ay boyunca depolanması herhangi bir olumsuzluğa sebep olmadan depolayabileceğini, bu aylardan sonra çimlenme ve kalite özelliklerinde olumsuzluklar başlayacağından depolamayı sonlandırmaları önerilebilir.

Anahtar Kelimeler: Maş Fasulyesi, Depolama, Çimlenme, Pişme Süresi, Su Alma Kapasitesi.

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1. INTRODUCTION

Given the increasing global demand for food today, it is crucial to ensure the conservation of plant genetic resources for future food production (Hoban et al., 2013; Jacoban et al., 2013). By 2050, it is estimated that more than one billion people will be added to the world population (WPP, 2023). Therefore, the food security problem will worsen with the increasing impact of hunger and poverty, especially in developing countries. The importance of seeds is increasing day by day to prevent food crises that may occur in the coming years. Seeds, which account for more than 80% of human nutrition (FAO, 2023), are important for biodiversity conservation as well as for economic aspects of trade and storage-related agricultural activities (Adetunji et al., 2021).

Although the lifespan of seeds varies according to plant species, they can generally remain viable for a period ranging from weeks to thousands of years. Seed senescence is as the loss of seed quality and viability over time (El-Maarouf-Bouteau, 2022). Various factors such as climatic conditions during seed production, moisture content, mechanical damages, storage time, relative humidity of the storage, diseases and pests affect the viability of seeds (Krishnan et al., 2003; Marshall and Lewis, 2004). During the aging of seeds, all physiological events of the cells are damaged, and the cells lose their functions and die. Physiological symptoms of seed deterioration include decreases in enzyme activity and respiration, and increases in the amount of leachate (electrolytes) and free fatty acids in seed soaking water (Copeland and McDonald, 2001). In addition, poor germination, abnormal seedling formation or non-germination are observed in old seeds. Seed vigour and viability decrease moderately in the early stages of storage, followed by a sharp decline and finally a gradual decrease in viability (Shaban, 2013). On the other hand, farmers keep harvested seeds in stock for months or even years before selling them or planting the next crop. Rapid seed aging and deterioration during storage is one of the major problems faced by farmers (Chan and Mohd, 2019). Rao et al. (2017) stated that under the same storage conditions, seeds of different genera, species, varieties or single plants often show differences in their storability. For these reasons, it is of great importance to determine how long the seeds of different plant species and varieties can be stored.

Mung bean is an important legume consumed all over the world, especially in Asian countries (Hou et al., 2019), and its production and consumption are increasing day by day in our country (Karaman and Türkay, 2022). It is known to be an excellent source of protein, dietary fiber, minerals, vitamins, and significant amounts of bioactive compounds including polyphenols, polysaccharides, and peptides (Gan et al., 2017; Hou et al., 2019), and its popularity as a functional food for improving health is increasing. Therefore, it is of great importance to determine the effect of aging on mung bean seed viability. Indeed, this could improve the storability and increase the productivity of mung bean seeds, thereby benefiting producers and national economies. In this study, it was aimed to determine the changes in germination and some quality characteristics of mung bean genotypes stored under the same temperature and humidity conditions in different years in order to maintain seed quality.

2. MATERIALS AND METHOD

Mung bean seeds obtained from Adıyaman (02 G 05; Gerger) and Antalya (07 A 05; Alanya and 07 G 01; Gazipaşa) provinces were used as seed material in the study (Karaman, 2019). The seeds used in the study were collected by survey study and grown in the same way every year and harvested in the first week of October. The seeds were then kept in storage at the same temperature and humidity (5°C and < 40% relative humidity). Palabıyık (2006) found that storage of bean seeds at +4 °C for up to 32 months did not have a negative effect on seed germination and field emergence rates, but if they were stored for longer periods such as 44 months, they suffered significant loss of viability. Considering these conditions, the storage period was started from the 36th month. In the study, the storage period started in October 2015 after harvesting in 2015 and ended in October 2022. Seeds were stored in the warehouse for 36, 48, 60, 72 and 96 months. The study was established according to the completely randomized design with 3 replications.

For each of the genotypes used in study, a total of 6000 seeds were stored, 2000 seeds per replicate. At the end of storage, 50 seeds for each replicate were left to germinate for 7 days at 20±1 °C according to ISTA (2012) rules for mung bean [*Vigna radiata* (L.) Wilzeck = *Phaseolus aureus* L.] paper seeds. During this period, seeds with rootlets reaching 2 mm in length every day were considered germinated (Murillo-Amador et al., 2002; Karaman and Kaya, 2017). When the germination period was completed (at the end of the 7th day), the number of germinated seeds was proportioned to the total number of seeds and multiplied by 100 to determine the germination rate. The germination index (Wang et al., 2004) was calculated by dividing the germinated seed rate by the number of counting days, and mean germination time (Ellis and Robert, 1980) was calculated by multiplying the number of germinated seeds per day by the number of germination days and dividing the sum by the total number of germinated seeds. While determining germination index and mean germination time, seeds were counted every day and the day when germination stabilized was determined as the last day of counting.

From the stored mung bean seeds, 1000 seeds for each replicate were weighed with a precision balance (M1) and the samples were placed in an oven at 105°C until the weight was fixed (17±1 hours) and moisture loss was ensured. The weights (M2) of the dehumidified samples were determined again. After these weights were determined, seed moisture content was determined according to the following formula (Eq.1) (ISTA, 1993).

$$\text{Moisture content} = [(M1-M2)/M1]*100 \qquad \text{(Eq.1)}$$

The weights of 100 seeds for each genotype were taken from the stored seeds, then the seeds were placed in a 250 ml beaker and 150 ml of distilled water was added. The beakers were sealed and kept at room temperature for 16 hours. At the end of the period, the seeds in the beaker were drained and the excess water was removed with blotting paper. The seeds obtained were weighed and their wet weights were determined (Şehirali and Atlı, 1993). After separating the hard-shelled grains that were not swollen in the seeds whose wet weights were determined, the water absorption capacity (g/grain) of the weighed seeds was determined according to the following formulas (Eq.2; Eq.3).

$$\text{Water absorption capacity} = (Y-(X-(X/100) \times N2))/(N1 - N2) \qquad \text{(Eq.2)}$$

Y = Wet weight after separation of non-swelling grains, X = Dry 100 grain weight, N1= Initial number of grains, N2= Number of non-swelling hard-shelled grains.

If there are no non-swelling grains;

$$\text{Water absorption capacity} = (\text{Wet weight} - \text{Dry weight})/100 \qquad \text{(Eq.3)}$$

The water absorption index was calculated by dividing the water absorption capacity by the single grain weight (Eq.4). The value calculated for each sample indicated the number of times a grain would take up water compared to its original weight.

$$\text{Water absorption index} = [(\text{Water absorption capacity})/(\text{Grain weight (Dry weight}/100))] \qquad \text{(Eq.4)}$$

The seeds whose wet weights were determined were thrown into boiling water and the cooking time was calculated when the white spot on the cotyledons disappeared by checking every three minutes (Karayel, 2012). The cooked seeds were filtered after cooling and the cooking water was diluted to 200 ml with distilled water. 25 ml of the diluted cooking water was taken and placed in beakers. They were dried in an oven at 105°C until they stabilized and weighed with a precision balance (SA). The weighed seeds were proportioned to their weight before cooking (BS) and dry matter loss on cooking was determined according to the following formula (Eq.5) (Black et al., 1998).

$$\text{Dry matter loss on cooking (\%)} = [SA/(BA/\text{Number of seeds})*100] \qquad \text{(Eq.5)}$$

Among the stored seeds, 300 seeds were weighed and kept in pure water in a sealed jar for 24 hours. The electrical conductivity of pure water was determined before the seeds were added (EC1). At the end of the specified time, the seeds were removed and the amount of electrolyte leakage (EC2) of the remaining water was substituted in the following formula (Eq.6) and the electrical conductivity values of the seed batches were determined as µS/cm/g (Kulan, 2018).

Electrical conductivity (EC) (µS/cm/g)=[EC2-EC1)/Initial seed weight] (Eq.6)

The data obtained from the study were analyzed using the MINITAB statistical package program according to the completely randomized design. Tukey comparison test was used to determine the differences between storage periods and genotypes. In order to determine the relationship between the traits examined in the study, a heat map of the correlation analysis was created using the plot.corr_coef package program in the R program (RStudio 4.1.2).

3. RESULT AND DISCUSSION

3.1. Results

In the study, the seeds of mung bean genotypes were stored for different periods of time, and when the data obtained as a result were analyzed, genotypes were found to be statistically significant in germination rate, water absorption capacity, water absorption index, electrical conductivity, cooking time, dry matter loss during cooking; storage time was found to be statistically significant in all examined traits; genotype x storage time interaction was found to be statistically significant in moisture content, water absorption capacity, electrical conductivity and dry matter loss during cooking traits (Table 1; 2).

Germination rate, which is one of the main indicators of seed viability, was highest in 02G05 and lowest in 07G01 genotypes. It was determined that there was no statistical difference between 02G05 with 98.15% germination rate and 07A05 genotypes with 97.60% germination rate. In terms of the storage period, the highest germination rate was 100% in 36 months storage and the lowest germination rate was 93.78% in 96 months of storage. It was determined that there was no statistical difference between 36, 48 and 60 months storage periods. Although the genotype x storage period interaction was insignificant, the germination rate generally decreased as the storage period increased (Table 1). Although there was no statistical difference between the genotypes in the germination index, the highest value was determined in the 07G01 genotype. The highest germination index was 23.67 at 36 months and the lowest was 19.11 at 96 months. It was determined that there was no statistical difference between 36, 48 and 60 months, in the storage period germination rate (Table 1). When the storage period was taken into consideration in mean germination time, it varied between 0.73-0.95 days. The fastest germination was found in seeds stored for 36 months, and the latest germination was found in seeds stored for 96 months. In the study, no difference was observed in germination times when the seeds were stored for 36, 48 and 60 months. In general, mean germination time was lowest in the seeds stored for the least time and highest in the seeds stored for the longest time (Table 1).

Table 1. Mean values of germination characteristics and moisture content of mung bean genotypes stored for different times

Application		Germination Rate (%)	Germination Index (%)	Mean Germination Time (Day)	Moisture Rate (%)*
Genotypes					
02G05		98.13 a	21.60	0.86	7.98
07A05		97.60 a	21.27	0.85	8.17
07G01		95.47 b	22.43	0.81	7.83
F-value /MS		5.85**'29.87'	2.12 ns/5.42	1.05 ns/0.01	1.78 ns/0.44
Storage Times (months)					
36		100 a	23.67 a	0.73 b	8.96 a
48		98.22 ab	23.17 a	0.77 b	8.27 b
60		97.33 ab	22.67 a	0.85 ab	8.05 b
72		96.00 bc	20.22 b	0.91 a	7.66 bc
96		93.78 c	19.11 b	0.95 a	7.01 c
F-value/MS		9.68**/49.42	13.91**/35.89	7.72**/0.08	19.29**/4.72
Interactions					
02G05	**36**	100.00	23.50	0.73	8.82 ab
	48	100.00	23.00	0.79	8.46 ab
	60	97.33	23.33	0.92	8.09 a-c
	72	97.33	19.83	0.93	7.57 b-d
	96	93.33	18.33	0.94	6.95 cd
07A05	**36**	100.00	23.50	0.86	8.48 ab
	48	96.00	22.83	0.78	8.37 abc
	60	96.00	21.50	0.76	8.21 abc
	72	93.33	19.50	0.91	7.90 bc
	96	92.00	19.00	0.94	7.90 bc
07G01	**36**	100.00	24.00	0.60	9.59 a
	48	98.67	23.67	0.73	7.97 bc
	60	98.67	23.17	0.87	7.86 bc
	72	97.33	21.33	0.91	7.53 bcd
	96	96.00	20.00	0.96	6.17 d
F-value /MS		0.80 ns/4.09	0.34ns/0.87	1.69 ns/0.02	3.24*/0.79

* The difference between the means in the same column and starting with the same letter was statistically insignificant according to the Tukey–HSD test ($P<0.05$). MS: Mean Square

The moisture content of the seeds of different genotypes decreased by 27.8% with the increase in storage period. The highest moisture content was determined in seeds stored for 36 months, and the lowest moisture content was determined in seeds stored for 96 months. When the genotype x storage period interaction was examined, the highest moisture content was determined in the seeds of genotype 07G01 stored for 36 months with 9.59% and the lowest was determined in the seeds of the same genotype stored for 96 months (6.17%) (Table 1).

It is very important to determine the water absorption characteristics during aging of seeds. The mean water absorption capacity and water absorption index of mung bean genotypes aged for different periods varied between 0.031.0.070 g/grain and 1.23-1.55, respectively. The highest value in water absorption capacity was determined in genotype 07G01, while the highest value in water absorption index was determined in genotypes 02G05 and 07G01. The smallest value in water absorption capacity and water absorption index was determined in genotype 07A05. The water absorption properties (water absorption capacity and index) generally decreased with the extension of the storage period (Table 2).

As a matter of fact, the highest water absorption capacity and index were determined in seeds at the end of 36th month and the lowest in seeds at the end of 96th month. However, the highest value in water absorption capacity was found in the seeds of genotype 02G05 at the end of 36th month and the lowest value was found in the seeds of genotype 07A05 at the end of 96th month (Table 2).

Electrical conductivity, which is a measure of seed quality, varied between 98.56-108.02 µS/cm/g according to mung bean genotypes, with the highest mean electrical conductivity in genotype 02G05, followed by genotypes 07G01 and 02G05. The electrical conductivity values of mung bean seeds varied between 49.62-128.07 µS/cm/g according to the storage period and the electrical conductivity values increased with the extension of the storage period (Table 2).

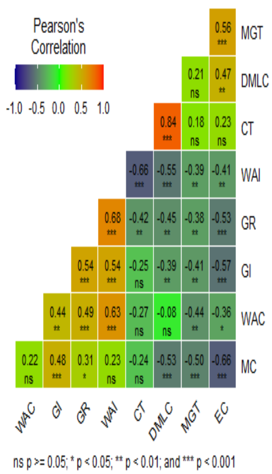
Cooking time of legumes is one of the quality criteria and it was determined that the cooking time of mung bean genotypes varied between 10.4-18.8 min. The shortest cooking time was 02G05 genotype and the longest cooking time was 07A05 genotype. The cooking time also increased with the prolongation of the storage period. As a matter of fact, the shortest cooking time was determined at 36th month and the longest cooking time was determined in mung bean seeds stored for 96th months. On the other hand, dry matter loss during cooking showed similar results to cooking time, with the lowest dry matter loss during cooking in genotype 02G05 (2.69%) and the highest value in genotype 07G01 (4.70%). Dry matter loss during cooking varied between 2.80-4.93% according to the storage periods, and an increase in dry matter loss during cooking was observed with increasing storage period (Table 2).

Table 2. Means of quality characteristics of mung bean genotypes stored for different times

Application		Water Absorption Capacity (g/grain)	Water Absorption Index	Electrical Conductivity (µS/cm/g)	Cooking Time (min)	Dry Matter Loss During Cooking (%)
Genotypes						
02G05		0.051 b	1.55 a	108.02 a	10.4 c	2.69 c
07A05		0.031 c	1.23 b	98.56 b	18.8 a	4.19 b
07G01		0.070 a	1.50 a	103.82 ab	17.4 b	4.70 a
F-value/MS		404.26**/0.01	44.24**/0.45	6.04**/337.15	300.93**/303.8	115.60**/16.4
Storage Times (months)						
36		0.071 a	1.61 a	49.62 d	13.33 d	2.80 d
48		0.052 b	1.54 ab	99.37 c	14.33 cd	3.61 c
60		0.046 c	1.44 bc	115.99 b	15.67 bc	3.78 bc
72		0.042 cd	1.32 cd	124.29 ab	16.00 b	4.16 b
96		0.041 d	1.24 d	128.07 a	18.33 a	4.93 a
F-value/MS		96.22**/0.00	20.39**/0.21	165.66**/9251.6	32.00**/32.3	38.70**/5.49
Interactions						
02G05	**36**	0.095 a	1.72	68.49 e	9	2.10 f
	48	0.044 d	1.63	89.43 de	10	2.20 f
	60	0.042 de	1.52	114.05 abc	10	2.23 f
	72	0.037 def	1.51	132.29 a	11	2.90 def
	96	0.036 dfg	1.39	135.85 a	12	4.00 bcd
07A05	**36**	0.035 dfg	1.47	40.62 f	16	2.80 ef
	48	0.035 dfg	1.44	101.19 cd	18	4.07 bc
	60	0.031 efg	1.26	113.61 abc	19	4.47 bc
	72	0.028 fg	1.01	117.27 abc	19	4.72 b
	96	0.026 g	0.97	120.11 abc	22	4.88 ab
07G01	**36**	0.083 b	1.63	39.75 f	15	3.49 cde
	48	0.080 b	1.55	107.51 bcd	15	4.56 bc
	60	0.061 c	1.53	120.29 abc	18	4.65 b
	72	0.061 c	1.43	123.30 abc	18	4.86 ab
	96	0.061 c	1.35	128.26 ab	21	5.93 a
F-value/MS		30.83**/0.00	1.77 ns/0.02	5.00**/279.12	2.28ns/2.30	2.69*/0.38

* The difference between the means in the same column and starting with the same letter was statistically insignificant according to the Tukey–HSD test (P<0.05). MS: Mean Square.

The heat map of the correlation coefficients of the correlations between the traits examined in the study is given in Figure 1. The highest and positive correlation was determined between cooking time and dry matter loss during cooking (0.84***); the lowest negative correlation was determined between moisture content and electrical conductivity (-0.66***) and water absorption index and cooking time (-0.66***). A positive and significant correlation was found between moisture content and germination rate and germination index, while a negative and significant correlation was found between electrical conductivity, mean germination time and dry matter loss during cooking. There was a positive and significant relationship between water absorption capacity and water absorption index, germination rate and germination index, and a negative and significant relationship with electrical conductivity and mean germination time. There was a positive and significant relationship between germination index and water absorption index, germination rate, moisture content, water absorption capacity and negative and insignificant relationship with cooking time. There was a positive and significant relationship between germination rate and water absorption index, and a negative and significant relationship with electrical conductivity, mean germination time, dry matter loss during cooking, and cooking time. A negative and significant relationship was determined between water absorption index and electrical conductivity, mean germination time, dry matter loss during cooking and cooking time There was a positive and significant relationship between electrical conductivity and dry matter loss during cooking and mean germination time.



GR: Germination rate; GI: Germination Index; MGT: Mean Germination Time; MC: Moisture Content; WAC: Water Absorption Capacity; WAI: Water Absorption Index; EC: Electrical Conductivity; CT: Cooking Time; DMLC: Dry Matter Loss in Cooking

Figure 1. Heat map of the correlation coefficients between the properties examined in the study

3.2. Discussion

In this study, the changes in germination and some quality characteristics of mung bean genotypes stored under the same temperature and humidity conditions in different years were determined. Significant differences were determined in germination characteristics (germination rate, germination index, mean germination time), which is one of the best indicators of seed viability, according to the storage period. The germination rate and germination index decreased and the mean germination time increased with increasing storage time (Table 1). In addition, there was a positive and significant correlation between germination rate and germination index and water absorption characteristics (water absorption capacity and index) (Figure 1). Among the genotypes, statistical differences were determined only in germination rate. Indeed, genotypes 02 G 05 and 07 A 05 maintained their viability more than the seeds of genotype 07G01 during the storage period. This shows the negative effect of storage time on germination and it was concluded that it may differ according to mung bean genotypes (Table 1). Indeed, Rao et al. (2017) stated that the storability of seeds of different genera, species, varieties or individual plants stored in warehouses with the same storage conditions varies.

During storage, germination, which is one of the most important factors for evaluating seed quality, decreases even before the loss of quality and quantity of stored seeds is detected (Jian, 2022). In addition, after the physiological maturity period, which is the highest level of seed germination power and emergence performance in the field, the seeds begin to age depending on the environmental conditions. Then the germination power of the seed weakens and finally the seed loses its viability (İlbi and Geren, 2005; Palabıyık, 2006). In addition, Rajjou and Debeaujon (2008) reported that seeds that deteriorate during storage lose their strength and become more susceptible to stress during germination. Garoma et al. (2017) stated that maize seeds produced and stored for less than one year show better germination and emergence and this is also shown in the second years, but this varies according to maize lines and storage time. The researchers also reported that longer seed storage delayed the mean germination time, as well as decreased the germination index and seedling characteristics. Tatić et al. (2008) stored soybean varieties for 6 and 12 months (under normal and controlled conditions) and found that the germination rate decreased with increasing storage time and this difference varied according to varieties and storage conditions. However, many researchers (Basra et al., 2003; Verma et al., 2003; Mrđa et al., 2010) stated that the germination and emergence rate of seeds decreased with increasing storage time and this supports the findings of this study.

In the study, the moisture content of the seeds decreased with the extension of the storage period, the highest moisture content was determined in seeds of genotype 07 G 01 stored for 36 months and the lowest moisture content was determined in seeds of the same genotype stored for 96 months. The aging rate of seeds is strongly influenced by environmental and genetic factors such as storage temperature, seed moisture content and seed quality (Walters et al., 2005). For stored cereal seeds, a decrease in moisture content or temperature is known to increase viability and hence safe storage time. However, even different varieties of seeds under the same storage conditions may have different moisture contents and therefore different germination and storage times. Cortelazzo et al. (2017) found that the moisture content of freshly harvested bean seeds stored in a refrigerator at 8 °C for 12 years was 6.5±0.3% and they had lower moisture content than freshly harvested seeds (12.9±1.2%). Similar to the findings of this study, many researchers (Berjak and Pammenter, 2008; Parkhey et al., 2014) reported that the moisture content of seeds decreased with the prolongation of storage time in different plant species.

During the storage of edible grain legumes, determination of water absorption capacity, water absorption index, electrical conductivity, cooking time and dry matter loss during cooking is important for determining the germination power and quality losses of seeds. In this study, water absorption capacity and water absorption index properties decreased, while electrical conductivity, cooking time and dry matter loss during cooking properties increased with increasing storage time. On the other hand, among the mung bean genotypes stored for different periods, genotype 02G05 stood out in terms of the quality criteria (except water absorption capacity) (Table 2). As a matter of fact, as a result of the decrease in water absorption properties and increase in electrical conductivity values with the prolongation of the storage period, germination rate and germination index decreased and the mean germination time was prolonged (Table 1; 2).

In addition, there was a negative and significant correlation between water absorption characteristics and electrical conductivity (Figure 1), which supports the other findings of the study (Table 1; 2). Singh et al. (2010) stated that the differences in hydration properties varied depending on the permeability of the seed coat and softer cotyledons. In this direction, it can be concluded that the permeability of the seed coat of mung bean seeds decreases with increasing storage time and this difference varies according to genotypes.

Seeds with high water absorption have higher electrical conductivity values because they secrete more cell solution (Palabıyık, 2006). As a matter of fact, in this study, the electrical conductivity values of the varieties with high water absorption were also high (Table 2). Electrical conductivity values are an indicator of seed secretion and are similar to water absorption rates of varieties (Kantar and Güvenç, 1995). Electrical conductivity and tetrazolium tests are defined as tests that determine seed quality more quickly and accurately and give more reliable results than germination tests (Kolasinska et al., 2000). Palabıyık (2006), in the study in which he stored bean varieties for different periods of time, stated that the electrical conductivity value increased with the increase in storage time, while the germination rate decreased. As in the findings of this study, electrical conductivity decreases with increasing storage time in different plant species (Singh et al., 2015; Brar et al., 2019).

The cooking time of mung beans is one of the main factors affecting the ease and prevalence of consumption. The cooking time for mung bean grains ranges from 14-60 minutes (Dahiya et al., 2015) and has been attributed to the phenomenon of "hard cooking", which is related to variety and storage conditions and storage time (Rodriguez and Mendoza, 1990). This has been attributed to the development of tissues that are difficult to cook. This leads to hardening of the bean cotyledon and although the beans are able to absorb water properly, it prevents the beans from softening and prolongs the cooking time (Shiga et al., 2004; Shiga and Lajolo, 2006). On the other hand, due to the long cooking time of legumes, the nutritional value of their proteins decreases (Bishnoi and Khetarpaul, 1993), thus the essential amino acid content decreases (Chau et al., 1997). Since an important nutrient passes into water during cooking, low dry matter loss is desired (Çulha and Bozoğlu, 2017). As a matter of fact, in this study, mung bean showed significant differences according to the varieties and storage time, and dry matter loss in cooking increased as the storage time increased. However, it was determined that there was a positive and significant relationship between cooking time and dry matter loss during cooking (Figure 1). These reasons are due to the prolonged cooking time of mung bean seeds during storage (Table 2).

4. CONCLUSION

Quality losses occur in many processes throughout the viability of the seed. In agricultural production, seeds should be stored without losing their viability and germination power or with minimum loss. As a matter of fact, the study revealed significant differences in germination and quality characteristics of mung bean genotypes stored for different periods. In this study, seeds of mung bean genotypes stored for less than 36 months showed better germination rate and germination index, followed by seeds stored for 48 and 60 months. Genotype 02 G 05 stood out in terms of germination characteristics and some quality characteristics and was the least affected by storage periods. In addition, germination rate, germination index, moisture content, water absorption capacity and water absorption index of mung bean seeds decreased, while mean germination time, electrical conductivity, cooking time and dry matter loss during cooking increased as storage time increased. Since farmers need high quality seed that ensures germination of a high percentage and uniformity of seedlings under the required conditions, agricultural seed quality traits have a direct impact on seed quality. For this reason, it can be recommended that farmers can store mung bean seeds for 36 months without causing any negativity in germination characteristics, but after this month, storage should be terminated as negativity in germination and quality characteristics will start from the 60th month.

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Conflict of Interest

The author declare that there is no conflict of interest.

Ethics

This study does not require ethics committee approval.

Author Contribution Rates

Design of Study: RK (%80), CT (%20)

Data Acquisition: RK (%60), CT (%40)

Data Analysis: RK (%80), CT (%20)

Writing up: RK (%80), CT (%20)

Submission and Revision: RK(%100)

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