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Research Article

Farmers' Practices in the Storage of Soybean (*Glycine max*) Seeds and Their Effects on Viability and Vigour of Seeds

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Abstract
A study was conducted to evaluate farmers' storage methods on the viability and vigour of soybean seeds in Northern Region of Ghana. Soybean seeds were obtained from certified seed producers in the Tamale Metropolis and farmers' seed lots from four districts (Kumbungu, Savelugu, Tolon and Yendi) in the Northern Region of Ghana. The work was carried out in three phases: a questionnaire survey using Snowball sampling method to identify farmers and ascertain how they store their seeds for planting; a field work to determine the viability and vigour of seeds obtained from farmers and finally a laboratory experiment in the regional ultra-modern seed laboratory of the Ministry of Food and Agriculture in Tamale, to confirm the results from the field experiment. The field experiment was conducted using Nested design. For the field and laboratory experiments, data were collected on the following parameters: germination percentages, plant/shoot height, number of leaves, root length and seedling dry weights. Results from the survey shows that farmers store their soybean seeds mainly in sacks placed on materials (wood and stones). Again, it was also revealed that farmers in Northern Region stored seeds from their previous harvest and use for planting rather than patronizing certified seeds. Farmers reported diseases and pests as the most important production constraint in the production of soybean in Northern Region. Results from the field and laboratory studies indicate that certified seeds are significantly ($P < 0.05$) better than farmers saved seeds in terms of vigour. Seed sources have an effect on viability and vigour.
Keywords: Certified Seeds, Farmers' Seeds, Germination, Seed Vigour, Viability and Storage Methods.

1. Introduction

Soybean (*Glycine max* (L.) Merrill) cultivation is increasing in Bangladesh due to its high demand for making animal feed as well as for different forms of human food. It is an important crop for the farmers of char land of Laxmipur, Noakhali, Chandpur, Sariatpur, Bhola and Barisal districts of southern part of Bangladesh (Sultana *et al.,* 2020; Chowdhury *et al.,* 2013). According to USDA (2020) soybean area and production level were estimated to 80,000 hectare and 152,000 tonnes, respectively in 2019. The soybean and soymeal imports were 1.1 million tons and 550,000 tons, respectively to keep pace with the demand in the feed industry. Farmers use soybean seeds of different sources for cultivation, such as their own preserved seeds, seeds from private sectors and Bangladesh Development Corporation (BADC, 2015).

The storage conditions and storage materials may enhance or damage the viability of soybean seeds to a great extent (Balesevic-Tubic *et al.,* 2010). Differences in micro-environment could be the possible cause of variation in seed viability which consequently subject seeds to loss or decline vigour. Differences in canopy position have been reported to cause variation in seed viability (Adam *et al.,* 1989; Smiciklas *et al.,* 1992). Quality attributes variation of seeds in a seed lot can result from variation between plant features of the crop where the seed lot is produced from, differences in natural conditions in a crop and differences occurring from cultural practices. Favorable temperatures and marginal rainfall for the period of seed development contribute to greater viability and vigour of seeds (Copeland and McDonald, 2001). Considerably less significant germination rates occur at late stages of seed development with higher temperature than initial stages of seeds (Spears *et al.,* 1997; Egli *et al.,* 2005).

Additionally, seed growth and development could be affected by environmental factors such as light, water and the type and amount of nutrients available (Pallais *et al.,* 1987). Seed quality and yield is said to be affected by insufficient water during seed filling as well as pathological damage (Dornbos *et al.,* 1989). Seed quality is a complex trait that is determined by the genetics, physical, physiological and health properties of a seed (Delouche and Baskin, 1973; Marco-Filho *et al.,* 1997; McDonald, 1999). These properties are in turn influenced by the agro-ecological conditions in the seed production field, seed handling and processing, storage conditions and storage period (McDonald, 1998; Vieira *et al.,* 2001). At each stage of the seed production process, great care is taken by the seed producer to ensure optimum quality. Seed vigour can be measured through germination rate, seedling length, root length, seedling fresh weight, seedling dry weight, seed longevity, and tolerance to adversity. These vigour-related traits are quantitative in nature and often interact with the environment during seed maturation, harvest and storage to determine the vigour of the seed at any point in time (Sun *et al.,* 2007). Even though soybean is a relatively new crop in Ghana (Akramov and Malek, 2012), the increasingly important role the crop is playing in the rural economy of farm households in northern Ghana, and especially the eastern corridor of the Northern Region of the country, cannot be overemphasized. Northern region alone contributes about 70 percent of national soybean area and about 77 percent of national production (SRID, 2012). Several soybean demonstrations are established annually in the region by both governmental and non-governmental organizations with the aim of increasing productivity and production. Etwire *et al.,* (2013) reported that the crop is gaining popularity and acceptance among farmers in Ghana including those of Saboba and Chereponi districts. Soybean is a legume and normally provides itself nitrogen, through a symbiotic relationship with nitrogen fixing bacteria of the species, *Bradyrhizobium japonicum* (Sarkodie-Addo *et al.,* 2006).

1.1. Problem Statement

A serious challenge in the soybean seed industry is the production of seeds with low vigour (TeKrony *et al.,* 1980). In many cases, the highest seed quality level achievable is lower than the least acceptable standards. The capability of seeds to be stored is mainly regulated by genetic character and this depends on seed quality during storage period, moisture content of seed or ambient relative humidity, pre-storage history of seed (environmental factors during pre-and post-harvest stages), duration of storage and biotic agents, temperature of storage environment (Baleševiæ-Tubic *et al.,* 2005; Shelar *et al.,* 2008; Khatun *et al.,* 2009; Biabani *et al.,* 2011). It is inevitable to eliminate seed damage during storage (Balesevic-Tubic *et al.,* 2005). Narayan *et al.,* (1988) stated that chemical, physical and biochemical changes can arise in soybeans; dependent on environmental conditions and time of storage, temperature and relative humidity parameters in storage are decided by the loss process of seed viability and changes in grain color and structure (Liu, 1997; Whigham and Minor, 1978; Lacerda *et al.,* 2003). Like all legume crops, soybean starts losing quality as soon as they are harvested, processed and/or even during storage. Soybean seed deteriorates much faster compared to various other crops (Priestley *et al.,* 1985). Soybean seed is more susceptible to mechanical injury due to its characteristically weaker structure which makes it deteriorate faster and loss of seed quality (TeKrony *et al.,* 1987; Lori *et al.,* 2001) in post-harvest handling (Shelar, 2008). The seed has a fragile thin coat and can develop cracks if too dry and while being handled, leading to deterioration. These cracks are further multiplied in storage (Ujjinaiah and Sreedhara, 1998; Parde *et al.,* 2002). Some seeds like soybeans, sunflower, peanuts and onions naturally have short shelf life due to its high lipid content and polyunsaturated acids (Jyoti and Malik, 2013).

Quality seed is essential for optimum stand establishment and maximum yields in soybeans (Wekesa *et al.,* 2015). The difference in the ability to retain germination during storage may also be attributed to differences in seed vigour (Delouche and Baskin, 1973). This is caused by depletion of stored food reserves reducing the vigour and viability. Loss of viability is the last step in the long process of seed deterioration (Delouche, 2016). Jyoti and Malik (2013) revealed that deteriorated seeds had reduced germination percentage, vigour, emergence growth uniformity, yield impaired biosynthetic mechanisms, increased leachates and abnormal seedlings and fungal infection such as purple stain. Long storage periods of soybean seed extending over three months in non-optimal storage conditions has been a major cause of loss of vigour and viability (Jaya *et al.,* 2014). Seeds of poor-quality as results of storage limit the potential yield and productivity of the farmer's labor, its therefore necessary to investigate farmers storage methods on soyabean seeds vigour and viability to enhance productivity.

1.2. Objectives

1) To identify how farmers' store soybean seeds for planting the next season.
2) To determine the effects of farmers' storage practices on the viability of soybeans seeds.
3) To examine the effects of farmers' storage practices on seed vigour of soybean.

2. Materials and Methods

The study was conducted in the Northern Region of Ghana which is located in the southern Guinea Savanna agro-ecological zone of Ghana. The Northern Region lies in latitude 9.5439°N and 0.9057°W, the vegetation of the area is characterized by grassland, predominantly drought-resistant trees such as acacia and baobab (*Adansonia digitata*). The region experiences a monomodal rainfall pattern which starts from May and ends in October with a dry period between November and April. The annual precipitation of the area ranges between 750 to 1050 mm.

2.1. Survey to Identify How Farmers Store Soybean Seeds

A survey was conducted in four districts in the Northern Region of Ghana (Kumbungu, Savelugu, Tolon and Yendi) to identify how local farmers store soybean seeds for planting the next season. The selection was based on the scale of production of soybean in the region.

2.2. Sampling Methods and Sampling Size for Survey

Purposive sampling was used to select the four districts for the study; simple random sampling method was also used to choose four (4) communities each in the four districts making sixteen communities. Finally snowball sampling method was used to identify hundred and sixty (160) soybean farmers in the various communities under the four districts.

2.3. Data Collection Procedures for Survey

Qualitative and quantitative data were collected using close and open-ended structured questionnaire for the survey work to identify how local farmers' store soybean seeds in their own way for planting the next season.

2.4. Field Experiment to Determine the Effects of Farmers' Practices on Viability and Vigour of Soybean Seeds

The field experiment was conducted at the research farm of the University for Development Studies at Nyankpala campus which lies on latitude 9°25 N and longitude 9°58 W with altitude 185m above mean sea level (SARI, 1997). Mean annual total rainfall is about 800 to 1200 mm, and is characteristically unimodal in distribution, which occurs from May to October with a dry season characterized by harmattan winds occurring between October to April. Temperature is uniformly high throughout the year, with mean minimum and maximum annual values of 25°C and 38°C respectively. The field work was conducted to determine the effects of farmers' storage practices on the viability and vigour of soybeans seeds.

2.5. Experimental Design and Field Layout

Nested design was used to lay the experimental field. Farmers were nested in communities and communities were also nested in districts.

2.6. Seeds Source and Sampling Method for Field Experiment

A total of 160 kg lots of sample seeds were purchased from 160 farmers (1 kg of seeds from each of the 160 farmers). Out of the purchased seed lots, fifty-four (54) farmers' soybean seeds of variety "Jenguma" were randomly selected from four districts. In each of the four districts where the survey was conducted, three communities were randomly selected, and for each community, four farmers were also randomly selected given a total of twelve (12) farmers in each district from whom seeds of soybean variety "Jenguma" were obtained. This gave a total of 48 seed lots. Three seed growers from the Tamale Metropolis were also selected from whom four seed lots each from their seeds (Jenguma) were also sampled and added to the 48 seed lots from the farmers making a total of 60 seed lots which were used for both the field and the laboratory for experiments.

2.7. Land Preparation

The field was ploughed using a tractor. It was then harrowed using tractor drawn harrow and demarcated into plots each measuring 0.1 acres (404.68m^2). The size of the experimental field was 0.5 acres (2,023.4 m$^{2)}$ in five plots. On July 7th, 2016 the seeds were sown. One seed was sown per hole at a spacing of 60 cm between rows and 5 cm between stands. Hundred seeds were planted per row for each treatment and replicated four times.

2.8. Data Collection Procedures in the Field

In the field, data were collected on germination count, plant height, number of leaves, seedling, shoot and root lengths, and dry weight shoot and root per plant.

2.9. Germination Count in the Field

Germination data was collected daily on the field by counting the number of seedlings which emerged daily. This lasted for two weeks (14 days) starting from the 4th day after planting. Germination percentage was calculated as follows:

Germination percentage = (Normal seedlings emerged/total seeds sown) × 100

Figure 1. Field germination in second week.

2.10. Plant Height

Plant height was measured from the ground level to the highest tip of the stem for ten sampled plants from each plot. This was done weekly for a period of four weeks with the aid of a meter rule. Average plant heights were subsequently calculated.

2.11. Number of Leaves

The number of leaves of the ten-sampled plants were also counted weekly for a period of four weeks. This was done manually, and the average sampled plants were also computed at each period.

2.12. Uprooting of Plants

Sixty-one days (61) days after planting, the ten sampled plants were removed from the field for each treatment and data on root and shoot length and root and shoot dry matter were collected.

Figure 2. Uprooted sampled plants in nine weeks after planting.

2.13. Seedling Root and Shoot Lengths

Seedling root and shoot lengths of the ten sampled plants were taken with the use of a meter rule to determine vigour. Vigour index was determined according (Abdul-Baki and Anderson, 1973) as follows:

Vigour Index = (Shoot length + Root length) × Germination %

2.14. Dry Weight

At 61 days after planting, fresh shoot weights were taken respectively from the ten sampled plants with a digital scale and subsequently oven dried in the laboratory at the University for Development Studies in the Nyankpala campus at a temperature of 100˚C for a period of twenty-four (24) hours and the dried weight were then taken.

2.15. Experiment 3: Germination Test in the Laboratory

The laboratory work was conducted at the Regional Ultra-Modern Seed Laboratory of the Ministry of Food and Agriculture in Tamale, Ghana. Germination test was conducted by using Between Paper (BP) Method in accordance with ISTA (1985). Hundred (100) seeds were randomly taken from each of the sixty (60) farmers' seeds initially sampled for the field test and replicated four times. The laboratory work was conducted to complement the field work and reaffirm the objectives below.

2.16. Procedure Used for Germination Test in the Laboratory

Seeds were plated in hundreds and kept in between two layers of paper towels placed on plastic bag in four replicates. The seeds were covered with an additional layer of paper. Towel papers were rolled and placed in an upright position. Finally, the substrates were placed in trays in a germinator which was set between 25˚C to 30˚C throughout the germination period while 12 hours light and darkness were both provided daily.

Figure 3. Seeds for laboratory germination test.

2.17. Data Collection Procedures in the Laboratory

Data were collected on the following parameters: germination count, root and shoot lengths.

2.17.1. Germination Count

In the laboratory, germination count was done daily on the germinated seeds from the 4th to 10th days as prescribed in the Association of Official Seed Analysts (AOSA, 1983). Seeds with emerged radicle were considered germinated.

Figure 4. Germinated seedlings at one week after laboratory test.

2.17.2. Shoot and Root Lengths

Shoot length was measured on the 10th day from the hypocotyl to the highest tip of the shoot for ten sampled plants from each treatment whilst root length was also measured on the same day from the hypocotyl to the tip of the root. The vigour index was determined and the recorded values were tabulated.

2.18. Data Analysis and Presentation

The survey data was analyzed using Statistical Package for Social Sciences (SPSS) version 17. The field and the laboratory experimental data were also analyzed in one-way ANOVA using GenStat Statistical Package (Edition 4) and the treatment means were compared using the Least Significant Difference (LSD) at 5 % level of probability. Results are presented in tables, and figures.

3. Results

3.1. Objective: To Identify How Farmers' Store Soybean Seeds for Planting the Next Season

3.1.1. Experiment 1: Survey to Identify How Farmers' Store Soybean Seeds

Table 1. Farmers' methods of storing soybean seeds.

Storage method	N = 160	Percent (%)
Kept in polybag, put in sacks and placed on top of wood	5	3.1
Kept in polybags, put in sacks and placed on bare floor	3	1.9
Put in sacks and placed on bare floor	36	22.5
Put in sacks and placed on racks	1	0.6
Put in sacks and placed on top of stones	15	9.4
Put in sacks and placed on top of wood	98	61.3
Store seeds in local pot	2	1.2
Total	**160**	**100**

It is revealed in Table 1 that 61.3% of soybeans farmers' store their seeds in nylon sacks placed on top of wooden materials and 22.5% store their seeds in sacks and placed on the bare floor. The practice of farmers where seeds are kept in sacks and placed on top of wooden materials is line with the findings of Dugje *et al.,* (2009) who suggests that 50-kg or 100-kg bags of clean soybean should be placed on a rack in the cold room or in shade. High moisture content in stored soybean encourages the development of various agents of deterioration, such as insects and microorganisms. Good storage management can greatly influence the storability of soybean and subsequent germination when planted in the field. Efforts should be made to ensure that soybean seeds are not exposed to high temperatures, as it will increase deterioration and reduce seed viability.

Table 2. Criteria for selecting soybean for planting by farmers.

Variety	N = 160	Percent (%)
Does not shatter	93	58.1
Early maturing	20	12.5
High yielding	46	28.8
Late maturing	1	0.6
Total	**160**	**100**

Table 2 shows that 93 soybeans farmers representing 58.1% select soybean variety based on its non-shattering ability while 46 (28.8%) farmers selected soybean variety based on yield. The choice of variety of soybean for cultivated by farmers in Northern Region is in response to Dugje *et al.,* (2009) finding which indicated that, the Jenguma (TGX 1448-2E) variety of soybean is recommended for the southern and northern Guinea savannas agro-ecological zones of West Africa for cultivation due to its desirable characteristic including its low shattering, medium maturity, high yield, high oil content and excellent grain color.

Soybean variety selection by farmers is based on maturity, yield potential, lodging, drought tolerance, and resistance to pests and diseases. It was expected the maturity period should have been the first consideration when farmers are choosing a variety suited to their geographical zone. Normally, varieties that are early maturing rather than late maturing are considered in areas with low rainfall. It is too risky to cultivate late-maturing varieties in drier locations because of late-season drought even though later maturity increases yield potential (Dugje *et al.,* 2009).

Table 3. Challenges in soybean cultivation.

Responses	N = 250	Percent (%)
Viability of seed	3	1.2
Marketing of grains	65	26
Poor germination of seeds	6	2.4
Pest and diseases	132	52.8
Poor access to input services	36	14.4
Inadequate finance	8	3.2
Total	**250**	**100**

Pest and diseases incidence (52.8%) are the most important challenge faced by soybean farmers in the Northern Region of Ghana (Table 3). Perceptions of farmers that disease and insect pests are the major challenge in soybean cultivation is surprising since soybean is a new crop. Responses from the study indicate that pest and diseases incidence is the most important challenge faced by soybean farmers in the Northern Region of Ghana. The responses by farmers that pest and disease are the most challenging factor in soybean production in Ghana is not supervising since similar findings are been discovered, in many locations, insect pest damage to soybean may be negligible. In some areas however, leaf eating caterpillars and pod-sucking bugs may cause serious yield losses if not controlled. The pod-sucking bugs suck sap from the developing pods and seeds causing them to shrivel and drop-off. Furthermore, Dugje *et al.,* (2009) also reported that, though several different insects occur in soybean fields, few are normally of any economic importance and the species that cause damage are usually not abundant enough to warrant control measures. In the vegetative stage, the crop is very tolerant of caterpillars but very susceptible to silver leaf whitefly attack. From flowering onwards, soybean becomes attractive to pod-sacking bugs that can seriously reduce seed quality.

Soybean farmers' perception on the effect of soybean seeds source on viability and vigour of seeds is shown in Figure 5. The results did show that about 79.4% of the farmers perceived that source of seeds have effect on germination, viability and vigour of seeds. Soybean grows in diverse agro-ecological conditions; therefore, seed germination and vigour are affected by numerous unfavorable environmental influences such as drought, extreme temperatures, untimely sowing, etc. (Casenave and Toselli 2007). It is common for soybean, even when stored properly, not to germinate after 12–15 months in storage, it easily loses its viability. Therefore, it is appropriate for farmers indeed to use seeds which have not been stored more than 12 months old to ensure good germination. Farmers are advised not to purchase seeds from the open market as the germination potential is not guaranteed.

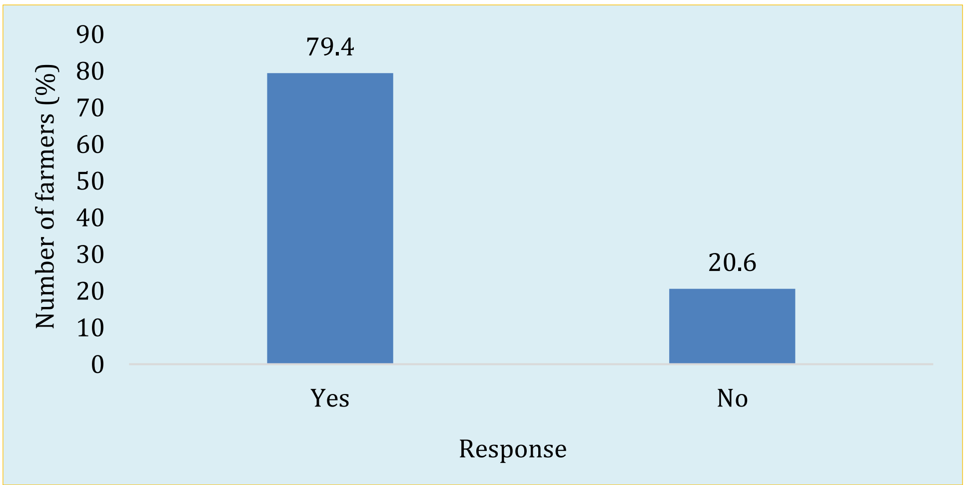

Figure 5. Seed source effect on viability and vigour of soybean seeds.

From Figure 6 below, 61.3% of the respondents said that storage method will not influence the viability and vigour of soybean seeds. The reason for this response from the farmers was that seeds that were immature and yet stored properly, would not germinate per their experience so therefore in their opinion storage methos will not affects seed viability and vigour, the pinion of the farmers collaborates with the work of Vasudevan *et al.,* (2008), who reported that in early harvested seed crop, the seed quality (viability and vigour) will be very poor due to a greater number of immature and undeveloped seeds. Similarly, Perry (1982) also reported that seed maturation is one of the main components of seed viability and vigour and a prerequisite for successful germination and emergence. Furthermore, farmers' experience of soybean easily losing its viability after 12 months of storage could also be a factor rather than how it was stored. Soybean seed is well known for its short storage life and is currently not carried-over to the next planting season (Nkang and Umoh, 1996). Also, the work of Gokhale (2009), further shows that the amount of moisture in the seeds, coupled with the temperature within the store is probably the most important factors influencing seed viability during storage.

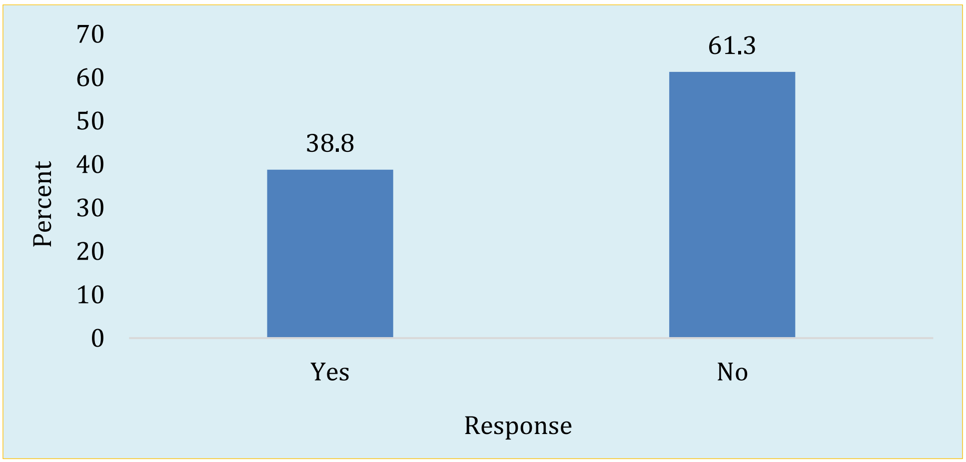

Figure 6. Storage method effect on viability and vigour of soybean seeds.

3.2. Objective 2: To Determine the Effects of Farmers' Storage Practices on the Viability of Soybeans Seeds

3.2.1. Experiment 2: Field Work to Determine the Effects of Farmers' Practices on Viability and Vigour of Soybean Seeds

3.2.2. Germination Percentage for Seeds Obtained from Different Sources in Two Weeks After Planting

The results of the effects of seed source on germination at 2 weeks after sowing (WAS) are presented in Table 4. The results show that there were significant ($p < 0.05$) differences in the percentage of germination among the various districts. Seeds obtained from Savelugu Municipality followed by certified seeds had the highest germination of 69.5% and 68.9% respectively while seeds obtained from Tolon District had the lowest (56.6%) percentage germination. The percentage germination of seeds from Savelugu Municipality was not statistically different from germination of seeds obtained from certified seeds, but was higher than those of seeds from Tolon and Kumbungu Districts and Yendi Municipality. There were also significant differences ($p < 0.05$) in germination percentage of seeds obtained among communities within districts as well as among farmers within communities. With regards to seeds obtained from communities in the various districts, germination percentages were not uniform. For instant Nyoglo and Challam communities in Savelugu Municipality recorded the highest percentage germination of 72.2% and 71.3% respectively and were not significantly different but were statistically much higher than seeds from Yong community within the same district. In the case of certified seeds, seeds obtained from Heritage Seed Company and Regional Seeds Inspection Unit (RSIU) had the highest germination percentage of 72.4% and 71.3% respectively which were not different but significantly higher than seeds from University for Development Studies (UDS) which had the lowest (63.1%) germination. With respect to Kumbungu District, seeds from Kpaliga community had the highest germination percentage and were significantly different from those from Cheshegu and Chayohi communities.

In Tolon District, seeds from Tuunaayili community had the highest percentage germination of 63.7% and were significantly different from seeds from other communities. Similarly, in Yendi Municipality, seeds from Tusani community had the highest germination percentage of 69.2% and statistically were different from seeds from other communities. Germination percentages of seeds obtained from farmers within communities in the same district were not uniform. For example, apart from seeds obtained from farmer 4 (f 4), seeds from all other farmers in Chayohi community in Kumbungu District were the same; seeds obtained from farmers in Cheshegu community were also not significantly different. Seeds from f1 in Gbulahigu community in the Tolon District were significantly lower than those from other farmers. Interestingly, seeds from farmers in Tuunaayili and Yipelgu communities respectively were not statistically different. In the same way, seeds from farmers within Kulkpanga and Kushegu communities in Yendi Municipality were not significantly different from each other. However, seeds from f2 and f4 in Tusani community had the highest germination percentage and statistically were different from seeds from f3. Surprisingly, except seeds from f4 which was significantly lower in germination percentage, seeds from other farmers in Heritage were significantly higher and similar. Farmers seeds obtained from and within RSIU and UDS were statistically similar in germination percentage. The difference in germination percentage could be attributed to the differences in weather conditions among the districts where the seeds were obtained especially during seed maturation. For instance, the locations of seeds from Savelugu Municipality and certified seeds from Tamale Metropolis had the same amount of rainfall and were the highest from September to November in the production year 2015 with 136.2 mm and 136.2 mm respectively while Tolon District had 119.8 mm. It is therefore possible that most of the seeds from Tolon developed during the tail end of the season when the rainfall was less. This observation corroborates with the work of TeKrony *et al.,* (1980) who pointed out that soybean seed viability can be reduced by extremes in rainfall.

Table 5 shows location effects on vigour index of plants from seeds from various districts, communities as well as farmers'. Significant differences ($p < 0.05$) were observed in vigour index of plants from seeds obtained from the various districts. Vigour index of plants obtained from seeds from Yendi Municipality had the highest value, which was statistically greater than that of other districts. However, vigour index of plants from seeds obtained from Savelugu Municipality and Tolon District were statistically similar. For communities in districts, vigour index of plants from seeds obtained from Chayohi community in Kumbungu District were significant with f4 being lower than the rest. Again, in Savelugu Municipality, vigour index of plants from seeds acquired from Nyoglo community were significantly different from plants from seeds obtained from Challam and Yong communities whose values were statistically the same. Additionally, vigour index of plants from seeds obtained from communities in Tolon District were statistically different from each other except those from seeds obtained from Gbulahigu and Yipelgu communities were similar. Similarly, vigour index of plants from seeds obtained from communities in Yendi Municipality were statistically different however vigour index of plants from seeds obtained from Kulpanga and Kushegu communities were similar. In the case of certified seeds, vigour index of plants from seeds obtained from RSIU and UDS were significantly different from each other however. The study further revealed significant difference in vigour index of plants from seeds obtained from farmers within communities in the same district. Within the certified seed category, vigour index of plants from seeds acquired from farmers in Heritage Seed Company were statistically similar. Again, vigour index of plants from seeds obtained from farmers' in RSIU were all statistically similar except that those from f1 and f2 as well as f1 and f3 were significantly different, in the same way, vigour index of plants from seeds from farmers' in UDS were statistically the same. However, those from f1 were statistically different.

Furthermore, vigour index of plants from seeds from farmers' in Chayohi community in the Kumbungu District were non-significant with the exception of vigour index of plants from seeds from f1 and f4, f2 and f4 as well as f3 and f4 which were significantly different. Yet still vigour index of plants from seeds from farmers' in Cheshegu and Kpaliga communities were statistically similar. Additionally, vigour index of plants from seeds from farmers' in Challam and Nyoglo communities in the Savelugu Municipality were identical statistically. Likewise, vigour index of plants from seeds from farmers in Yong community were significantly the same except that vigour index of plants obtained from seeds from f1 and f2, f2 and f3 as well as f2 and f4 were significantly different. Equally, vigour index of plants from seeds from farmers' in Gbulahigu community in Tolon District were statistically similar, excluding vigour index of seeds from plants from f1 and f2, f1 and f3 as well as f1 and f4 which were significantly different from each other. Again, vigour index of plants from seeds from farmers' within Tuunaayili community were statistically similar. In the same way, vigour index of plants from seeds from farmers' in Yipelgu community were statistically the same, apart from vigour index of plants from seeds from f2 and f4 as well as f3 and f4 which were significantly different. Additionally, with the exception of vigour index of plants from seeds obtained from f1 and f3, f2 and f3 as well as f3 and f4 which were statistically different in Yendi Municipality, vigour index of plants from seeds from all other farmers were statistically the same. However, in the case of vigour index of plants from seeds from farmers in Kushegu community, significance differences were not observed. Finally, with the exception of vigour index of plants from seeds from f1and f3, f2 and f3 as well as f2 and f4 where significant differences were obtained, vigour index of plants from seeds from other farmers were statistically similar.

The differences observed in vigour index among plant from seeds obtained from the districts could be attributed to variation in micro environmental and meteorological conditions at the time of seeds maturation. Yendi Municipality experienced the highest rain fall (147 mm) between Septembers to November in the production year 2015 while Kumbungu District had lower (135 mm) rainfall (Ghana Metrological Service, 2015). The current findings have agreed with the work of Rienke and Joke, (2005) and

Addo-Quaye *et al.,* (1993) who report that two periods are critical for soybean moisture requirement; from sowing to germination and flowering to pod filling periods). Similarly, the differences observed in vigour index between plants of seeds from farmers within communities in a particular district may also be due to variations in environmental conditions (soil nutrients and moisture as well as relative humidity) in the field where seeds were acquired. This is in line with the findings of Sun *et al.,* (2007), who indicated that seed production environments are defined by the availability of soil nutrients, soil moisture and humidity during seed development and maturation. It is also reported that differences in micro-environment could be the possible cause of variation in seed viability which predisposed seeds to loss or decline in vigour (Smiciklas *et al.,* 1992; Adam *et al.,* 1989). Seedling lengths along with germination percentage have significant and positive association with seed vigour (Egli and TeKrony, 1996; Rezapour *et al.,* 2013).

3.3. Objective 3: To Examine the Effects of Farmers' Storage Practices on Seed Vigour of Soybean

3.3.1. Experiment 3: Laboratory Experiment to Determine the Effects of Farmers' Practice on Viability and Vigour of Soybean Seeds

Table 6 shows the results of the laboratory germination test over time. Significant differences ($p < 0.05$) were observed in the germination of seeds from among the various districts. Seeds from Yendi Municipality had the highest germination percentage after 10 days of laboratory experiment and were significantly different from seeds from the other districts whereas Tolon District had the lowest. Germination of seeds from Kumbungu District was not statistically different from those of seeds from Savelugu Municipality. Also, there was significant difference in percentage of germination of seeds obtained from communities in the same districts. The results further revealed significant difference in seeds from farmers in the same communities in the same district. The results of the laboratory germination test indicate the mean percentage germination ranged from 66.2% with seeds from Tolon District to 79.7% for seeds from Yendi Municipality with significant differences ($p < 0.05$) between the districts. There were also significant differences in germination of seeds from different communities within the same districts. In Savelugu Municipality, seeds from Nyoglo community recorded the highest germination percentage of 78 while those from Challam community recorded the lowest germination percentage of 68.9 but the percentage germination of seeds from Challam community was not significantly different from that of seeds from Yong community.

In Yendi Municipality seeds from Kushegu community recorded the highest germination whereas seeds from Kulkpanga community recorded the lowest germination but the percentage germination of seeds from Kulpanga community was not statistically different from those of Tusani community. Seeds from Tolon District which had the least germination in the field also recorded the least germination at the laboratory. The higher germination percentage recorded for seeds from Yendi Municipality may also be due to variation in environmental conditions as well as culture practices given to the mother plants during growth and also harvesting, processing and seeds source. For example, Yendi Municipality witnessed a higher rainfall of 147 mm during the period of seeds maturation (September to November) compared to Tolon District which recorded 119.8 mm rainfall during the same period (Ghana Metrological Service, 2015). This assertion is in line with the work of Gokhale (2009), who reported that fluctuations in environmental conditions during seeds production are a factor affecting seed viability. Differences among seeds from communities in the same districts and seeds from farmers in the same communities in the same district could further be due to variation in harvesting time and period of soybean. In early harvested seed crop, the seed quality (viability) will be very poor due to a greater number of immature and undeveloped seeds, while in delayed harvesting, seed quality (viability) is affected because of field weathering (Vasudevan *et al.,* 2008).

In the field germination, seeds obtained from Savelugu Municipality and certified seeds recorded the highest germination percentages of 69.5 and 68.8 respectively. However, seeds obtained from Tolon District had the lowest germination percentage of 56.6. Comparing both field and laboratory germination test, germination percentages for seeds obtained from the various districts and certified seeds were below the standard germination test figure of above 85%. This is worrying compared with the work of Dugje *et al.,* (2009), who reported that germination test of seeds should be carried out prior to planting; the rate of germination should be above 85% to obtain a good stand. The standard germination test, described in the Rules for Testing Seeds, the Association of Official Seed Analysts (AOSA, 1983), is the most widely accepted test for estimating seed viability internationally. Unfortunately, viability tests are inadequate predictors of field emergence for two reasons: 1) seldom are field conditions optimum as assumed by standard test conditions, and 2) seedlings are classified as either germinable or non-germinable after a seven-day period without regard to the progressive nature of seed deterioration (McDonald, 1980). Standard germination test according to Johnson and Wax (1978) and Vieira *et al.,* (1991) shows non-significant correlation with field emergence under unfavorable environmental conditions. Green and Pinnell (1968) reported that field emergence and laboratory germination tests have low broad sense heritability estimates due to large environmental variances.

Table 7 presents the results of vigour index of plants from seeds obtained from different sources ten (10) days after the laboratory experiment. Significant differences ($p < 0.05$) were observed in vigour index of plants from seeds obtained from among the districts. Plants from seeds from Yendi Municipality had the highest vigour index and were statistically different from those of seeds from other districts. However, vigour index of plants from seeds obtained from Tolon District was the lowest. In the case of communities within districts, vigour index of plants from seeds obtained from Chayohi community in Kumbungu District were significantly lower as compared to other two (Kpaliga and Cheshegu) communities. For Savelugu Municipality, vigour index of plants from seeds from Challam was highest while Young had the lowest vigour index. For Tolon District, vigour index of plants from seeds from Tuunaayili community was significantly higher and different from others. Vigour index of plants from seeds from Gbulahigu and Yipelgu communities were similar. Plants from seeds obtained from Kushegu community in the Yendi Municipality were more vigorous as compare to the rest. Vigour index of plants from seeds obtained from Tusani and Kulkpanga communities registered lowest and were similar in vigour index.

For certified seeds, vigour index of plants from seeds obtained from RSIU were statistically higher than the rest while vigour index of plants from seeds obtained from Heritage seeds grower and UDS were similar. With regards to vigour index of plants obtained from seeds from farmers within same communities, plants from seeds obtained from farmers' in Chayohi community in the Kumbungu District were statistically different, however, vigour index of plants from seeds from f2 and f4 were significantly similar. Plants from seeds from farmers' in Cheshegu community in the Kumbungu District were significantly different with seeds from f4 being more vigorous than others. Additionally, vigour index of plants from seeds from farmers' in Kpaliga community were statistically similar except f2 which was better than the others. Moreover, vigour index of plants from seeds obtained from f2 in Challam community in the Savelugu Municipality were higher than the rest, vigour index of plants from seeds from farmers in Nyoglo community were similar in most cases, except that f1 was significantly different from f2 and f4.

Similarly, vigour index of plants from seeds from farmers in Yong community were statistically different except for plants from seeds from f3 and f4 which were identical in vigour. Equally, plants from seeds from farmers in Gbulahigu community in the Tolon District were significantly different in vigour index with f4 seeds being most vigorous while those from f2 showed least vigour. Seeds from f4 in Tuunaayili community were more vigorous than the other farmers. In Yipelgu community, seeds from f2 had the least vigour index while those from f1 and f4 had the highest. Vigour index of plants from seeds from farmers' in Kulpanga community in the Yendi Municipality revealed that seeds from f4 were more vigorous as compared to those from others farmers. Likewise, vigour index of plants from seeds from farmers' in Kushegu community were statistically different with those from f1 being more vigorous than seeds from f3 and f4. In Tusani community, vigour index of plants from f1 were more vigorous than those from f2 and f3. Expectedly, vigour index of plants from seeds obtained from farmers' growing certified seeds from a particular seeds' producer did not show any significant difference (Table 7).

The differences in vigour index ten (10) days after the laboratory experiment might be due to variation in weather conditions of the sources of the seeds. Rainfall in Yendi Municipality from September to November of the production year in 2015 was 147 mm whereas Tolon District had 119.8 mm (Ghana Metrological Services, 2015). The environment where seed develops can have great influence on viability as well as seed viguor (Sun *et al.,* 2007). The finding of the present study is in agreement with Kandil *et al.,* (2013) who as well reported differences in root and shoot length and root/shoot ratio in soybean in a similar experiment. The differences in vigour index of plants from seeds obtained from communities as well as farmers' may be attributed to distinctions in natural environmental condition of the locations of the community where seeds were produced as well as individual farmers practices at the time of seed production and development. The current finding may be supported by the fact that seed growth and development could be affected by environmental factors such as light, water and the type and amount of nutrients available (Pallais *et al.,* 1987). Also seed quality is said to be affected by insufficient water during seed filling (Dornbos Jr *et al.,* 1989). Hampton, (1995) reported that, it is often significant for differences to occur in seed viability and vigour between and within seed lots, since many factors affects seeds quality attributes. The bases for these differences are the consequences of decisions made during planning of seed production and management or conditions of the environment for the period of growth and development (Carter and Hartwig, 1963).

Table 4. Field percentage germination of soybean seeds obtained from different sources at two weeks after sowing.

Districts	**Communities/farmers**				**Mean**	**Communities/farmers**				**Mean**	**Communities/farmers**				**Mean**	**District mean**
Kumbungu District	Chayohi				57.1	Cheshegu				65.5	Kpaliga				70.4	64.3
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	62.5	58.6	61.4	45.7		69.1	64.5	67.1	61.3		71.1	68.9	70.4	71.1		
Savelugu District	Challam				71.3	Nyoglo				72.2	Yong				65.1	69.5
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	72.1	71.6	69. 5	71.8		71.7	70.2	70.7	76.0		70.0	45.7	73.9	70.8		
Tolon District	Gbulahigu				56.3	Tuunaayili				63.7	Yipelgu				49.9	56.6
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	48.0	58.1	60.9	58.1		63.2	64.0	63.6	63.9		50.2	55.1	49.9	44.3		
Yendi Municipality	Kulkpanga				64.6	Kushegu				65.2	Tusani				69.2	66.3
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	67.2	61.7	64.2	65.3		64.5	64.5	67.8	63.9		68.1	72.7	63.9	72.2		
Certified seeds	Seeds from Heritage				72.4	Seeds from RSIU				71.3	Seeds from UDS				63.1	68.9
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
(Control)	74.0	71.9	76.7	67.0		74.9	72.9	68.9	68.6		65.1	65.8	58.8	62.6		

District: L.S.D 1.857, P-value, < .001
District*Community: L.S.D 3.216, P-value, <.001
District *Community*Farmer L.S.D 6.432, P-value, <.001
Where; f1 means farmer 1, f2 means farmer 2, f3 means farmer 3, f4 means farmer 4

Table 5. Vigour index of seeds obtained from different sources at nine weeks after sowing.

Districts	**Communities/farmers**				**Mean (10^2)**	**Communities/farmers**				**Mean (10^2)**	**Communities/farmers**				**Mean (10^2)**	**District mean (10^2)**
Kumbungu District	Chayohi				32.5	Cheshegu				34.7	Kpaliga				35	34.1
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	37.9	34.4	35.0	22.4		36.4	32.7	37.5	32.3		37.5	32.7	37.5	32.3		
Savelugu District	Challam				41.4	Nyoglo				41.6	Yong				36.9	39.9
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	39.7	40.6	42.3	42.9		44.7	40.3	42.2	39.1		44.7	20.7	41.7	40.6		
Tolon District	Gbulahigu				29.0	Tuunaayili				53.9	Yipelgu				32.4	38.5
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	20.3	31.9	31.8	31.9		54.4	52.4	56.7	52.3		33.7	38.8	33.0	24.2		
Yendi Municipality	Kulkpanga				49.3	Kushegu				51.8	Tusani				68.4	56.5
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	47.8	46.3	57.7	45.3		56.2	49.7	53.6	47.7		63.6	83.4	60.4	66.3		
Certified seeds (Control)	Seeds from Heritage				49.5	Seeds from RSIU				50.3	Seeds from UDS				45.5	48.4
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	54.6	47.3	48.2	47.8		57.2	47.5	44.9	51.3		50.1	48.2	39.9	43.7		

District: L.S.D 2.63, P-value, < .001
District* Community: L.S.D 4.55, P-value, <.001
District*Community*Farmer: L.S.D 9.10, P-value, <.001
Where; f1 means farmer 1, f2 means farmer 2, f3 means farmer 3, f4 means farmer 4
NB: Higher value means higher seed vigour

Table 6. Location (district) effects on laboratory germination at ten days for soybean seeds obtained from different sources.

Districts	Communities/farmers				Mean	Communities/farmers				Mean	Communities/farmers				Mean	District mean
Kumbungu District	Chayohi				65.8	Cheshegu				69.9	Kpaliga				80.7	72.1
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	74.2	64.7	72.2	52.1		73.4	74.7	73.5	58.1		79.9	81.8	81.4	79.6		
Savelugu District	Challam				68.9	Nyoglo				78.0	Yong				69.3	72.1
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	66.3	72.6	67.5	69.5		76.8	79.8	76.8	78.6		75.9	53.1	75.4	72.9		
Tolon District	Gbulahigu				59.8	Tuunaayili				75	Yipelgu				63.8	66.2
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	52.2	72.3	53.9	60.8		70.1	76.5	72.8	80.6		67.9	67.9	57.0	62.4		
Yendi Municipality	Kulkpanga				76.7	Kushegu				81.6	Tusani				80	79.4
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	77.6	74.2	77.5	77.5		81.6	81.4	84.6	78.9		80.1	82.0	81.0	76.9		
Certified seeds	Seeds from Heritage				73.3	Seeds from RSIU				71	Seeds from UDS				64.9	69.7
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
(Control)	79.7	79.4	66.3	67.8		74.2	72.9	67.7	69.2		68.3	66.5	61.2	63.8		

District: L.S.D 1.695, P-value, < .001
District* Community: L.S.D 2.936, P-value, <.001
District*Community*Farmers: L.S.D 5.872, P-value, <.001
Where; f1 means farmer 1, f2 means farmer 2, f3 means farmer 3, f4 means farmer 4

Table 7. Location (district) effects on vigour index of seeds obtained from different sources at ten days after experiment.

Districts	**Communities/farmers**				**Mean (10^2)**	**Communities/farmers**				**Mean (10^2)**	**Communities/farmers**				**Mean (10^2)**	**District mean (10^2)**
Kumbungu District	Chayohi					Cheshegu					Kpaliga					
	f1	f2	f3	f4	40.2	f1	f2	f3	f4	36.9	f1	f2	f3	f4	15.7	30.9
	14.4	67.0	12.9	66.6		16.9	16.9	16.8	97.3		12.5	21.4	13.4	15.4		
Savelugu District	Challam					Nyoglo					Yong					
	f1	f2	f3	f4	15.1	f1	f2	f3	f4	12.8	f1	f2	f3	f4	19.9	15.9
	14.5	19.4	12.6	14.0		10.4	14.2	12.4	14.2		14.9	43.1	10.3	11.4		
Tolon District	Gbulahigu					Tuunaayili					Yipelgu					
	f1	f2	f3	f4	50.7	f1	f2	f3	f4	14.1	f1	f2	f3	f4	63.7	42.8
	63.4	11.8	51.1	76.6		12.4	13.7	12.9	17.4		92.8	11.8	56.9	93.3		
Yendi Municipality	Kulkpanga					Kushegu					Tusani					
	f1	f2	f3	f4	15.9	f1	f2	f3	f4	22.0	f1	f2	f3	f4	16.9	18.3
	12.6	15.6	15.4	20.2		24.3	23.5	20.8	19.6		19.3	15.9	15.8	16.9		
Certified seeds	Seeds from Heritage					Seeds from RSIU					Seeds from UDS					
	f1	f2	f3	f4	12.3	f1	f2	f3	f4	16.3	f1	f2	f3	f4	11.3	13.3
(Control)	12.5	14.2	11.0	11.5		15.1	16.8	15.3	18.0		11.7	10.1	10.9	12.3		

District: L.S.D 0.93, P-value, < .001 NB: Higher value means higher seed vigour
District* Community: L.S.D 1.61, P-value, <.001
District*Community*Farmer L.S.D 3.23, <.001
Where; f1 means farmer 1, f2 means farmer 2, f3 means farmer 3, f4 means farmer 4

4. Conclusion

Soybean farmers in Northern Ghana primarily store seeds in sacks on wooden materials, many farmers believe that their storage methods do not affect seed viability and vigor, despite experimental evidence suggesting otherwise, farmers recognize that the source of seeds impacts viability and vigor, yet most prefer using their own seeds over purchasing certified ones, major production constraints identified by farmers include pests and diseases, farmers believe that soybean seeds stored for over a year should not be used for planting due to decreased viability, experimental results confirm that certified seeds have greater vigor, especially in leaf production.

No significant differences were found in plant height, dry shoot weight, and root weight between plants grown from certified seeds and those from farmers' seeds, despite the advantages of certified seeds, many farmers continue to rely on their own stored seeds, indicating a need for increased awareness and support for adopting quality seeds to improve soybean production.

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