EFFECT OF SEED RETENTION ON SOYBEAN (*GLYCINE MAX* L.) PRODUCTION IN SOUTH AFRICA

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DECLARATION

I, Zuzumuzi Sizwe Buthelezi hereby declare that this mini-dissertation for the degree BSc. Agric. Hons-Agronomy at the University of the Free State is my own work and has never been submitted by myself at any other university. The research work reported here is the result of my investigation except where acknowledged.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Soybean (*Glycine max* L.) is a leguminous crop and the world's primary source of protein and edible oil. It also vital for human daily existence due to a number of its important uses that include but not limited to livestock feed, industrial uses such as paints, printing inks, soap, and insecticides. However, its production is highly affected by high use of farm-saved or stored seeds because seed viability is decreases with time, especially with resource-smallholder farmers. To examine the effect of storing seeds on seed viability, an experiment was carried-out at the Agronomy Lab at the University of the Free State. The influence of seed retention seed viability and seedling growth parameters (length of coleoptile and shoot, fresh weight and dry weight per seedling) was studied. Although the response to storage duration differed from one cultivar to another, but in most cases germination, seedling growth of S1 was significantly lower than S2 and S3, and there was no significant difference between S2 and S2. The results further revealed that a decline of 38% in germination after 12 months from harvest could result.

Keywords; soybean, seed viability, seed vigor, storage

1 CHAPTER 1: INTRODUCTION

Soybeans (*Glycine max* L.) are native to Manchuria, China. The crop is recognized as one of the five oldest cultivated crops and was utilized by the Chinese as a source of food before 2500 BC. However, it was only discovered by the western world as a source of oil and protein in the 19th century. In the past 35 years, world production of soybean increased to more than 100 million metric tons. Of this, 51% is produced by the United States of America (USA), 20% by Brazil, 10% by Argentina and 10% by China (Table 1). The first report of soybean production in South Africa is believed to be in the Cedara Memoirs of 1903 (DAFF, 2010: IITA, 1984).

Table 1: Major soybean producing countries (Karuga, 2018)

Country	Production (million tonnes)
United States of America	108
Brazil	87
Argentina	53
China	12
India	11
Paraguay	10
Canada	6
Ukraine	4
Bolivia	3
Uruguay	3
Total	**297**

Even though soybeans have incredible nutritional qualities, they form a very small percentage of the average household's diet in South Africa (Dlamini, et al., 2014). The primary uses of soybeans include soybean oil, soybean cake (full fat cake and low fat cake) and soybean products for human consumption, with the latter being relatively low. Soybean consumption for oil and protein is about 25%, whilst ab out 60% is for animal feed. Seeds furnish one of the world's most important sources of oil and protein. Unripe seeds are eaten as a vegetable and dried seeds are eaten whole, split or sprouted (DAFF, 2010). Soybean grain is a source of protein and maybe used for all types of livestock (PANNAR, 2006).

The use of pure and high quality seeds is a first prerequisite for soybean production. However, resource-poor smallholder farmers normally produce soybean from farm-retained seeds. They harvest and store seeds to use them for next planting season. This is because new cultivars are expensive. However, this practice does not only prevent seed companies from investing in soybean industry, thus preventing new and improved cultivars from entering local market, but also affect food security because farm-saved seeds lose viability and vigor over time (GrainSA, 2018 and PANNAR, 2006).

The need to test viability of retained seeds is to inform if the practice of retaining seeds from the previous season contributes to food insecurity especially on leguminous soybean, which remain a primary source of protein and edible oil in South Africa. The results of this study may be used to inform farmers about the effect of using retained in terms of seed viability, and subsequent effect of such practices on food security.

1.1 The objective of the study

This study aims at determining the effect of storing or retaining soybean seed on:

- Seed viability and vigor

2 CHAPTER 2: LITERATURE REVIEW

2.1 Soybean production

Soybean crop is one of the most important oil crops in the agricultural economy of the world as food for man (Kandil, 2013). The USA, Brazil, Argentina, China, and India are the top 5 soybean producing countries globally (Table 1).

South Africa's soybean production ranges from 450 000 to 500 000 tons per annum at an average of 2.5 to 3t/ha under dry land conditions (DAFF, 2010). In 2016/2017 season, yield were estimated to have reached 1.3 million tons at an average of 2.29t/ha; the highest yield record (Grain SA, 2017). Mpumalanga is the highest (42%) soybean-producing province, followed by Free State (22%), KwaZulu-Natal (15%), Limpopo, North West and Gauteng (2%).

2.2 Soybean germination and seedling growth

Seed germination process starts with imbibition (water uptake) followed by root protrusion. The whole process consists a number of interlinked events such as protein hydration, subcellular structural changes, respiration, macromolecular synthesis and cell elongation (Schabes *et al.,* 2006). According to Moshtaghi-Khavaran *et al.* (2014), proper seed germination and seedling establishment are the most vital processes in the survival and growth cycle of majority of field crops since it determines the uniformity, density of crop stand and water and nutrient efficient use by individual plant, which ultimately influences the yield and quality of soybean crop.

There are seven different developmental stages of seedling development (Figure 1). Stage 1: pre-emerging hypocotyl, Stage 2: emerging radicle 8-10 mm long, Stage 3: 15-20 mm long hypocotyls, Stage 4: 30:35 mm long, Stage 5: primary root development, Stage 6: cotyledons growing straight from the hypocotyl and the last stage is stage 7 with a fully developed root system, and unifoliate leaves exposed (Figure 1).

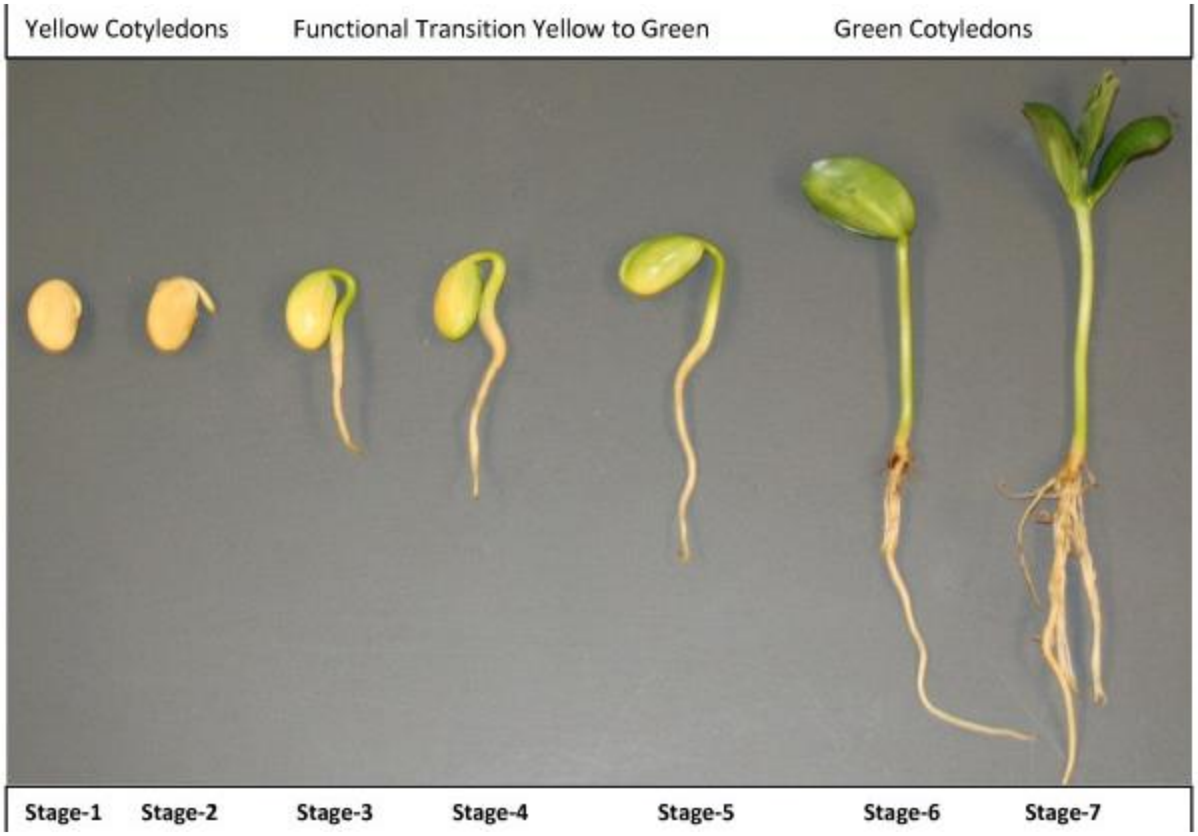

Figure 1: Soybean seedling development stages (Shamimuzzaman & Vodkin 2013).

2.3 Storage conditions effect on seed viability

Seed quality is a multiple criterion that encompasses several important seed attributes: genetic and chemical composition, physical condition, physiological germination and vigor, size, appearance and presence of seed borne pathogens, and moisture content. During storage, seed quality can remain at the initial level or decline to a level that may render the seed unacceptable for planting purpose (Simic, *et al.,* 2006).

Storage conditions (temperature and humidity), seed moisture content and duration are important factors affecting germination parameters. According to Shelar *et al*. (2008) soybean seed quality is affected during pre and post-harvest periods. Soybean seed reaches its maximum potential for germination and vigor at physiological maturity. The germination potential (viability) is very short-lived in soybean as compared to other oilseed crops. Loss of viability is one of the basic reasons for low productivity in soybean. Under favorable storage conditions, the initiation of decline in germination may be from few months to many years depending on storage conditions, seed type and conditions during seed development.

Soybean is short-lived as compared to other major crop species. In subtropical and tropical areas, poor storability of soybean seed is a major constraint on production. Seed viability often drops to an extent that it is worthless for planting within a few months after harvest (IITA, 1984). Nasreen *et al*. (2000) observed that seeds with low and medium moisture content have high germination percentage except at a temperature of 37 and 57 °C, at which germination percentage declines after two months. Similar results were reported by De Alencar, *et al.* (2006), in which soybean grain stored with moisture content of 14.8 at 40°C strongly deteriorated and were classified as out-of-market standard after 90 days. Storage conditions also have a significant effect on the average of root length, shoot length, seedling fresh weight and seedling vigor index. Kandil, *et al.* (2013) reported that storage under refrigerator conditions at 10°C surpassed ambient conditions in root length, shoot length, root/shoot ratio by 5.47, 1.94, 2.60, 5.50 and 9.99 %, respectively.

3 CHAPTER 3: MATERIALS AND METHODS

3.1 Experimental site

This study was conducted at Agronomy Lab, Department of Soil, Crop, and Soil Sciences (29˚6’27.08” S, 26˚11’32.90”E).

3.2 Experimental design and treatments

The design of the experiment was factorial in a completely randomized design. There were two factors (cultivar and seed type) with 5 and 3 levels, respectively. Seeds were collected from Agricultural Research Council (ARC) – Grain Crops Institute. Five cultivars: (i) NS5009R (C1), (ii) PAN1532R (C2), (iii) DM5953R (C3), (iv) SSS5052TUC (C4), and (v) LS6161R (C5), each replicated 3 times were used in the current study. Commercial seeds (S3), freshly harvested seeds (S2), and seeds retained for1-year (S1) were used. The interaction between cultivar and seed retention type resulted in 15 treatments (C1S1, C1S2, C1S3, C2S1, C2S2, C2S3, C3S1, C3S2, C3S3, C4S1, C4S2, C4S3, C5S1, C5S2, and C5S3) as shown in Table 2.

Table 2: Treatment combination

Cultivar	Seed type	Combination	Code
NS5009R	Last year	Cultivar + seed type	C1S1
NS5009R	Freshly harvested	Cultivar + seed type	C1S2
NS5009R	Commercial	Cultivar + seed type	C1S3
PAN1532R	Last year	Cultivar + seed type	C2S1
PAN1532R	Freshly harvested	Cultivar + seed type	C2S2
PAN1532R	Commercial	Cultivar + seed type	C2S3
DM5953R	Last year	Cultivar + seed type	C3S1
DM5953R	Freshly harvested	Cultivar + seed type	C3S2
DM5953R	Commercial	Cultivar + seed type	C3S3
SSS5052TUC	Last year	Cultivar + seed type	C4S1
SSS5052TUC	Freshly harvested	Cultivar + seed type	C4S2
SSS5052TUC	Commercial	Cultivar + seed type	C4S3
LS6161R	Last year	Cultivar + seed type	C5S1
LS6161R	Freshly harvested	Cultivar + seed type	C5S2
LS6161R	Commercial	Cultivar + seed type	C5S3

3.3 Data collection

Seed vigor, a single concept reflecting several characters determines the seed quality and uniform emergence potential of plants in field under variable range of environments. There is no universal seed vigor testing method because seed vigor is influenced by multiple factors. The most widely used methods are standard germination test and accelerated aging test (Sharma, 2018).

a. *Germination test*

A standard laboratory germination test was carried-out to determine germination. Germination percentage was determined using the following model:

$$Germination\,\% = \frac{Number\ of\ germinated\ seeds}{Number\ os\ seeds\ used}\ x\ 100$$

Figure 2: Standard germination test

3.3.1 Growth test

a. Root, and shoot length

To evaluate seedling growth, seedlings were used to measure the root length, and shoot length. The average values were computed using caliper and expressed in millimeter. The same seedlings used for root length and shoot length were weighed to determine fresh weight. Thereafter, mean values were calculated and expressed in grams. Then, seedlings were oven-dried at 60˚C for 72 hours at to determine dry mass and average values were computed and expressed in grams.

3.4 Data analysis

The Statistical Analysis System (SAS) used to analyze the data collected from the experiment (Statistical Analysis System Institute Inc., 2001). Means were compared using the least significance difference (LSD) to test probability levels at 5 % (*P=0.05*) using Tukey's Studentized Range (HSD) Test as suggested by Dlamini (2015).

4 CHAPTER 4: SEED GERMINATION

4.1 Introduction

Seed germination process starts with imbibition and ends with root protrusion (Fanny *et al*., 2016). This process is of significant importance in the survival and growth cycle of field crops since it determines the uniformity and crop stand density, efficient use of nutrients and water available to individual plants and eventually affect the crop yield and quality. According to Shelar *et al.* (2008), germination capacity of soybean is short-lived compared to other oil crops. Germination drops to an extent that seeds are worthless for planting purpose (Simic *et al*., 2006). However, the extent in which germination declines might depends on the cultivar. Hence, the aim of this chapter is to investigate the effect of seed storage period on seed germination of different soybean cultivars.

4.2 Materials and methods

Five cultivars (C1, C2, C3, C4, and C5) were used in this experiment. Each cultivar had three seed types: S1, S2, and S3 (seeds retained from last year (2018) harvest period, freshly harvested seeds (2019-harvest period), and commercial seeds. Each treatment was replicated 3 times.

For each replicate, 20 seeds were randomly selected, and lined at 10-cm from the top of the filter paper. The filter paper was then wetted with distilled water, rolled and placed in an Erlenmeyer flasks filled with 250 ml distilled water. The flasks were incubated in a growth chamber at 31˚C for 5 days (Figure 2). After 5 days, the number of germinated seeds was recorded.

4.3 Results and discussion

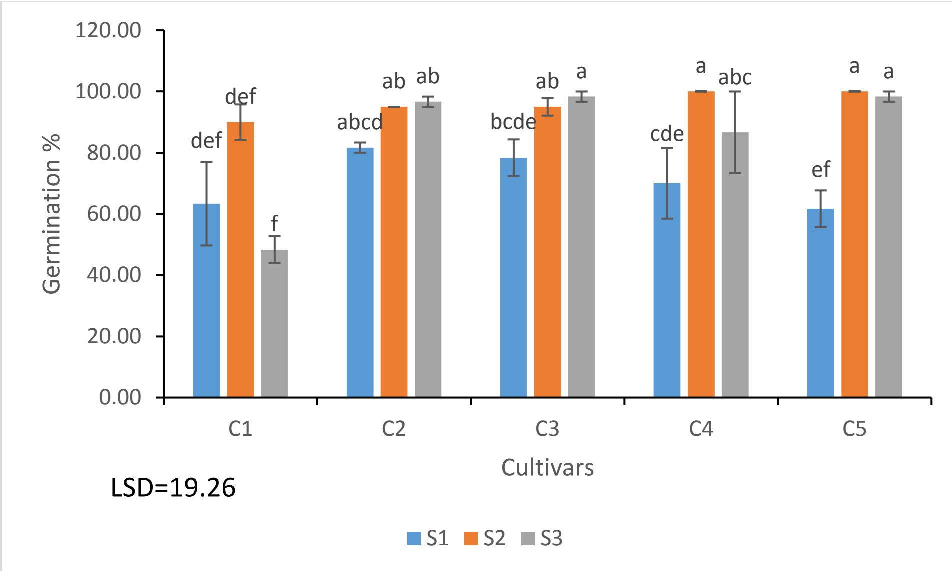

Figure 3: Germination of different cultivar as influenced by seed type.

In majority of the cultivars, except for C1, S1 germination was lower compare to S3 and S2. The results revealed that germination for C1S3 and C1S1 was 42% and 27% lower than that of C1S2, respectively. For both C2S1 and C3S1, germination was 15% and 20% lower than that of C2S3 and C3S3, respectively. The results further revealed a similar trend for all the cultivars after 1-year period from harvest. A decline in germination of all cultivars was observed. However, the extent of a drop in germination differed with cultivar. The highest decline was observed from C5 with a decline of 38.35%, followed by C4, C1, and C3 at 30, 26.65, and 16.65%. Cultivar C2 showed least reduction with 13.35% decline in germination after 1-year storage period.

This shows that storage duration and seed germination have an inverse relationship. In a similar study, Kandil *et al.* (2013) found that increasing storage period from 3, 6, 9 and 12 months decreased germination percentage by 5.73, 11.51, 24.44, and 33.42%, respectively compared to germination percentage of pre-storage treatment. In another study by Singh *et al*. (2016), seeds harvested from 2008 to 2015 were used to assess the effect of storage on germination of soybean seeds. Seeds from the year 2009, 2010, 2011, 2012, 2013 and 2014 showed 0, 0, 15, 40, 55, and 70% germination, respectively, while only seeds from 2015 showed 100% seed germination.

The results further show that there was no significant difference (*P<0.05*) between cultivar C2, C3, C4, and C5. Cultivar C1 showed significant decline (*P<0.05*) in germination compare to all other cultivars in the current study. There was a significant difference (*P<0.05*) between all seed types. S2 had a significantly higher germination percentage compare to S3 and S1. A significant decline in LY seeds was observed. This implies that beside cultivar differences, seed germination may also be influenced by retention period.

According to (Balesevic-Tubic *et al*., 2010) suggests that magnitude and rate of decline in seed quality depends on the plant species, initial seed quality, and genetic make-up of seeds. The difference in germination among cultivars may be attributed to the fact that seed genotypes differ in their ability to maintain seed longevity (Shelar *et al*., 2008).

4.4 Conclusion

Germination is a critical process for successful crop production, particularly for field crops such as soybean. The germination capacity of crops usually differs with cultivar and duration of storage period. The results of this study show that different soybean cultivars respond differently to retention, however there a decline in germination for seeds retained for a period of 1-year compared to freshly harvested seeds. The high decline of 38.35% in germination was observed in cultivar C5, and the least decline of 13.35% from C2. S2 showed significantly (*P<0.05*) higher germination compare to S3 and S1. The significantly lower germination observed from S1 was understandable since seed viability is lost over a period.

Therefore, it we conclude that seed retention has effects on soybean germination regardless of the cultivar. However, the magnitude and intensity of the effect differs with both cultivars and retention period. It remained unclear why S2 showed some superior than S3, as one would expect commercial seeds to be superior to all other seed types.

5 CHAPTER 5: SEEDLING GROWTH

5.1 Introduction

Crop yield and resource use efficiency depends on successful plant establishment in the field and it is seed vigor that determines their ability to germinate and establish seedlings fast and uniformly (Finch-Savage & Bassel, 2016). The proper seedling establishment is a critical process in the survival and growth of soybean crop since it influences the density of the crop stand and efficient use of nutrient and water resources available (Moshtaghi-Khavaran et al., 2014). The process of seedling establishment starts with seed germination and completes when seedling has gained photosynthetic capacity and become autotrophic. The post-germination development is fueled by storage reserves on seeds (Gommers & Monte, 2018). The aim of this section was to investigate the effect of storage duration on seed vigor.

5.2 Materials and methods

a. *Root, and shoot length*

To evaluate seedling growth, the root and shoot length were measured from germinated seedlings. The average values were computed using caliper and expressed in millimeter.

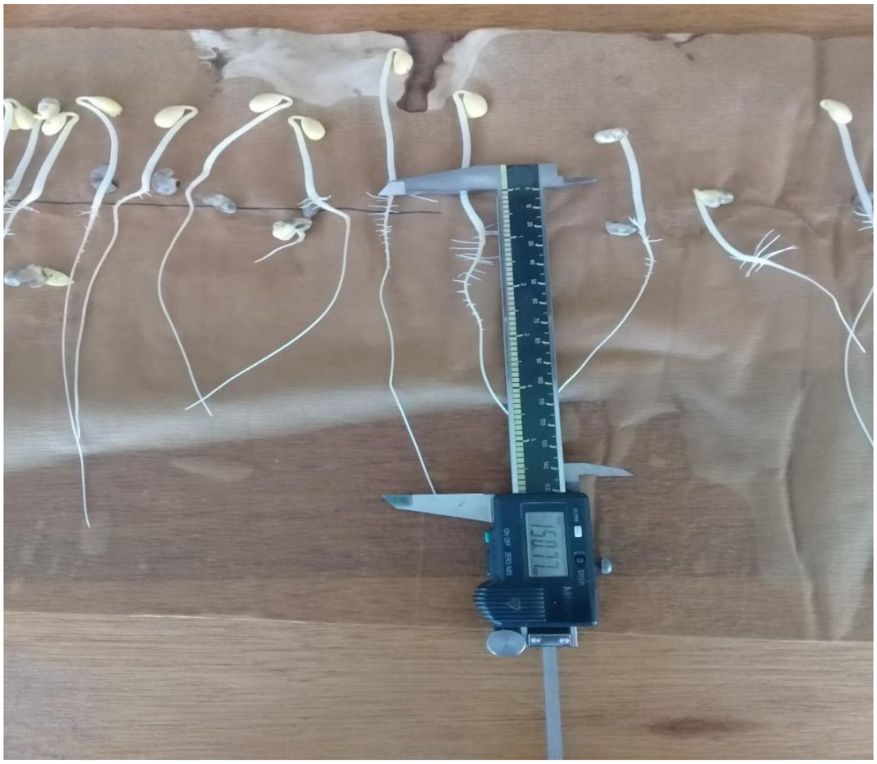

Figure 4: Measuring of root length using caliper

b. Seedling fresh weight

Seedlings that were used for root and shoot length determination were also weighed to determine fresh weight. The mean values were calculated and expressed in grams.

c. Seedling dry weight

Seedlings were dried at 60˚C for 72 hours, and then weighed for dry weight. The average values were computed and expressed in grams

5.3 Results and discussion

a. Shoot, and root length

Results reveal that there was a significant difference among cultivars in response to storage period in terms of both shoot, and root length. Shoot length for C4S2 was significantly ($P<0.5$) higher than the remainder of the treatments, while root length for C5S2 was significantly higher than other cultivars. The results further show that seed type had no effect for C2 and C4, but for other cultivars, and S1 was lower compare to S2 and S3 (Figure 5). These results are in line with the results reported by Kandil *et al*. (2013).

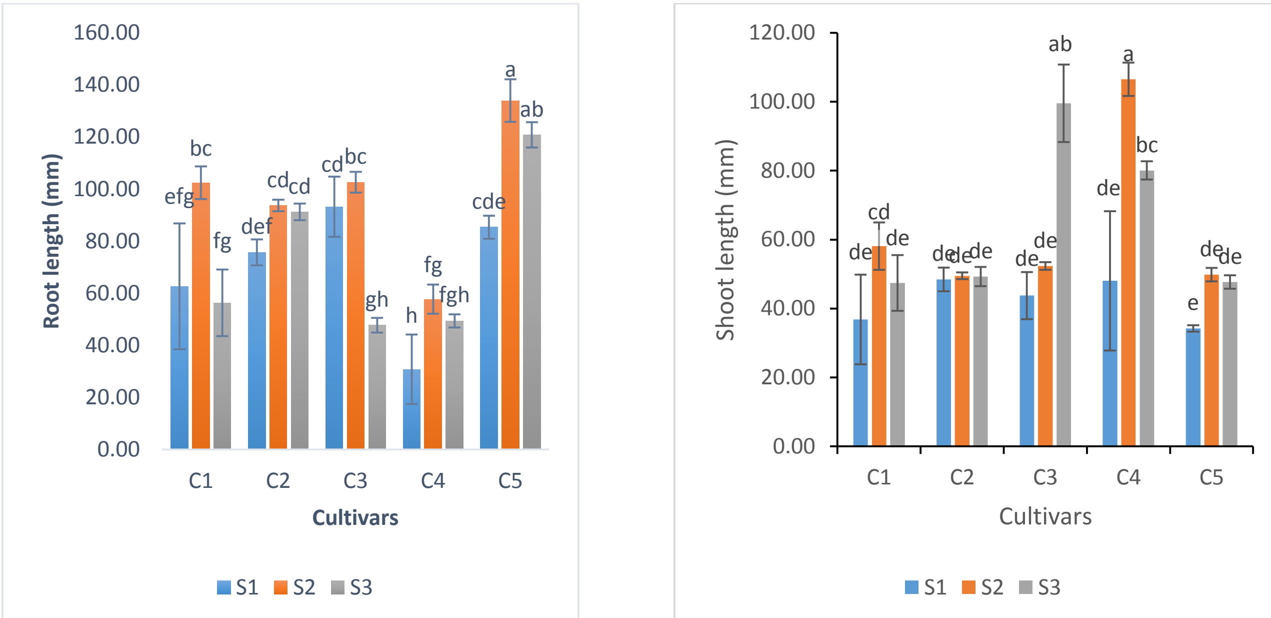

Figure 5: Response of (a) root length and (b) shoot length, to storage period.

b. Fresh weight and dry weight

For fresh weight, cultivars differed significantly, but for dry weight only C4 that was significantly lower (*P<0.05*) than all other cultivars. C5S3 and C3S3 fresh weights were significantly higher than the remainder of the treatments and a similar observation was made for dry weight.

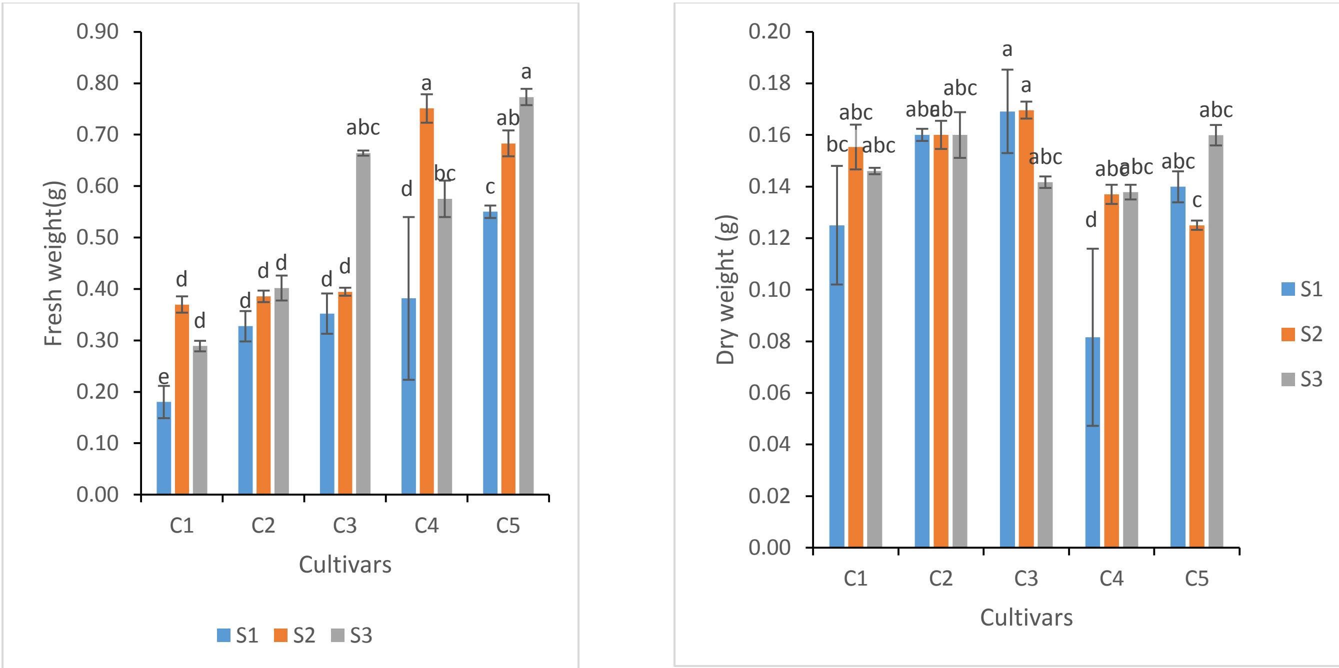

Figure 6: Effect of storage duration on fresh weight (a) and dry weight (b) of different cultivars.

5.4 Conclusion

Seed vigor is an important quality parameter defining seed germinability and seedling establishment. The aim of this chapter was to assess the effect of storage duration on seed vigor. The results revealed that there were difference between treatments. C3S3 and C53 means were significantly higher than the rest of the treatments. This implies that commercial seeds perform better than both fresh seeds and seeds that have been stored for 1-year period.

6 GENERAL CONCLUSIONS

The results showed that seed viability and vigor can be affected by storage. However, this may differ from one cultivar to another. In most seeds with one-year storage period produced lower results compare to fresh seeds and commercials.

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