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Effects of Seed Source and Storage Duration on Seed Quality of Soybean [*Glycine max* (L) Merrill] Varieties at Pawe, Northwestern Ethiopia

Chaluma Tujuba[1,*], Wassu Mohammed[2], Abebe Atilaw[3]

[1]Ambo Agricultural Research Center, Ethiopian Institute of Agricultural Research, Ambo, Ethiopia

[2]Department of Plant Science, College of Agriculture and Envinmental Science, Haramaya University, Haramaya, Ethiopia

[3]Department of Seed Science, Debre Zeit Agricultural Research Center, Ethiopia Institute of Agricultural Research, Bishoftu, Ethiopia

Email address:

Chalumatujuba13@gmail.com (C. Tujuba)

[*]Corresponding author

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Abstract: In northeastern Ethiopia, soybean [*Glycine max* (L) Merril] is one of the most important legume crops. However, one of the manufacturing bottlenecks is the lack of high-quality seeds. Quality seed production necessitates the development of seeds from improved types under optimal growth conditions and storage for the shortest time possible. The purpose of this study was to see how seed source and storage time affected the seed quality of four soybean types. Four cultivars (AFGAT, Cheri, Clark 63k, and Davis) x two seed sources (rain-fed and irrigation) x two storage durations (one and two years stored at ambient temperatures) were arranged in factorial combinations for the treatments. At the Pawe Agricultural Research Center laboratory, treatments were evaluated using a completely randomized design with four replications. The findings demonstrated that one or more major factors had a considerable impact on seed quality measures (variety, seed source and storage period. The findings of the experiment revealed that seed quality was significantly affected by the effects of variety, storage time, seed source, and the interaction of the two and/or three factors on seed characteristics. The seeds of improved varieties obtained from irrigation seed sources and maintained at room temperature for a year yielded high quality seeds in the majority of cases. As a result, it is recommended that varieties, seed source, and seed storage length be considered in order to generate high-quality seeds and increase soybean yield.

Keywords: Correlation, Seed Source, Seed Quality, Storage Period

1. Introduction

Glycine max (L.) Merrill is a major global legume crop that thrives in tropical, subtropical, and temperate settings. It is a member of the Leguminoceae subfamily Papilionideae, which includes peas, beans, lentils, and peanuts. It is a self-fertile species with less than 1% out-crossing and has 40 chromosomes (2n = 2x = 40). [33]: [19]. Soybean is a herbaceous annual legume that originated in China and grows usually upright, bushy, and leafy [28]. Because of its susceptibility to short day length in the tropics, the crop has a short growth period [18]. Soybean is grown widely throughout the world and has a lot of promise in Africa [1].

In Ethiopia, during 2016/17 cropping season a total of 36,635.79 hectares of land covered by soybean with a total production of 81,234.66 tonnes and in 2017/18, it was 38,072.70 hectares with 86,467.87 tonnes in which land coverage and total production increased by 3.92 and 6.44%, respectively. The National average yield was 2.217 and 2.271 t/ha during 2016/17 and 2017/18 cropping seasons, respectively [9]. The average yield is by far lower than the world's average yield of 3.72t/ha [12].

Soybean has great agricultural value in crop rotation and nitrogen fixation, in addition to its position as an export product. Soybean, like many other legumes, enhances soil fertility by converting atmospheric nitrogen to its own use, which benefits the following crop in the rotation. As a result, the amount of nitrogen fertilizer that farmers must purchase to apply to their crops to increase output is reduced. This is especially important in Africa, where soils are depleted of nutrients and fertilizers are costly and unavailable to farmers [19].

The quality of seeds worsened as a result of germination loss, which is substantially more severe in tropical conditions and reduces soybean productivity. Soybean cultivars range in their susceptibility to seed deterioration owing to prolonged storage, and their responses to different seed sources may differ in terms of quality seed production. Seed quality and viability throughout storage are determined by the seed's initial condition and the method in which it is preserved [32].

Seed quality is a multi-criteria criterion that includes genetic and chemical composition, physical condition, physiological germination and vigor, size, appearance, and presence of seed-borne diseases, crop and varietal purity, weed and crop pollutants, and moisture content, among other things [36]. The stored seed quality as well as the storage conditions have an impact on the seed's storage longevity. Unfavorable storage conditions, regardless of starting seed quality, lead to seed deterioration in storage, making it difficult to determine the effective storage period because seed storability is a function of both beginning seed quality and storage condition [3]. To generate high-quality soybean cultivar seeds, it is required to investigate the seed source and storage duration. However, no equivalent research has been done in Ethiopia. The following questions were used to start this investigation.

2. Materials and Methods

The laboratory experiment was conducted to determine the seed quality of soybean varieties collected from different seed sources and storage duration of four varieties.

Table 1. *Description of soybean varieties.*

Variety	Year of release	Yield t ha^{-1}		Maturity Type	Altitude (m.a.s.l.)	Maintainer Center
		research	farmer			
AFGAT (TGX-1892-10F))	2007	14.8	13	medium	750-1800	AwARC/SARI
Cheri (IPB-81-EP7)	2003	22	15	medium	1300-1800	BARC/OARI
Clark 63k	1981/2	25-30	15-20	medium	100-1700	AwARC/SARI
Davis	1981/82	25-30	15-20	medium	1000-1700	AwARC/SRARI

Source: MoANR (2016).

The sixteen basic seed samples for four varieties (AFGAT, Cheri, Clark-63k and Davis) each from two seed sources (Irrigation and Rain-fed) and two storage duration (One and Two year) were collected and used as treatments (4 x 2 x 2) factorial arrangement in four replications. The experiment was conducted in pawe agricultural research center laboratory, which was carried out as per International Seed Testing Association rules and procedures [21]. The experiment was laid out as Completely Randomized Design (CRD). Storage has 75% relative humidity and 25°C temperature mean during storage period.

2.1. Determination of Seed Physical Purity

Moisture Content Determination

The amount of water within the seed was determined with low constant temperature oven method and the temperature was maintained at 103±2°C and the seed was dried for 17±1 hours. The difference between the weight of fresh seeds and the dry seeds was established by the formula [21].

$$\text{MC}\ (\%) = \frac{\text{M2}-\text{M3}}{\text{M2}-\text{M1}} \text{x} 100$$

Where; MC= Seed moisture content.

M1=Weight of the empty container with its cover

M2=Weight of the container with its cover and seeds before drying.

M3=Weight of the container with its cover and the seed after drying.

A seed sample of 1000 gram (g) was obtained from each experimental treatment for laboratory analysis. The 1000 g of seeds from each treatment was divided into 4 each 250 g which was used for the laboratory tests that include purity, moisture content determination, germination, vigor. Each sample was sorted into three components that include pure seed, inert matter and other crop as suggested by the International Seed Testing Association [21]. Hundred seed weight (HSW) randomly taken from each experimental treatment, weighed using an electric sensitive balance and adjusted to 10% moisture content.

$$\text{MC}\ (\%) = \frac{\text{M2}-\text{M3}}{\text{M2}-\text{M1}} \times 100$$

2.2. Determination of Seed Physiological Quality

2.2.1. Standard Germination Test

The germination test for soybean was done at the temperature of 25°C [20]. Thus, the first and second counts were done at 5 and 10 days after planting, respectively. Sand will be used as a substrate for germination. The germination test was done from the pure seed fractions obtained from the purity test. Four hundred seed (400) pure seeds were taken from each treatment, and divided into four replicates of 100 seeds. Each replicate was sown on a sterilized sand medium on plastic box. Finally, at the 10th day of the planting seedling was categorized in to normal, abnormal, dead seeds and their percentages was calculated.

$$\text{StG} = \frac{\text{Total number of normal seedling}}{\text{Total number of seeds planted}} \times 100$$

2.2.2. Speed of Germination

Speed of germination was calculated from the daily germination records. In case of soybeans, speed of germination shall be obtained within 10 days of germination period; the first count was done on the 5th day. Finally, speed of germination was calculated using the following formula which was given by [13]

$$\text{Speed of germination} = \frac{N1}{C1} + \frac{N2}{C2} + \ldots + \frac{NF}{CF}$$

Where: N1= number of normal seedlings at first count, N2= number of normal seedlings at second count, NF= number of normal seedlings at final count, C1= days to the first count, C2= days to the second count and CF= days to the final count.

2.2.3. Seedling Vigour Test

Seedling vigour test was determined by measuring shoot and root length of seedlings. The seedling shoots and root length was measured after the final count of the germination test. Ten normal seedlings were randomly taken from each replicate and shoot length was measured from the point of attachment to the cotyledon. Similarly, the root length was measured. The averages of shoot and root lengths were computed by dividing the total shoot or root lengths by the total number of normal seedlings measured [13].

The seedlings dry weight was measured after the final count of the standard germination test. Ten randomly taken seedlings from each replicate was identified and placed in envelopes and dried in an oven at 80°C for 24 hrs. The dried seedlings were weighed by using sensitive balance and the average seedling dry weight was calculated.

For each treatment, two vigour indices were calculated. Seedling vigour index one was calculated by multiplying the number of normal seedlings with the average sum of shoot and root lengths and Vigour index two was calculated by multiplying the standard germination percentage with mean seedling dry weight. Mathematically;

$$\text{Vigour Index One (VIG-I)} = \text{Average Seedling Length} \times \text{Normal seedling \%}$$

$$\text{Vigour Index Two (VIG-II)} = \text{Normal seedling \%} \times \text{Seedling mean Dry Weight.}$$

2.3. Data Analysis

The data recorded in this study were subjected to statistical analysis. The analysis of variance was carried out using SAS software (SAS, 2000). Significance differences between treatment means were delineated by Least Significance Difference (LSD) test at 5% level of significance.

3. Results and Discussion

3.1. Seeds Physical Quality Test

Analysis of variance revealed that the main effect of variety, interaction of variety and seed source, interaction of variety and storage duration and three factors interaction (variety x seed source x storage duration) had significant effect on seeds moisture content. Hundred seed weight was significantly influence by variety, interaction of variety and seed source (Table A1).

The highest hundred seed weight (11.08) was registered for sample seeds of *Davis* variety obtained from rain-fed. The seeds of *Davis* and *AFGAT* variety from irrigation and the seeds of *AFGAT* variety from rain-fed also had higher hundred seed weight and had non-significant difference with hundred seed weight of *Davis* variety from rain-fed. Lowest hundred seed weight (8.91) was registered for both seeds of *Clark-63k* and *Cheri* varieties from rain-fed seed source (Table 2). This indicated that the soybean varieties had significant difference for inherent characteristics of seeds weight which might be the function of genetic factor. The seed weight has a large effect on seed germination, seed vigor, seedling establishment and yield production. This suggestion might be supported by other workers; [27]; and [8]. that noted high seeds weight will increase germination percent, seedling emergence, tillerring, density, spike and yield.

Table 2. *Effects of variety x Seed source on hundred seed weight of soybean varieties during pre-sowing test at Pawe in 2019.*

Variety	Seed source	Hundred seed weight (g)
AFGAT	Irrigation	9.83^{bc}
Cheri	Irrigation	9.75^{bc}
Clark-63k	Irrigation	10.00^{b}
Davis	Irrigation	10.41^{ab}
AFGAT	rain-fed	10.58^{ab}
Cheri	rain-fed	8.91^{c}
Clark-63k	rain-fed	8.91^{c}
Davis	rain-fed	11.08^{a}
LSD (0.05)		0.94

The highest moisture content (10.50%) was registered for seeds of *Cheri* variety from rain-fed seed source and stored for two year which had non-significant difference with moisture content of *Cheri* variety from both seed source and stored for one and Clarck-63k from irrigation and stored for two years. Similarly, moisture content from seeds of *AFGAT* variety stored for two years had non-significant with seeds of *Clark-63k* variety stored for one year and obtained from irrigation seed source. Lowest moisture content (8.16%) was registered for both seeds of *Davis* variety stored for one year and *Cheri* variety stored for two year and obtained from irrigation. The seeds of *AFGAT* variety from irrigation, *Clarck-63k* and *Davis* varieties from rain-fed source and stored for one year, *AFGAT, Clarck-63k* and *Davis* varieties from rain-fed and *Davis* from irrigation and stored for two years had non-significant (Table 3). This showed that the prolonged storage duration increases moisture content of soybean varieties at both seed source. Seed moisture content can talk about the physiological activities which are undergone within the seed while it was in the store or at harvest if the test was conducted within short period of time after harvest. Similar result was reported by Hampton that an increase in the seed moisture not only leads to more rapid seed aging, but the activity of saprophytic fungi, insects and mites also increases as the relative humidity and seed moisture content increased [16].

One of the major constraints to the production of soybean in the tropics is the rapid loss of seed viability and vigor during storage under ambient conditions [26].

The rate of deterioration of seed in storage is greatly influenced by moisture content [11, 17]. The higher the moisture content, the more rapidly vigor and germination are reduced. Harrington's "rule-of-thumb" that a1% decrease in moisture content doubles the storage life of seed holds in a general way for soybeans [17, 10].

Table 3. *Interaction effect of variety x storage duration x seed source on soybean seeds moisture content and abnormal seedling during pre-sowing test at Pawe in 2019.*

Varieties	Seed source	Moisture Content (%)		Abnormal seedling (%)	
		One year	Two years	One year	Two years
AFGAT	Irrigation	8.83^{e}	9.50^{cd}	5.75^{c}	9.50^{b}
	Rain-fed	9.83^{bc}	8.83^{e}	6.25^{c}	10.00^{b}
Cheri	Irrigation	10.16^{ab}	8.16^{f}	4.50^{c}	12.25^{ab}
	Rain-fed	10.16^{ab}	10.50^{a}	3.75^{c}	10.75^{b}
Clark-63k	Irrigation	9.50^{cd}	10.00^{ab}	4.00^{c}	11.00^{ab}
	Rain-fed	8.83^{e}	8.83^{e}	5.50^{c}	11.75^{ab}
Davis	Irrigation	8.16^{f}	9.16^{e}	6.25^{c}	13.25^{a}
	Rain-fed	8.83^{e}	8.83^{e}	10.25^{b}	13.25^{a}
LSD (0.05)		0.65		2.01	

3.2. Seed Physiological Quality Test

3.2.1. Proportion of Dead Seeds, Abnormal Seedlings, Germination and Speed of Germination

Percentage of germination and dead seeds was significantly influenced by variety, storage duration, interaction of variety x storage duration and seed source x storage duration. Proportion of abnormal seedlings was significantly influenced by variety, storage duration, interaction of variety x seed source and seed source x storage duration as well as by the interaction of three factors (variety x storage duration x seed source). Speed of germination was significantly influenced by storage duration, interaction of variety x storage duration and seed source x storage duration (Table A1).

The highest germination percentage (92.25%) was registered for seeds of *Cheri* variety stored for one year. The seeds of *AFGAT* variety stored for one year had non-significant difference with germination percentage of *Clarck-63k* variety stored for one year. Similarly, seeds of *AFGAT* variety stored for two years had non-significant difference with germination percentage of *Clarck-63k* variety stored for two years. Lowest germination percentage (41.37%) was estimated from seeds of *Davis* variety stored for two years. On other hand, highest percentage of dead seed (45.37%) was estimated from seed sample of *Davis* variety stored for two years. The seeds of *AFGAT* variety stored for two years had higher dead seed and had non-significant difference with dead seed of *Clarck-63k* variety stored for two years. Lowest proportion of dead seed (3.62%) was registered from seed sample of *Cheri* variety stored for one year. The seeds of *AFGAT* and *Clarck-63k* varieties stored for one year had non-significant difference with dead seed of *Davis* variety stored for one year (Table 4). However, all varieties from two-year sources recorded below minimum requirements germination percentage set by the Quality and Standards Authority of Ethiopia which was 75% for basic seed class [30]. This showed that the prolonged storage duration of soybean varieties retarded seed germination and increased the proportion of dead seeds. Bailly reported decreasing of germination percentage in aged seeds of sorghum could be due to reduction of α amylase activity and carbohydrate content [6].

Table 4. *Interaction effect of variety x storage duration on proportion of dead seeds, seeds germination percentage and speed of germination of soybean varieties during pre-sowing test at Pawe in 2019.*

Treatment		Seed quality parameter		
Variety	Storage duration	Dead seed (%)	Standard germination (%)	Speed of germination
AFGAT	One year	8.00^{d}	86.00^{bc}	12.96^{b}
Cheri	One year	3.62^{e}	92.25^{a}	13.99^{a}
Clark-63k	One year	6.87^{d}	88.37^{b}	13.34^{b}
Davis	One year	7.75^{d}	84.00^{c}	12.87^{b}
AFGAT	Two years	38.37^{b}	51.87^{e}	7.57^{d}
Cheri	Two years	32.50^{c}	56.00^{d}	8.34^{c}
Clark-63k	Two years	39.50^{b}	49.12^{e}	7.33^{d}
Davis	Two years	45.37^{a}	41.37^{f}	6.14^{e}
LSD (0.05)		2.73	3.01	0.57

The percentage of seed germination was higher for seeds both irrigation and rain-fed seed source and stored for one year. The proportion of dead seeds was significantly lowest for seeds from both irrigation and rain-fed and stored for one year.

The seeds from irrigation and stored for two years had significantly highest dead seeds (Table 5). This indicated that prolonged storage duration decreased seed germination percentage at both seed source. The result of this study is in line with the findings of Murali who indicated that germination of the pulse seed decreased with increase storage period [25].

Table 5. *Interaction effect of seed source x storage duration on proportion of dead seeds, germination and speed of germination of soybean varieties during pre-sowing test at Pawe in 2019.*

Seed source	Storage duration	Dead seed (%)	Standard germination (%)	Speed of germination
Irrigation	One year	5.93[c]	88.93[a]	13.52[a]
	Two years	40.87[a]	47.62[c]	7.06[b]
Rain-fed	One year	7.18[c]	86.37[a]	13.06[a]
	Two years	37.00[b]	51.56[b]	7.63[b]
LSD (0.05)		2.95	3.58	0.57

Higher abnormal seedlings were recorded for seeds of *Davis, Cheri and Clarck-63k* varieties from irrigation and *Davis* and *Clarck-63k* varieties from rain-fed and stored for two years. However, abnormal seedlings seeds of *AFGAT* variety from irrigation had non-significant difference with abnormal seedlings proportion of *AFGAT* and *Cheri* varieties from rain-fed and stored for two years as well as Davis variety from rain-fed seed source and stored for one year. The lowest abnormal seedling proportion was registered for seeds of *Cheri, AFGAT, and Clark-63k* varieties from rain-fed seed source which had non-significant with seed of *AFGAT*, *Cheri, Clarck-63k* and *Davis* varieties from irrigation and stored for one year (Table 3). This showed that the prolonged storage duration of soybean varieties increased the proportion of abnormal seedlings at both seed source. An immature seed leads to increase abnormality of seedlings and dead seed (mechanically damaged, broken seeds). The normal seedling growth in the laboratory obtained from higher seed weight of large seed size that had mature endosperm of food storage, because after germination seedlings use the endosperm food for growth and development. The higher food reserve in the endosperm results higher seed weight and leads to vigorous crop in the field. Majid and Mohsen reported that two wheat cultivars, Sivand and Pishgam, had the highest (100%) and Parsi cultivar (93.3%) had the lowest germination percent. This might be due to Sivand and Pishgam variety had large seeds size and thus resulted in high potential for seed germination and vigor than cultivar Parsi [23].

The highest speed of germination (13.99) was registered for seeds of *Cheri* variety stored for one year. Speed of germination from seeds of *AFGAT, Clark-63k and Davis* varieties had non-significant difference and stored for one year. Similarly, seeds of *AFGAT and Clark-63k* varieties stored for two years had non-significant difference speed of germination. Lowest speed of germination (6.14) was registered from seeds of *Davis* variety stored for two years. The prolonged storage duration of soybean varieties retarded speed of germination (Table 4). This showed that increasing seed storage period reduces the general metabolic activity of soybean, death of seed and leads to the reduction of germination and time of escaping seedling from difference climatic condition. Speed of germination indicates the rate at which the seeds are germinating rapidly and seedling can emerge and escape adverse field conditions [37]. Seeds that have high germination speed were found vigorous in the field and could be escaped harsh conditions.

The highest speed of germination was registered from sample seeds from both seed source and stored for one year with statistical parity. Lowest speed of germination was registered from both seed source and stored for two years with statistical parity (Table 5). This indicated that prolonged storage duration retarded speed of germination. This suggestion was supported by Bailly who reported decreasing of speed of germination in aged seed of sorghum could be due to reduction of α amylase activity and carbohydrate content [6].

3.2.2. Seedlings Shoot Length, Root Length and Dry Weight

Shoot and root length seedlings were significantly influenced by variety, seed source, interaction of variety x seed source and three factors interaction (variety x seed source x storage duration). In addition, shoot length also influenced by storage period and interaction of variety x storage period. Seedling dry weight was significantly influenced by storage duration, interaction of variety and seed source and seed source x storage duration (Table A1). Zewdie indicated that seedlings with well-developed shoot and root system would withstand adverse conditions and provide better seedling emergence and seedling establishment in the field and thus, seedlings with higher index are expected to show rapid germination and emergence that eventually leads to escape adverse field conditions [39].

The highest shoot length (15.25cm) was recorded for seeds of *Cheri* variety from irrigation seed source and stored for one year. Shoot length from seeds of *Cheri* variety from rain-fed, *Clarck-63* and *Cheri* varieties from irrigation and stored for two and *Cheri* variety from rain-fed seed source and stored for one year had non-significant difference. Similarly, shoot length of *AFGAT* and *Davis* varieties from irrigation, *AFGAT* produced under rain-fed and stored for one year as well as *AFGAT* variety from rain-fed seed source and stored for two years had non-significant difference. Also shoot length of *AFGAT* variety from irrigation had non-significant difference with shoot length of *Davis* variety from rain-fed seed source and stored for two years. The seeds of *Clarck-63k* and *Davis* varieties from rain-fed and stored for one year had non-significant difference. The lowest shoot length was registered for seeds of *Davis* variety from irrigation and *Clarck-63k* variety from rain-fed seed source and stored for two year (Table 6). This showed that that prolonged storage duration decrease seedlings shoot length of soybean varieties at both seed source In agreement with this study results, Kapoon found significant declining of seedling length and vigour as the storage period increased in seeds of chickpea varieties [22]. Similarly, other authers found that seedling length had sharply declined when the seed of timothy grass storage period increased from 1 year to 5 years. However, a sharp reduction in seedling length was registered for seeds stored above three years. This could be because seeds with increased their age it loses the viability and vigorusity and finally produce shorter shoot and root length [31].

Table 6. *Interaction effect of variety x storage duration x seed source on seedlings shoot and root length of soybean varieties during pre-sowing test at Pawe in 2019.*

Variety	Storage duration	Seedlings shoot length (cm)		Seedlings root length (cm)	
		Irrigation	Rain-fed	Irrigation	Rain-fed
AFGAT	One year	12.62^{cd}	12.56^{cd}	7.62^{fg}	8.11^{cd}
	Two year	11.98^{de}	12.58^{cd}	7.45^{g}	8.67^{bc}
Cheri	One year	15.25^{a}	13.25^{bc}	8.63^{bc}	8.71^{bc}
	Two year	13.31^{bc}	13.87^{b}	8.02^{cd}	8.50^{cd}
Clark-63k	One year	11.46^{ef}	10.93^{fg}	7.93^{de}	7.47^{g}
	Two year	13.66^{b}	10.55^{g}	8.22^{cd}	7.87^{ef}
Davis	One year	12.57^{cd}	10.75^{fg}	8.11^{cd}	9.87^{a}
	Two year	10.43^{g}	12.00^{de}	9.25^{ab}	8.12^{cd}
LSD (0.05)		0.85		0.73	

The highest root length (9.87cm) was recorded for seeds of *Davis* variety from rain-fed seed source and stored for one year and *Davis* variety from irrigation and stored for two year with statistical parity. The root length of *Cheri* varieties from both seed source and stored for one year and root length of *AFGAT* variety from rain-fed and stored for two year had non-significant. Similarly, root length of *Cheri* variety from irrigation had non-significant difference with shoot length of *AFGAT* from rain-fed and stored for one year as well as *Cheri and Clarck-63k* varieties from irrigation also with Davis and Cheri varieties from rain-fed seed source and stored for two years. The lowest root length was registered for seeds of *AFGAT* variety from irrigation and stored for two year and for seed of *Clarck-63k* varieties from rain-fed seed source and stored for one year with statistical parity (Table 6). This showed that the prolonged storage duration and use of irrigation growing condition of soybean varieties decrease seedlings root length.

The highest seedling dry weight was registered for seeds of *Clark-63k*, *AFGAT, Cheri* and *Davis* varieties from irrigation seed source as well as *AFGAT*, *Cheri* and *Davis* varieties from rain-fed seed source with statistical parity. Least seedling dry weight (1.41gm) was estimated from seed of *Clark-63k* variety from rain-fed seed source (Table 7). This indicated that use of from irrigation source increase seedling dry weight and varietal variation significantly influenced soybean seedling dry weight. This result was in agreement with the findings of Gharineh and Moshatati who reported that more seedling weight of the heavy seeds might be attributed to large food reserves of the seeds [15].

Table 7. *Interaction effect of variety x seed source on seedling dry weight of soybean varieties during pre-sowing test at Pawe in 2019.*

Variety	Seed source	Seedling dry weight (gm)
AFGAT	irrigation	1.47^{ab}
Cheri	irrigation	1.49^{ab}
Clark-63k	irrigation	1.65^{a}
Davis	irrigation	1.56^{ab}
AFGAT	rain-fed	1.58^{ab}
Cheri	rain-fed	1.57^{ab}
Clark-63k	rain-fed	1.41^{b}
Davis	rain-fed	1.60^{ab}
LSD (0.05)		0.18

Higher seedling dry weight was estimated from for seed from both seed source and stored for one year while least seedling dry weight (1.42gm) was estimated from seed from irrigation and stored for two year (Table 8). This showed that the prolonged storage duration decreases seedling dry weight at both seed source. The effect of seed storage period on seedling dry weight under natural condition had been well explored by Ryszard and Dortota on timothy grass. They found low seedling dry weight from seeds stored for 5 years and the highest for seeds stored for one year [31].

Table 8. *Interaction effect of seed source x storage duration on seedling dry weight vigor index I of soybean varieties during pre-sowing test at Pawe in 2019.*

Seed source	Storage duration	Seedling dry weight (gm)	Vigor index I
Irrigation	One year	1.66^{a}	915.16^{a}
	Two years	1.42^{c}	503.68^{b}
Rain-fed	One year	1.56^{ab}	882.93^{a}
	Two years	1.52^{bc}	532.21^{b}
LSD (0.05)		0.12	60.93

3.2.3. Seedling Vigor Index

Vigor index one and vigor index two was significantly influenced by variety, storage duration, interaction of variety x storage duration. In addition, Vigor index one also influenced by interaction of seed source x storage period. Also, vigor index two was significantly influenced by interaction of variety x seed source and three factors interaction (variety x seed source x storage duration) Table A1. The assumption for the importance of this index is that vigorous seed produces strong and healthy/uniform seedlings having better field establishment and exhibiting relatively greater longevity. Vanangamudi reported that the vigor index of any seed is the sum of those properties of seed which determine the potential level of activity which help to withstand under a wide range of field condition [38]. Seed vigor indicates that seed properties, which determine the potential for rapid, uniform emergence and development into normal seedlings under a wide range of field conditions [37]. Vigor is not a single measurable character but a concept describing different attributes, which are associated with the various aspects of performance of germinating seed or the subsequently growing seedling [2]. Seed vigor has quantitative and qualitative values that describe the quality of a seed lot based on observation of seedling growth [7].

Highest vigor index one (1012.68) was registered for *Cheri* variety stored for one year. The seeds of *AFGAT* variety stored for one year had non-significant difference with vigor index one of *Davis* variety stored for one year. Least vigor index one (411.71) was estimated for *Davis* variety stored for two year (Table 9). This showed that the prolonged storage duration decreases vigor index one. Sterlic (2010) observed the reduction in vigor index of two wheat varieties which were stored for varying storage periods up to 360 days and the reduction in seedling length were attributed to the decline in vigor through storage.

Table 9. *Interaction effect of variety x storage duration on vigor index one of soybean varieties during pre-sowing test at Pawe in 2019.*

Variety	Storage duration	Vigor index I
AFGAT	One year	879.67^{b}
Cheri	One year	1012.68^{a}
Clark-63k	One year	835.78^{c}
Davis	One year	868.05^{bc}
AFGAT	Two years	527.81^{e}
Cheri	Two years	638.98^{d}
Clark-63k	Two years	493.29^{e}
Davis	Two years	411.71^{f}
LSD (0.05)		42.55

Highest vigor index one was estimated from both seed source and stored for one year with statistical parity while least vigor index one was estimated for both seed source and stored for two years with statistical parity (Table 8). This showed that the prolonged storage duration decreases vigor index one. This might be due to the ageing or deterioration of seeds which accompanied by progressive process and accumulation of metabolites thereby progressively depresses growth of seedling with increased age [14].

Higher vigor index II was recorded for both sample seeds of *Clark-63k* variety from irrigation and *Cheri* variety from rain-fed seed source and stored for one year. Seeds of *AFGAT* and *Davis* varieties from irrigation had non-significant with vigor index II seeds of *AFGAT* and *Clarck-63k* from rain-fed seed source and stored for one year. Vigor index II from seed of *AFGAT* variety of from rain-fed had non-significant with vigor index II from seeds of *AFGAT* and *Clarck-63k* varieties from irrigation seed source and stored for two years. Lowest vigor index II was estimated for seeds of *Davis* variety from irrigation, *Clarck-63k* and *Davis* varieties from rain-fed seed source and stored for two years with statistical parity (Table 10). This showed that the prolonged storage duration decreases vigor index two at both seed source. This might be due to the ageing or deterioration of seeds which accompanied by progressive process and accumulation of metabolites thereby progressively depresses growth of seedling with increased age [14].

Table 10. *Interaction effect of variety x storage duration x seed source on vigor index two of soybean varieties during pre-sowing test at Pawe in 2019.*

Variety	Storage duration	vigor index II	
		Irrigation	Rain-fed
AFGAT	One year	119.37^{cd}	131.68^{c}
	Two years	82.31^{ef}	82.95^{ef}
Cheri	One year	114.60^{d}	148.83^{ab}
	Two years	90.71^{e}	92.60^{e}
Clark-63k	One year	149.60^{a}	126.83^{cd}
	Two years	76.37^{ef}	71.13^{f}
Davis	One year	124.33^{cd}	132.43^{bc}
	Two years	67.06^{f}	67.98^{f}
LSD (0.05)		16.94	

3.3. Relation Between Pre-sowing Seed Quality and Seed Yield and Related Traits

The correlation analysis was conducted between seed quality traits of four soybean varieties and seed yield and yield related traits to understand the relationship between seed quality as affected by storage durations, seed source and yield and related traits after sowing the seeds in the field. The results showed that all pre- sowing seed quality traits of four soybean varieties had positive and significant correlation coefficient with seed yield except hundred seed weight, moisture content, shoot length, root length and seedling dry weight (Table 11). Number seed per pod also had positive and significant correlations with germination percentage, speed of germination, vigor index one, and vigor index two of seeds. Number of pods per plant had positive and significant correlations with germination, speed of germination, seedling dry weight, vigor index one and vigor index two. Number of branches per plant had positive and significant correlations with germination percentage, speed of germination, vigor index one and vigor index two. Also, days to maturity had positive and significant correlations with moisture content and shoot length. Days to flowering had positive and significant correlations with moisture content and shoot length. However, the correlation coefficient of seed root length with days to maturity was negative and significant (Table 11).

The significant correlation between pre- sowing seed quality parameter with seed yield, biological yield and harvest index indicate the true relationship between the parameters and selection of appropriate storage period which the variety will be effective, since these characters had high correlation and also high direct effect thus direct selection for these characters should be a major concern for seed grower and plant breeders. The present finding confirms with Arshad reported that seed yield per plant was positive and significantly correlated with plant height, germination percentage, vigor index, pods per plant, 100 seed weight and biological yield [5].

The significant correlation between most pre-sowing seed quality parameters with phenological and yield component of soybean may be due to high deterioration of seeds contributing the production of weak seedlings and increase the plant performance on the field and finally influence seed yield and yield components. The relationship of seed quality with phenological and yield components were direct or indirect. The result was agreed with Singh and Chaudhary who reported that when the correlation coefficient between a causal factor and the effect (i.e., seed quality, yield components) is almost equal to its direct and indirect effect and the correlation explains the true relationship and direct selection through this trait will be effective [34].

Table 11. *Pearson correlation coefficients of pre-sowing seed quality parameters as influenced by seed source and seed storage duration, seed yield and yield related traits of soybean varieties.*

	DF	DM	PH	NBPP	NPPP	NSPP	SY
PS	-0.08^{ns}	-0.05^{ns}	-0.10^{ns}	0.15^{ns}	0.20^{ns}	0.25^{ns}	0.32*
HSW	-0.26^{ns}	-0.20^{ns}	-0.14^{ns}	-0.05^{ns}	0.01^{ns}	-0.26^{ns}	0.15^{ns}
MC	0.35*	0.32*	0.28*	-0.11^{ns}	0.01^{ns}	0.07^{ns}	-0.01^{ns}
GP	0.15^{ns}	0.09^{ns}	0.14^{ns}	0.41**	0.62**	0.40**	0.78**
SG	0.14^{ns}	0.07^{ns}	0.13^{ns}	0.40**	0.61**	0.40**	0.77**
SL	0.57**	0.29*	0.47**	-0.01^{ns}	-0.01^{ns}	-0.005^{ns}	-0.16^{ns}
RL	-0.19ns	-0.39*	-0.242^{ns}	-0.11^{ns}	-0.08^{ns}	-0.03^{ns}	-0.08^{ns}
SDW	-0.08^{ns}	-0.04^{ns}	-0.07^{ns}	-0.10^{ns}	-0.28*	-0.20^{ns}	-0.19
VI1	0.26^{ns}	0.11^{ns}	0.22^{ns}	0.38**	0.58**	0.38**	0.70**
VI2	0.10^{ns}	0.08^{ns}	0.09^{ns}	0.37**	0.50**	0.30*	0.72**

*,**, ns = correlation is significant and non-significant at 0.05 and 0.01 probability level, respectively. PS = pure seed, HSW = hundred seed weight, MC = moisture content, GP = germination percentage, SG = speed of germination, SL = shoot length, RL = root length, SDW = seedling dry weight, VI1 = vigor index one, VI2 = vigor index two, DF = days to flowering, DM = days to physiological maturity, PH = plant height, NBPP = number of branches per plant, NPPP = number pod per plant, NSPP = number of seed per plant, SY = seed yield.

4. Summary and Conclusion

Soybean [*Glycine max* (L.) Merrill] is among the important legume crops produced in Ethiopia including the northwestern part of the country for home consumption and as domestic and export commodity. However, the availability of quality seeds is one of production constraints. The production of seeds from improved varieties from right seed source and stored for shortest possible duration period are among the requirements of quality seed production. Therefore, this study was conducted to assess the effect of seed source and storage duration on seed quality of four soybean varieties and its subsequent effect on growth, yield and its components and seed quality of soybean. The treatments were four varieties (AFGAT, Cheri, Clark 63k and Davis) x two seed source (rain-fed and irrigation) x two storage duration (one and two years stored under room temperatures) arranged in factorial combinations. Completely randomized design with four replications in laboratory and randomized complete block design with three replications on field were used to evaluate treatments at Pawe Agricultural Research Center experimental laboratory and site during 2019/2020 cropping season.

The results from pre-sowing test revealed that seed quality parameters were significantly influenced by one or more main factors (variety, seed source and storage period). Moisture content, abnormal seedling, shoot length, root length and vigor index two was significantly influenced by interactions of variety x seed source x storage period. Hundred seed weight was significantly influenced by interaction of variety x seed source. Germination percentage of seeds was significantly influenced by interaction of seed source x storage period, and variety x seed source whereas speed of germination was significantly influenced by interaction of variety x storage duration and seed source x storage period.

The effect of soybean seeds as influenced by three main factors (variety, seed source and storage period) and all possible two and three factors' interactions on seed quality parameter was evaluated in laboratory. The highest moisture content (10.50%) was estimated from seeds of *Cheri* variety from rain-fed seed source and stored for two years while lowest moisture content (8.16%) was estimated from seeds of *Davis* variety from irrigation source and stored for one year. The highest germination percentage (92.25%) was estimated from seeds of *Cheri* variety stored for one year while lowest germination percentage (41.37%) was estimated from seeds of *Davis* variety stored for two years. Most of the seed quality parameters from pre-sowing test had significant and positive correlation with seed yield and related traits. Moreover, the proportion of pure seeds, germination percentage of seeds, seedling vigor index one and two had positive and significant correlation with seed yield.

The results from experiments showed that after growing the soybean seeds of different quality influenced by variety, storage duration, seed source and interaction of the two and/or three factors had significant effect on seed quality parameters. In most cases, the seeds of improved varieties from irrigation and stored at room temperatures for one year produced high quality seeds. Thus, it is suggested to consider varieties; seed source and seed storage duration to produce high yield and quality seeds to improve the productivity of soybean. However, to come to a conclusive recommendation, additional experiments should be conducted at different locations using more number of varieties, seed source and storage durations.

Appendix

Table A1. *Mean squares from analysis of variance for pre-sowing seed quality parameters of soybean varieties at Pawe in 2019.*

Parameter	Variety (3)	Seed source (1)	Storage (1)	V*Ss (3)	V*Sd (3)	Ss*Sd (1)	V*Ss*Sd (3)	Error (32)	CV (%)
Hundred seed weight	5.31**	0.18	1.02	2.81*	0.28	0.18	1.11	0.65	8.11
Moisture content (%)	2.005**	0.25	0.25	2.17**	1.61**	0.42	1.56**	0.15	4.26
Speed of germination	7.40	0.05	565.60***	1.31	1.35**	4.17***	0.15	0.19	4.31
Standard germination (%)	349.95**	7.56	23180.06**	33.6	54.68**	169.00**	1.37	4.69	3.15
Abnormal seedling (%)	46.97**	6.89	467.64**	8.84**	7.18	15.01**	9.14**	1.97	16.26
Dead seed (%)	165.68**	28.89	17062.89**	14.22	62.39**	83.26**	3.59	4.28	9.1
Shoot length (cm)	20.21**	5.76**	2.06*	3.29**	2.98**	0.005	6.77**	0.35	4.85
Root length (cm)	3.25**	1.08*	0.03	1.07*	0.54	0.67	2.79**	0.26	6.25
Seedling dry weigh (mg)	0.009	0.0001	0.15*	0.09*	0.05	0.29**	0.04	0.02	9.93
Seedling vigor index one	108961.82**	54.64	2323780.11**	5593.68	10748.98**	14763.46**	1353.68	1363.01	5.21
Seedling vigor index two	512.72*	226.5	43383.68**	703.88	612.20**	283.5	419.31*	142.09	11.36

ns, * and **= non-significant significant, significant at $P<0.05$ and $P< 0.001$ probability level, respectively. V= Variety, Ss = Seed source, Sd= Storage duration and CV (%) = Coefficient of variation. Number in parenthesis represents degree of freedom for the respective source of variation.

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