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Effect of Different Storage Periods and Medium on Germination and Seedling Parameters of Faba Bean (*Vicia faba* L.)

Hatice Bozoğlu[1,a], Zeynep Aybey[2,b,*]

[1]*Ondokuz Mayıs Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü, Samsun/Türkiye*
[2]*Ondokuz Mayıs Üniversitesi Lisans Üstü Enstitüsü, Samsun/Türkiye*
[*]*Corresponding author*

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ABSTRACT

Germination is the first stage of a plant's life. The seeds of grain legumes are used both as food and as seedlings. The vitality of the seeds is crucial for both uses. This study was conducted to determine the effect of storing seeds of the Lara variety of Faba bean (*Vicia faba* L.), harvested in 2023, in different periods (4, 6, 8, 10 and 12 months) and different storage medium (paper bag, plastic bag, glass jar and plastic bottle) on their biological value. The experiment was set up in a completely randomized design with three replications. Germination was done in 2 different materials (sand and paper) in room conditions. Germination speed, germination power, length of plumula and radicle, dry matter of them, seedling vigour index, allometric coefficient, germination energy were observed. On the 4th day, which is considered in determining the germination rate for faba beans, no germination value was determined in any process. Germination power values varied between 72.7% and 97.3%. The highest germination value was obtained from seeds stored for 8 and 10 months. The highest value was recorded in plumula and root length values in 12 and 8-month-old stored seeds, respectively. It was determined that storage medium did not have a single effect on the observed measurements for these experiments. However, statistical differences between storage period and storage material interactions were found to be significant. The statistical differences between storage period and storage material interactions were found to be significant. As a result, it was concluded that the germination rate of the faba bean was early on the 4th day, the counting day, and this value should be studied. It has been concluded that the loss of germination power is very low in about 1 year of storage of faba bean, which have strong germination ability.

[a] hbozoglu@omu.edu.tr https://orcid.org/0000-0003-4776-2566 | [b] zeynepaybey4@gmail.com https://orcid.org/0009-0003-1678-8197

Introduction

Today, while there are major changes in all sectors of the world, interest in the plant-based food sector is increasing with the goals of protecting the medium and healthy nutrition, and the importance of sustainability in food is frequently emphasized (Anon, 2022). Boğusoğlu, (2022) reports that by 2054, the total protein demand in the world will double, and the growth rate of the plant-based protein market is increasing yearly. Legumes are one of the few families of protein-rich plants (Gotor & Marraccini, 2022). Turkiye is the homeland of many legume plants. Considering the richness of our country, the goal should be to rediscover legumes, whose cultivation areas have been decreasing especially after the 1990s, and to take their place in the protein market. Among legumes, Faba bean (*Vicia faba* L.) represents an excellent but not yet discovered source of sustainable and high-quality dietary proteins with its high protein content (27.6%) and agricultural advantages. Faba bean is one of the sustainable, high-quality plant protein sources that have the potential to meet the increasing global demand for more nutritious and healthy foods. Faba bean is one of the rain-fed crops in continental, oceanic and Mediterranean climates (Floresa et al., 2013).

Faba bean is a cool season legume that can be sown in winter in all coastal regions of our country. In our region, it is cultivated in small businesses primarily for family needs. However, considering that this plant's climate requirements are suitable for many conditions of our country and its agricultural characteristics contribute to sustainability, we believe that the development potential of the sowing areas is high. Fewer studies have been conducted on faba beans, both in the world and our country, compared to other legumes such as chickpeas, lentils and beans. Research is needed at every stage, starting from the seed until it reaches the table.

The most important and first condition for growing successful crops in field agriculture is to use seed material that has high viability, will provide uniform emergence and whose performance will not decrease under stress conditions. In order to obtain material of this quality, the storage conditions of the seed are important (Sivritepe, 2011). Healthy storage is significant for both food and seed. Legumes are more accessible to store than many field plant seeds because they do not contain high amounts of oil. Although faba bean has a thick seed coat, it does not experience significant problems in germination (Oğuz & Bozoğlu, 2022). As we witnessed in the seed collection surveys in the Western and Eastern Black Sea region, small family businesses generally store seeds in plastic bottles or sacks in a dark warehouse. One of aims this study to determine the effect of the container used in storage on the vitality of the seed, especially in seed batches and storage time that are not very large in quantities or in enterprises that do not have a special storage medium. Another aim is to compare germination test types in legume seeds such as Faba bean.

Material and Methods

This study used Lara variety seeds of Faba bean, sown in winter in Samsun ecological conditions and harvested in July 2023. After dry harvest, the seeds were dried in the air and then in a 50 ºC oven to equalize their moisture. The experiment used 5 different storage periods (4, 6, 8, 10 and 12 months) and 4 different storage materials (pet bottle, nylon bag, paper bag and glass jar) as factors. The fifty seeds were placed in storage materials with 3 replications. Considering there is no possibility of storage under controlled conditions in small enterprises, the experiment was carried out under uncontrolled room conditions. The experiment was carried out according to the completely randomized design. The germination medium type was also considered a factor in the experiment for problems such as rot occurring more frequently in germination between papers. The seeds were germinated with 2 different mediums: sand and paper. The sand medium was sterilized before each test to prevent microorganism contamination and filled into boxes at a depth of approximately 3 cm. In the paper, two layers of blotting paper were first soaked in pure water, and seeds were placed between them, rolled up and placed in nylon bags. Germinations were carried out in 3 replications with 25 or 30 seeds. Considering post-harvest storage periods, germination studies were carried out in November, January, March, May and July. The room temperatures and humidity values where germination was carried out for these months are given in Table 1. The first count was done on the fourth day to determine speed germination, and the second was done on the fourteenth day to determine the germination power (Şehirali & Yağcılar, 2011). Root length, plumule length, and dry weight of the germinated plantlet were determined.

According to the data obtained from four different storages, it was observed that the 4th day, considered when determining the germination rate, was an early period for Faba beans. For this reason, daily counts were made starting from the 4th day of germinating seeds stored for 12 months (July).

In the literature reviews, it was seen that there were different formulas and terminologies in the observation/measurement of the characteristics, except for the germination percentage, which corresponds to the germination power in Turkish sources. Measurements and analyses in our study were made according to the following sources;

$$\text{Eq1}\quad \frac{\text{number of germinated seed}}{\text{Total number of seed}} \times 100 \qquad \text{R1}$$

$$\text{Eq2}\quad \frac{\text{germinated seed number in t time}}{\text{count time (day)}} \qquad \text{R2}$$

$$\text{Eq3}\quad \frac{\text{Radicle lenght} + \text{Plumul lenght} \times \text{GP}}{100} \qquad \text{R3}$$

$$\text{Eq4}\quad \frac{\text{Plumule lenght}}{\text{Radicle lenght}} \qquad \text{R4}$$

$$\text{Eq5}\quad \frac{\text{germinated seed number (i day)}}{\text{count time (day)}} \qquad \text{R5}$$

$$\text{Eq6}\quad \frac{\sum(\text{nixdi})}{\text{N}} \qquad \text{R6}$$

Eq1: Germination speed (4th day and germination power (14thh day) (%); Eq2: Number of seed germinated daily; Eq3: Seedling vigour Index; Eq4: Allometric Coefficient; Eq5: Germination energy; Eq6: Meean germination time (day); R1: Şehirali (2011), Zahedifer & Zohrabi (2016); R2: Zahedifer & Zohrabi (2016), Damalas et al. (2019); R3: Sidding & Idris (2015); R4: Abbasi-Khalaki et al. (2019); R5: Farooq et al. (2002), Khan et al. (2022), Aziz & Peksen (2020); R6: Abbasi-Khalaki et al. (2019)

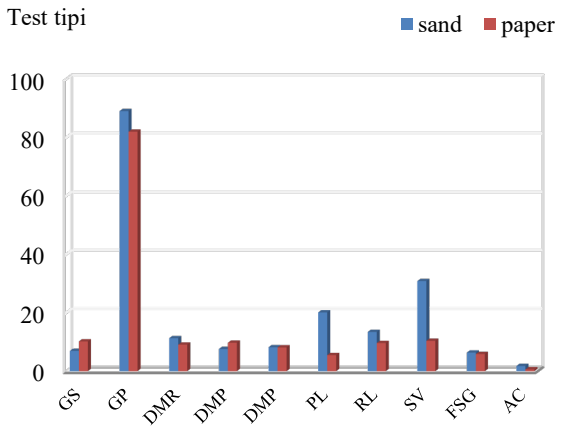

Figure 1. Mean of characteristics observed in germination test type

Apart from these, on the 14th day, the plantles's plumule and radicle lengths and dry matter contents were determined. Data that did not show normal distribution were transformed. The data analysis was carried out with the help of the SPSS 25 program in a randomized experiment design, considering the factorial order of test type, storage period and storage medium applications. Statistical groupings were made with the DUNCAN test with a 5% probability.

Results

Early and uniform emergence under field conditions is an important determinant in sowing time and the struggle with weeds, especially in the early period. These parameters are also important for the successful cultivation of most field crops, as they contribute to standard plant

growth and maturity, better competition with weeds and high productivity (Finch-Savage & Bassel 2016). In our region, faba bean is sown in autumn and completes its vegetative phase during the rainiest period of the region. This is especially important for the control of weeds and for surviving possible winter colds without being damaged.

Germination is important not only for product cultivation but also for nutrition. Germination increases the nutritional value of legumes by creating enzymes that reduce or eliminate anti-nutritional and indigestible substances in legumes (Saleh et al., 2019).

Seed quality is a general term that includes the seed's genetic, physiological and physical characteristics. It determines the product performance and yield in relation to the variety's potential (Sivritepe, 2011). This is the first subject that the researcher should know about when cultivating all plants produced by seed. One of the first tests that will determine the seed's potential is germination. According to seed physiologists, the term germination is defined as the emergence of the radicle (root) from the testa (seed coat), while according to seed technologists, it is defined as the emergence of the radicle and plumule (Sivritepe, 2011). In this study, germination was performed as accepted by seed technologists. In other words, seeds with radicle and plumule emergence were considered to have germinated.

The seeds we tested for germination were weighed in equal amounts and placed in the storage medium. Since the storage mediums are different, these were determined by considering that humidity and grain weight may change during storage (Table 2). Although the hundred seed weight of the seeds varied between 102.86 and 146.08, it was observed that there were no significant differences in storage period and averages. No statistical analysis was made on these data, and they were determined only to determine the characteristics of the starting material. In a study conducted in Sudan to determine the effect of seed size and sowing depth on germination in Faba beans, it was concluded that there was very little difference between large and medium-sized seeds and that the interaction of seed size and planting depth did not show any change in all parameters examined (Siddig & Idris, 2015). From November to July, the humidity change in the room conditions where germination was carried out was between 32.9-80.4%, and the temperature change was between 15.6-29.8°C (Table 1). While moisture loss occurred in seeds stored in paper bags before the test, the highest moisture increase occurred in nylon bags. When storage periods were examined, a 1.32 % increase in seed weight was determined in the shortest storage period of 4 months. In the measurements in January and March, which were six and eight months storage periods, it was determined that the grains lost moisture (Table 2). It can be said that this loss is related to the room temperature values exceeding 30 degrees in these months. Geren & Kavut (2020) studied to determine the effects of different storage media, temperatures and periods on the viability of quinoa seeds. They found the best emergence percentage result from stored in plastic tubes under -24 degrees C followed by nylon bags and vacuum bags at the same temperature, and the minimum values were recorded for seeds stored in cotton bags at ambient temperature.

Variance analysis results of some characteristics of faba bean seeds and seedlings, stored in four different storage mediums and for 5 different periods and germinated with 2 different tests, are given in Table 3. It was determined that the germination test type showed statistical differences in other characteristics except the total dry matter ratio of the seedlings. Extreme values may occur in the data due to microbial contamination, insufficient water during the test, or the possibility of the given water not being distributed equally to the seeds and roots remaining at the edge of the paper and extending towards the light. As a matter of fact, as can be seen in Figure 3, germination data in the sand medium was higher in all observed characteristics.

Table1. Mean of temperature and humidity in the room during the germination

Room conditions	Range	November	January	March	May	July
Temperature (°C)	min	18.9	16	15.6	17.9	27.2
	max	23.3	22.9	23.3	21.4	29.8
Humidity (%)	min	48.9	32.9	36.5	57.8	59.5
	max	66	65.8	68.9	80.4	71.4

Table 2. Hundred seed weights of seeds used in germination tests and moisture change during the storage period.

Medium	Storage Period (months)					Mean
	4	6	8	10	12	
	100 seed weight (g)					
Nylon bag	146.08	129.22	130.52	123.29	113.63	128.55
Plastic bottle	118.82	135.44	134.22	124.34	112.65	125.09
Sack paper	102.86	123.87	129.01	122.89	108.55	117.44
Glass jar	108.94	131.39	132.55	126.57	119.11	123.71
Mean	119.17	129.98	131.57	124.27	113.49	
	Humidity variation during storage period (%)					
Nylon bag	2.89	0.46	-0.94	0.45	0.45	0.66
Plastic bottle	1.34	0.25	0.42	0.32	0.32	0.53
Sack paper	0.40	-2.72*	-1.60	0.47	0.47	-0.60
Glass jar	0.67	0.20	0.11	0.23	0.23	0.29
Mean	1.32	-0.45	-0.50	0.378	0.37	

* Minus values indicate the moisture loss from the container

Table 3. Variance analysis results and statistical significance of some characteristics of Faba bean seeds stored in different periods and mediums.

SV	FD	GS (%)	GP (%)	DMR (%)	DMP (%)	DMP (%)	PL (cm)	RL /cm)	SVI	FSG	AC
Test type(TT)	1	**	**	**	**	ns	**	**	**	**	**
Time (T)	4	**	**	**	**	**	**	**	**	**	**
Storage Medium (SM)	3	**	ns	ns	ns	ns	ns	*	**	ns	ns
TT×T	4	**	**	**	ns	**	**	**	**	**	**
TT×SM	3	**	**	ns	ns	ns	ns	*	**	**	**
T×SM	12	**	ns	**	**	**	*	*	**	ns	**
TT×T×SM	12	**	ns	**	ns	ns	ns	**	ns	ns	**
Error	80	42.9	91.02	4.47	0.92	0.98	9.96	9.09	26.34	0.46	0.16

GS: germination speed, GP: germination power, DMR: dry matter of radicle, dry matter of plumula, DMP: dry matter of plant, PL: plumula length, RL: radicle length, SVI: seed vigour index, FSG: finish speed germination, AC:Allometric coefficient

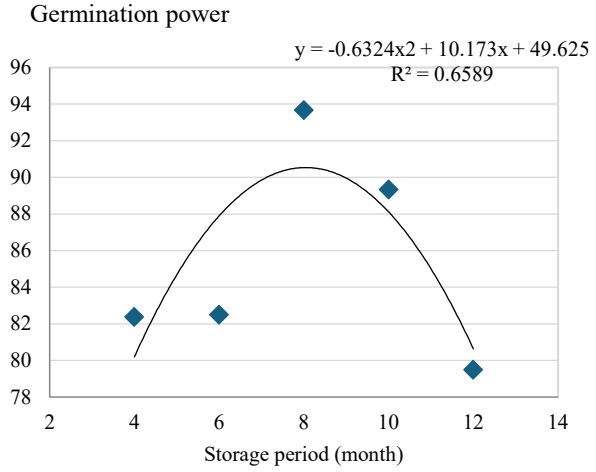

Figure 2. Change in germination power of faba bean seeds stored for different periods

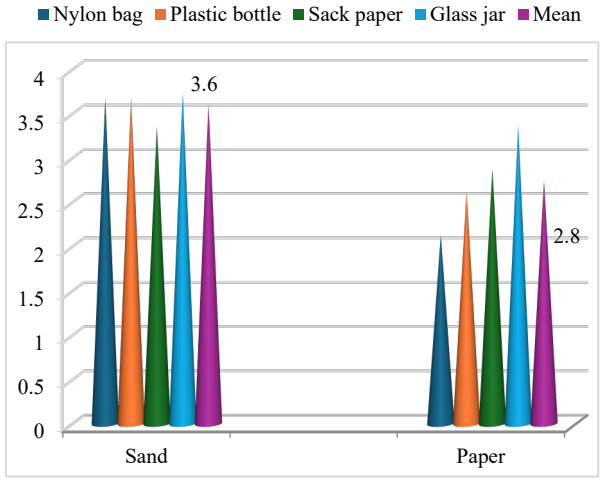

Figure 3. Mean germination days of seeds stored with different storage materials on sand and paper media (days)

Faba bean can be sown in winter or early spring. Satisfactory germination and seedling viability of faba bean seeds occur at a minimum soil temperature of 7 degrees C. Under optimum conditions, faba beans can germinate in 10-14 days, but this period may be extended if the weather is very cold (Damalas et al., 2019). In our domestic resources, the sum of the speed of germination and power value is considered the biological value of the seed. The germination determined on the first counting day gives the "germination speed", and the second count gives the "germination power" (Şehirali & Yağcılar, 2011). The concepts of germination speed and power are used in determining the early or late sowing time in field agriculture and in calculating the number of seeds to be sown according to the old or freshness of the seed (Kevseroğlu 2000, Şehirali & 2011). In the foreign sources examined, the germination speed value is found by dividing the germinated seeds on the counting day by the counting day (Abbasi-Khalaki et al., (2019). In our study, both the speed and power values specified in local sources and the value we call the final germination power on the 14th day were found, and their averages are given in Table 4. As seen from the table, there was no germination in the counting made on the 4th day in 6, 8 and 10 months of storage. Based on this, daily counts were made for the germination of seeds stored for 12 months, and the germination energy was found using the formula suggested by Farooq et al. (2005) (Table 5). According to these data, the value, which was only 1.99% in the sand medium on the 4th day, the first counting day, increased to 40.3% one day later. This value was very low in the paper medium but exceeded 68.7% on the 10th day. Santos et al. (2024) reported in their study that the changes in germination and vitality of Faba bean seeds stored in aluminium-coated plastic bags and semi-permeable plastic bottles were the least. Impermeable aluminium-coated plastic bags have been found promising for seed storage. Storage of faba bean seeds in permeable paper bags is not recommended.

Based on the germination power values, the average germination time was determined according to Sidding & Idris (2015) by considering the last count day (14th day), and the results are given in Figure 3. While the average germination time in the sand was 3.6 days, this value was 2.8 days in paper. While the average germination time in the sand was 3.6 days, this value was 2.8 days in paper. These data led to the conclusion that the 4th day was too early to find the value we describe as the first count or germination rate in faba beans.

According to the analysis of variance performed on the germination power values, which is the proportion of grains that germinated on the 14th day, which was the last counting day of the study, it was determined that test type, storage time, test type x time interaction, test type x medium interaction had a statistical effect (Table 3). The statistical effect of storage mediums was not significant.

Table 4. Mean of some germination characteristics of faba bean seeds stored in different periods and medium

	Plastic bag	Plastic bottle	Paper bag	Glass jar	Mean	Plastic bag	Plastic bottle	Paper bag	Glass jar	Mean
	germination speed (%)					plumula length (cm)				
4ay	53.7	42.5	19.7	51,1	41,8 a	11.3	8.0	7.2	6.8	8.8 d
6ay	0,0	0,0	0,0	0,0	0,0 b	9,6	9,4	10.2	11.7	9.7 d
8ay	0.0	0.0	0.0	0.0	0.0 b	15.2	15.7	15.9	15.7	15.6 b
10ay	0.0	0.0	0.0	0.0	0.0 b	14.4	12.1	13.2	14.2	13.3 c
12ay	2.7	0.0	1.3	0.0	1.0 b	32.4	29.2	24.7	22.2	28.8a
Mean	11.3 a	8.5 a	4.2 b	10.2 a		16.6	14.9	14.2	14.1	
	germination power (%)					radicle length (cm)				
4ay	89.5	87.2	74.2	78.6	82.4 b	14.5	10.7	8.0	5.6	11.1 b
6ay	82.7	81.3	83.3	82.7	82.5 b	12.7	12.2	11.0	10.5	12.0 b
8ay	91.3	97.3	90.7	95.3	93.7 a	14.9	17.1	13.0	14.3	15.0 a
10ay	88.0	94.0	88.0	87.3	89.3 a	11.7	11.7	10.3	10.1	11.2 b
12ay	72.7	78.7	78.0	88.7	79.5 b	11.3	9.7	11.6	12.9	11.4 b
Mean	84.8	87.7	82.8	86.5		13.0 a	12.3 a	10.8 b	10.7 b	
	dry matter of radicle (%)					seedling vigor index				
4ay	10.2	15.1	10.4		11.9 a	22.6	16.4	11.8	10.4	16.9 c
6ay	12.7	10.5	9.4		10.9 a	19.3	17.8	18.0	18.4	18.4 c
8ay	10.7	8.3	8.0		9.0 b	28.7	32.1	27.5	29.1	29.4 a
10ay	11.1	9.1	11.6		10.6 a	24.2	22.5	21.7	21.6	22.8 b
12ay	7.8	7.7	9.1		8.4 c	20.1	17.9	15.3	16.4	14.4 c
Mean	10.5	10.8	9.7			23.0 a	21.3 ab	18.9 b	19.2 b	
	dry matter of plumula (%)					finish speed germination				
4ay	8.3	6.1	7.3	8.2	7.2 c	6.4	6.2	5.3	5.6	6.0 b
6ay	8.7	9.8	9.2	9.6	9.3 a	5.9	5.8	6.0	5.9	5.9b
8ay	8.9	8.4	8.6	8.6	8.6 b	6.5	7.0	6.5	6.8	6.7 a
10ay	8.6	9.8	8.2	8.1	8.9 b	6.3	6.7	6.3	6.2	6.4 a
12ay	7.8	8.3	8.8	9.1	8.3 b	5.2	5.6	5.6	6.3	5.5 b
Mean	8.5	8.5	8.4	8.7		6.1	6.3	5.9	6.2	
	dry matter of plant (%)					Allometric coefficient				
4ay	8.9	8.5	8.5	9.4	8.6 b	0.8	1.0	1.1	2.4	0.9 b
6ay	9.8	10.1	9.3	10.4	9.7 a	0.7	0.7	0.9	1.0	0.8 d
8ay	5.6	4.2	3.6	3.6	4.4 c	1.0	1.0	1.2	1.0	1.0 cd
10ay	9.1	11.0	8.7	9.0	9.6 a	1.2	1.0	1.2	1.3	1.1 bc
12ay	7.8	8.1	8.9	9.1	8.3b	2.9	3.1	2.2	1.8	2.7 a
Mean	8.2	8.4	7.8	8.3	8.1	1.3 b	1.4 b	1.3 b	1.5 a	

Faba bean is a plant that is harvested after all the leaves have fallen and the stems and fruits have dried completely. Although the seeds were dried and stored at 50 ^{o}C before being taken into the experiment, the data show that the grains continued their physiological development for up to 8 months. This situation is also seen in the regression graph (Figure 2).

Germination does not mean seedlings will form healthy plants (Sivritepe, 2011). Therefore, it is important to determine the emergence, vitality, and growth course of the seedlings in germination. On the fourteenth day, the germinated seedlings' radicle and plumule lengths and dry matter contents were determined (Table 4). Radicle length in the different storage varied between 11.1-15 cm, and this difference was found to be statistically significant (Table 3). The longest radicle length was obtained from 8 months of storage, and all other periods were in the same statistical group. The test type also statistically affected radicle length ($P<0.01$). It was determined that the radicle was longer in the germination in the sand medium (Figure 1). Although the room temperatures in May, when the seeds stored for ten months were germinated, were not very variable, the moisture content was high (Table 1). Considering that this situation does not have much effect on the factor that makes this difference, but the germination power is in the highest statistical group during this period, it can be said that this may be the reason. It has also been found that storage mediums are different. The longest radicles were obtained in seeds stored in plastic bottles and nylon bags. It was determined that storage mediums did not affect plumule length, but storage period did. It was determined that seeds stored for one year gave the longest plumule (28.8 cm) and showed a statistical difference from other periods. Twelve months of storage coincided with July; ambient temperature and abundance of light conditions may have created this difference. These high values may be because the study was conducted under room conditions and in a brightly lit medium. Since the lengths were affected by medium conditions, the dry matter contents of these parts were also examined to determine what the dry matter accumulations were. The effect of test types and storage periods on the dry matter content of both parts was significant (Table 4). Among the test types, the plumule dry matter content was higher in paper, while it was higher in radicle among sand. The plantlet among paper may have photosynthesized less because it received less light. The statistical effect of storage mediums was not found to be significant.

Table 5. Germination energies (GE) of faba bean seeds stored for counting days on 12 months

	Medium	Counting day					
		4	5	6	7	10	14
Sand	Nylon bag	5.3	72.0	90.7	92.0	92.0	92.0
	Plastic bottle	-3.3E-16	52.0	82.7	90.7	92.0	92.0
	Sack paper	2.67	21.3	73.3	80.0	82.7	84.0
	Glass jar	2.22E-16	16.0	69.3	81.3	90.7	93.3
	Mean	1.99	40.3	79.0	86.0	89.3	90.3
Paper	Nylon bag	-1.1E-16	-8.8E-16	1.3	2.7	53.3	53.3
	Plastic bottle	1.11E-16	-2.65E-15	1.3	1.3	65.3	65.3
	Sack paper	-2.2E-16	-2.66E-15	2.7	4.0	72.0	72.0
	Glass jar	0.000	1.3	9.3	10.7	84.0	84.0
	Mean	0.00	0.3	3.7	4.7	68.7	68.7

In a study, the changes in germination and viability of faba bean seeds stored in aluminium-coated plastic bags and semi-permeable plastic bottles were the least. Impermeable aluminium-coated plastic bags were found promising for seed storage. It is not recommended to store Faba bean seeds in permeable paper bags (Santos et al. 2024). Radicle dry matter content varied between 8.4 - 11.9%. The lowest dry matter content was obtained from the 12-month storage period, with the highest germination power. Plumule was the highest in 6-month storage and showed a statistical difference. Santos et al. (2024) reported that aluminium-coated plastic bags had higher shoot and root weights, and those stored in glass containers gave lower root and shoot values. It was suggested that there was a significant difference between wet and dry matter values and storage in aluminium-lined plastic bags followed by pet bottles was recommended for best physiological potential.

The seed vitality index is given with different formulas in different literature. Some researchers used the seedling dry matter value and the seedling length. In our study, the formula of Khan et al. (2022) was used, which is calculated by multiplying the length of the germinated seedling by the germination rate and dividing by the hundred. The variance analysis determined that the test type, storage period, storage medium, and binary interactions were statistically effective. The index is expected to be higher in the sand because the seedling starts photosynthesis by seeing the light and remains away from microorganism contamination, as in paper. Abbasi-Khalaki et al. (2019) reported that stress conditions decrease the index. The highest storage medium value was obtained from plastic bags and pet bottles. In the storage period, the highest value was determined in 8 months (29.4) and statistically different from other periods (Table 4). Santos et al. (2024) reported that temperature and humidity during storage mainly affect seed viability. The same researchers also noted that the medium in which the seeds are stored and the type of packaging used are important as they determine the amount of water vapour exchange between the seeds and atmospheric and medium conditions and that aluminium-coated plastic bags and hard pet bottles minimize the variability in humidity, dry matter, germination rate and viability.

The term “allometric” in biology refers to the growth rates between different body parts of an organism. Each plant exhibits a specific allometric growth pattern under certain conditions; that is, plants exhibit allometric flexibility, which changes the quantitative relationships between the growth and distribution of organs. This study determined this value by the ratio of the plumule length to the radicule length reported by Abbasi-Khalaki et al. (2019). This value is expected to be positive, especially in germination in sand. Because the plumule sees sunlight and elongates faster. In our study, this value varied between 0.7-3.1. While glass jars gave the best value in storage mediums, they were given in 12 months of storage.

Germination energy values are determined by dividing the number of germinated seeds on the counting day by the counting day of Farooq et al. (2005) and Khan et al. (2022). The germination index is given in Table 5. As can be seen from the table, there are negative values on the 4th day in the sand and on the 4th and 5th day in paper, meaning that germination is insufficient on these days. Germination energy increases especially after the 5th day in sand. These data have not been subjected to statistical analysis. However, it is seen that there is a noticeable difference between sand and paper. While no significant difference was determined in the sand medium, it was observed that the germination energies of the seeds stored in glass jars were the highest among those germinated in paper.

The low germination rate on the 4th day, the first counting day, and the increase from the next day onwards necessitated determining the average germination time. However, when the sources are examined, it is seen that there are differences in the calculation of this value, and even Soltani et al. (2015) reported that there are problems in the use of this value, that the application of variance analysis is not correct, and that it would be correct to use the value expressed as t_{50}, where 50% of the seeds germinate, instead of this value. Wei et al. (2022) reported that all cultivars reached the germination percentage of nearly 90% at 72 h, and there was no significant difference of germination percent- age at 48 h and 72 h among cultivars. In this study, the average germination time was determined on the last germination day, the 14th day, with the formula reported by Abbasi-Khalaki et al. (2019) and is given in Figure 3. According to these data, the average germination day in the sand was determined to be 3.6 days; on paper, it was 2.8 days. A study examining the nutritional profile of faba bean determined that a gradual increase in the protein content of faba bean during 24–72 hours of germination could be due to starch utilization as an energy source (Dhull et al. (2024). This confirms that this value gives a problematic result, as Soltani et al. (2005) reported. Our study observed that germination increased rapidly after the first countingy in the sand medium, that is, from the fifth day, but on the paper, there was no germination in some applications on the fourth and fifth days (Table 5).

Conclusion

According to the Regulation on Vegetable Seed Certification and Marketing No. 26760 of the Ministry of Agriculture and Forestry, the minimum germination value required for faba bean-certified seeds has been reported as 75% (Anon., 2023). Based on this, the lowest germination power of faba bean seeds stored in different mediums and periods was obtained in 12 months (79.5%) and the highest in 8 months (93.7%) under room conditions. As can be seen, faba beans are a very strong plant, and their seeds do not lose their vitality for a long time. It was observed that storage for 12 months was higher than the mentioned value. Our study observed that germination gradually increased due to the continued development of grains for up to 8 months after harvest, but it decreased after this period. However, this decrease was lower than the values in the first 4 or 6 months. We think that if the study is extended further for 24 or 36 months, more informative results can be obtained. We believe that the effect of storage mediums will be more important, especially when the period is extended. Additionally, studies should be carried out in controlled cold storage facilities.

When the sources were examined, it was determined that many parameters were examined in germination tests, but there was no unity in the formulas of these parameters. It would be beneficial to simplify these parameters by conducting more detailed research and considering the ISTA rules.

In field agriculture, knowing the germination characteristics of the seed is important in calculating the amount of seed to be used. In this sense, it is helpful to update values such as germination speed, strength, and counting days, as in domestic sources.

In our studies that we have conducted for a long time, germination between papers creates many problems, especially in large-seeded plants such as Faba beans. When labour and time are also considered, it is recommended to prefer sand medium, especially in uncontrolled conditions.

Every researcher dealing with plant breeding must have sufficient knowledge about genotype, material, medium conditions, etc., in germination, which is the first vital phase of the plant.

Declarations

This paper was presented in III. International (XV. National) Field Crops Congress.

Author Contribution Statement

Hatice Bozoğlu: Project planning, methodology, statistical analysis, review and editing and writing

Zeynep Aybey: Setting up the experiment and collecting data, observation and measurement of the experiment

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