



Soybean farm-saved seed viability and vigor as influenced by agro-ecological conditions of Meru South Sub-County, Kenya.

Grace J. Chirchir^{1*}, Maina Mwangi¹, Desterio O. Nyamongo², Joseph P. Gweyi-Onyango¹

¹Kenyatta University, School of Agriculture and Enterprise Development, Department of Agricultural Science and Technology, Nairobi, Kenya;

²Genetic Resource Research Institute, Kenya Agriculture and Livestock Research Organization, Kenya.

*Corresponding Author: gjchirchir@gmail.com;

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ABSTRACT

Objective: The experiment was conducted with the aim of assessing the soybean farm-saved seed viability and vigor as influenced by agro-ecological conditions of Meru South Sub-County, Kenya.

Methodology and results: Within one month of harvest, soybean farm-saved-seed was randomly sampled from 30 households in February 2013 from areas representative of agro-ecological zones Upper Midlands II (Ann. Mean temp. (18.2-20.6°C); Upper Midlands III (19.2-20.6°C); Lower Midlands III (20.9-22.9°C) and Lower Midlands IV (21-24°C). Standard germination, electrical conductivity and moisture content tests were done according to ISTA rules (2007). Analysis of Variance was done using SAS (9.2) and means separated using LSD. Results revealed that seed moisture was lowest in the warmer LM4 (6.3%) than in the cooler LM3 (8%); UM3 (8.4%) and UM2 (10%). In addition, soybean seed from the cooler agro-ecologies - UM2 (94%), UM3 (86.6%) and LM3 (99.5%) had significantly higher germination than seed from the lower warmer LM4 (57%). Similarly, seed vigor was highest in the cooler UM2 (41.7 μ /cm/g), UM3 (45.8 μ /cm/g) and LM3 (31.6 μ /cm/g) as shown by reduced seed leachates; indicative of better integrity of seed membranes than seed from the warmer LM4 (79.1 μ /cm/g). In addition, there was a strong negative correlation between electrical conductivity and germination, showing a faster deterioration due to leakage of electrolytes.

Conclusions and applications of findings: The soybean farm-saved seed germination and vigor were significantly influenced by agro-ecological conditions. Considering that seed moisture content in the lower warmer agro-ecologies was significantly lower than those from higher cooler agro-ecologies the observed seed deterioration was attributable to the higher temperatures characteristic of lower altitudes agro-ecologies. Therefore, since the farm saved seed viability and vigor was better retained in the cooler higher agroecological zones (UM2, UM3 and LM3) of Meru South Sub-County, farmers should source better quality soybean seed from these areas. The results validate the need for ecological zoning of suitable areas for the production of high quality soybean seed in Kenya.

Key words: soybean farm-saved seed, agro-ecological zones, seed germination and vigor.

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is a drought tolerant multipurpose crop grown for edible oil, industrial use, human food, livestock feed bio-energy source (Myaka *et al.*, 2005) and for soil fertility improvement (Vanaluwe *et al.*, 2003). The crop therefore has the potential to improve food and nutrition security, alleviate poverty in rural areas, protect the environment and increase incomes through increased productivity and value addition (Mathu *et al.*, 2010). In spite of this high potential and an equally high demand in the Kenyan market (50,000 to 100,000 metric tons), there is negligible domestic production (of 1,000 to 5,000 MT per year) and hence over-reliance on imports (MOA, 2012) due to various constraints. Low seed quality resulting in poor stand establishment is one major constraint to soybean production in Kenya. Farmers have continued to use mixed varieties of soybean sourced from grain markets occasioning low yields (MOA, 2009). This is in spite of the availability of high yielding, drought tolerant, early maturing and adaptable varieties for short day tropical conditions (Myaka *et al.*, 2005; Mathu *et al.*, 2010). In addition, farmers experience poor retention of soybean seed viability between harvest and the next planting season due to adverse tropical storage conditions (Tinsley, 2009). Research has shown that the rate of seed deterioration is positively related to ambient temperature, relative humidity and seed moisture content (Ellis and Roberts, 1982 & 1989, Shelar *et al.* 2008). Hence, for production of high quality

soybean seeds, maturation and harvesting phases should occur under mild temperatures (Costa *et al.*, 2005) together with dry weather conditions. In addition, increased pre-harvest period after a crop has attained harvest maturity in the field has been found to impact negatively on seed quality (Hinson and Hartwig, 1977, Priestley 1986). Because of the effect of adverse climatic conditions (such as short mini-droughts, irregular rainfall distribution and high temperatures) on production of high quality soybean seeds, a system has been developed in Brazil for identification of suitable agroclimatic zones for planting high quality soybean seed (Pádua *et al.*, 2014). Many researchers have also discussed the storability of soybean. Soybean has been placed among a group of least storable seeds in the "relative storability index" classification (Justice and Bass, 1978). High temperature and relative humidity has been found to increase deterioration rate of seed lots in storage (Harrington, 1972; Roberts, 1973). In Kenya, one of the issues cited in the National Seed Policy is the lack of information on viability and longevity of seed, including soybean seed, under different environmental conditions (MOA, 2010). Consequently, the need to determine the quality of soybean seeds in various agro-ecologies with a view to prescribe appropriate seed management strategies that will enhance soybean production to meet the high market demand was imperative. On this basis, this study was initiated in Meru South Sub-county, Tharaka-Nithi County of Kenya.

MATERIALS AND METHODS

Study Location: The study was carried out in Meru South Sub-County of Tharaka Nithi County in Kenya. The area is situated between Longitudes 37° 18'37" and 37° 28'33" East and Latitude 00° 07'23" and 00° 26'19" South (NEMA & MOA, 2007). It lies to the East of Mount Kenya and borders the Sub-Counties of Embu East to the South, Maara to the North West and Tharaka to the East. Administratively, the sub-county is divided into three

wards: Chuka, Magumoni and Igambang'ombe wards. **Site Characterization:** The altitude of the cultivated area ranges from 500 to 2,200m resulting in a wide range of climatic conditions and Agro-ecological zones (MOA, 2013). The soybean growing agro-ecologies include Upper Midlands II and III and Lower Midlands III and IV (Table 1)

Table 1: Agro-ecological zones of the study sites in Meru South Sub-county

Agro-Ecological zone	Altitude (Meters above sea level)	Annual Average rainfall (mm)	Annual mean temperature (°C)
Upper Midlands II (UM2) (Main coffee zone)	1280 -1680	1500 - 2400	18.2 – 20.6
Upper Midlands III (UM3) (Marginal coffee zone)	1280-1520	1400 - 2200	19.2 – 20.6
Lower Midlands III (LM3) (Cotton zone)	910-1300	1000-1400	20.9 – 22.9
Lower Midlands IV (LM4) (Marginal cotton zone)	760 - 1300	800 - 1050	21.0 – 24

(Jaetzold *et al.*, 2006).

There is reduced rainfall but increased temperature with reduction in altitude from UM2 to LM4 agro-ecologies. The area is densely populated with high agricultural potential and complex farming systems with perennial cash crops, food crops, trees and livestock. The farmers practice small-scale rain-fed, mostly non-mechanized agriculture on smallholdings ranging from 0.1 to 2 ha with an average of 1.2 ha per household (MOA, 2013).

Treatments, Samplings and design: Thirty samples (half kg each) of soybean farm saved seed were randomly sampled from soybean growing households in Chuka, Mugumoni, Igambang'ombe wards of Meru South Sub-county in February 2013. The samples obtained were of the short rains (harvested) crop planted in October 2012 and harvested in Jan/Feb. 2013 sites representative of four agro-ecological zones – Upper Midlands 2 (UM2), Upper Midlands 3 (UM3), Lower midlands 3 (LM3) and Lower Midlands 4 (LM4) (Jaetzold *et al.*, 2006). All the sampled seed had utmost been stored for only one month before sampling. The soybean seed sampled was mainly of cultivar Gazelle (93.3%), with only 3.3% being SB 19 (TGx 1740-2F) and SB 13 (3.3%). Consequently, only results for cultivar Gazelle have been used in this study. The seeds were packed in 1 litre plastic Jeri cans (Nairobi Plastics Ltd –NPL) and lids screwed on to ensure airtight conditions. The seed were then transported to the Genetic Resources Research Institute Laboratories, Muguga for seed testing in March 2013. Seed moisture content, germination and electrical conductivity tests were performed following the ISTA (2007) rules.

Laboratory Analyses:

Germination tests - Seed germination test is normally conducted in the laboratory in order to determine the percentage of viable seeds in a sample (Ali and Kose, 2011; Panchal and Dhale, 2011). Seeds of soybean cv. Gazelle were treated for 40 seconds with sodium hypochlorite solution (3.85 % active ingredient) diluted

with water in 1:2 ratio for 40 seconds and then surface washed with distilled water three times, to retard saprophytic fungal infestation. Seeds were then germinated in four replicates of 50 seeds each and sown in 500mls plastic container germination boxes with lids, containing 1% water agar. The germination boxes were arranged in a completely randomized design (CRD) in a walk-in germination chamber held at 30/20°C with alternating 12 h fluorescent light and 12 hours darkness. Counts of germinated seeds were made daily, starting on the first day of imbibition and terminated 11 days after sowing, at which point, no more seeds were observed to be germinating. Seeds were considered germinated when 2mm of the radicals protruded and the germination percentage (GP) after the last count calculated as follows:

$$GP = \frac{\text{Number of germinated seeds 11DAS} \times 100\%}{\text{Total number of seeds sown}}$$

Electrical Conductivity test - The Electrical conductivity of seed leachates is used to quantify the leakage of electrolytes from the seed and is an indicator of the degree of seed ageing. To assess the electrical conductivity of various seed-lots, four replicate samples of 50 seeds were weighed and placed in 250ml plastic cups containing 200mls of distilled water. The seeds were gently stirred to remove air bubbles and the cups covered with aluminium foil. The seeds were then left to soak in the water for 24 hours at room temperature 20±2°C. Conductivity of seed leachates was measured using a Jenway 4020 conductivity meter and CRT-CAA-515B electrode dip type cell (Fisons Scientific Equipment). The conductivity meter was standardized with 0.01N potassium Chloride. The cell constant (K) value at 1.000, and temperature coefficient per °C of 2 % rise at 25°C was used to take the readings. The electrical conductivity of a control sample of an equivalent quantity of distilled

water was also determined. Conductivity was expressed on a weight basis in microsiemens per cm per gram ($\mu\text{s cm}^{-1}\text{g}^{-1}$) of seed (ISTA, 2007).

Seed moisture content - Was determined using a Grain moisture meter (GMK-303RS, G-Won Hitech Co. Ltd) which measures the electric properties of seed moisture either by conductivity or capacitance within the range of

6-25%. Four replicates per seed lot were sampled, placed inside the moisture meter, ground and readings taken on a fresh weight basis (fwb).

Statistical analysis: Analysis of variance was conducted using the general linear model of the SAS statistical software Version 9.2. Separation of means was done using least significant difference (LSD ($p \leq 0.05$)).

RESULTS AND DISCUSSION

Seed moisture contents: The study revealed significant differences in moisture content (MC) of soybean farm-saved seed, between seed lots sampled from different agroecologies (Fig. 1). A significant reduction in the percent moisture content was noted with reduction in altitude. Soybean seed lots from cooler higher agroecology UM2 (10.0%) had significantly higher seed moisture than seed obtained from the lower Upper Midland III (8.4%) and Lower Midland III (8.0%) and LM4 Lower Midland IV (6.3%) which had the lowest seed moisture. The decreased seed moisture content recorded in the lower altitude agro-ecologies was probably due to increased temperatures and reduced rainfall hence relative humidity (Table 1). High relative humidity during

storage has been found to decrease seed viability and seedling Vigor irrespective of the species (Suma *et al.*, 2013). Seed moisture content during storage is one of the most influential factors affecting longevity; hence, a conducive storage environment is necessary in order to minimize deterioration (Bass, 1980). However, safe storage of soybean has been achieved with moisture content of below 12%, temperature of less than 10°C and relative humidity less than 70% (Thomas 1980). In the present study, while the moisture content was within the cited safe storage levels, the ambient temperatures within the sampled agro-ecologies were well beyond the recommended 10°C.

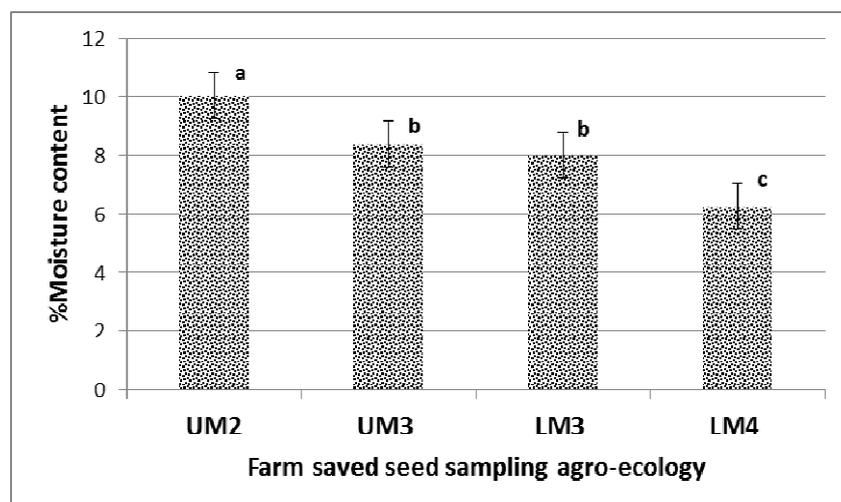


Figure 1: Seed moisture content (fwb) of farm saved seed of soybean Gazelle sampled at Upper midland II(UM2), Upper Midlands III(UM3), Lower Midland III(LM3) and Lower Midland IV(LM4) agro-ecologies of Meru South.

Seed leachate conductance: There were significant differences in electrolyte leakage in seeds from the lowest (LM4) altitude ecology as compared to that of seeds from the rest of the sampled ecologies. However,

the differences in electrolyte leakage among seeds from the other three sampled ecologies were not significant (Fig. 2).

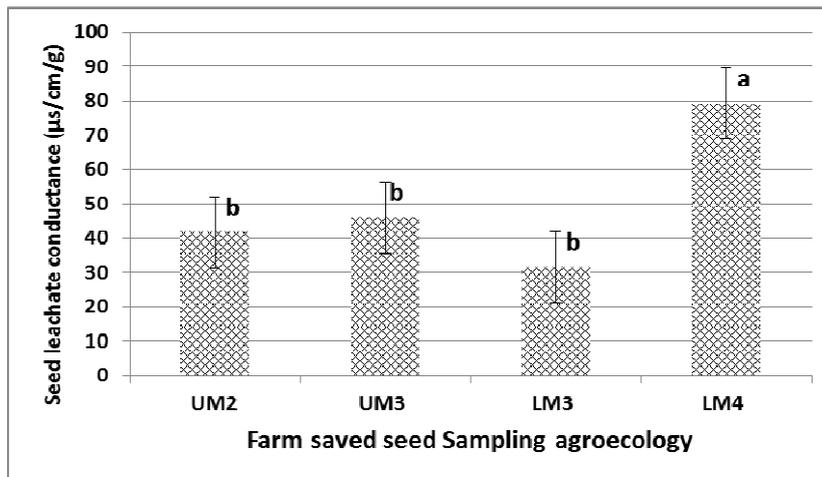


Figure 2: Seed leachate conductance (EC) of soybean cv. Gazelle farm-saved seed sampled at UM2 (Upper midland II (UM2), Upper Midlands III (UM3, Lower Midland III (LM3) and Lower Midland IV (LM4) agro-ecologies of Meru South

Reduced seed leachates were observed in soybean seed obtained from higher cooler agro-ecologies of UM2 (41.7 $\mu\text{s/cm/g}$), UM3 (45.8 $\mu\text{s/cm/g}$) and at LM3 (31.6 $\mu\text{s/cm/g}$) than in seed from warmer LM4 which had significantly higher leachates of 79.1 $\mu\text{s/cm/g}$. The higher temperatures experienced in the lower altitude agro-ecologies (table 1) is likely to have induced degradation and disorganization of the cytoplasmic seed membranes (Delouche and Baskin, 1973) leading to increased carbohydrates leakage; which has been highly correlated with seed deterioration (Keeling, 1974; Powell, 1988). High seed leachates have been found to characterize seed lots with low Vigor (Mathews and Powell, 2006) and low field seedling emergence (Vieira *et al.* 2004), hence the seeds obtained from LM4 would be of low Vigor and reduced field seedling emergence than seeds obtained from the cooler agro-ecologies (UM2, UM3 and LM3). The unfavourable soybean seed production and storage environments, particularly high temperatures experienced more in the lower agro-ecologies in the study area have been reported to modify the physiological quality of soybean seeds. Keigley and Mullen (1986) found that exposure to increasing periods of high temperature during seed fill and maturation resulted in a linear decline in seed germination, vigor and physical quality of soybean. During seed storage, Panobiancol and Vieira (2007) found that soybean seed lots stored for 3 to 18 months at a lower temperature (10°C) maintained physiological

quality with no significant differences in electrical conductivity; however, higher temperatures (20 and 25°C), had increased electrical conductivity values during the storage periods, revealing increase in deterioration of seed membranes. For the current experiment, there were observable differences associated with differences in agro-ecologies (temperatures of between 18-24°C). The lower seed leachates of soybean obtained from the cooler UM2, UM3 and LM3 agro-ecologies suggests better integrity of seed membranes hence higher Vigor and field emergence than seed from warmer LM4

Percent germination: Sampling agro-ecology had significant effect on soybean farm-saved seed germination percent (Fig 3). The results revealed significantly higher germination percent in seed obtained from higher cooler agro-ecologies of UM2 (94%); UM3 (86.8%) and LM3 (99.5%) than in seeds obtained lower warmer areas of LM4 (56.6 %). The significant reduction in soybean seed germination that occurred in the warmer LM4 (21– 24°C) as compared to the cooler UM2 (18.2 – 20.6°C), UM3 (19–21°C) and LM3 (21-23°C) agro-ecologies may have been caused by the deteriorative effects of higher temperatures on seed quality during seed fill and maturation (Keigley and Mullen, 1986; Khan *et al.*, 2011) as well as in storage (Bewley and Black, 1994; Mbofung *et al.*, 2013).

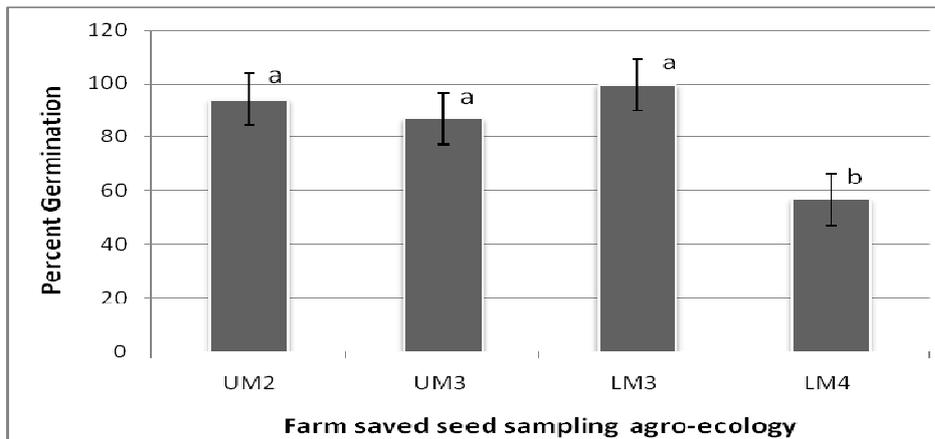


Figure 3: Percent germination of soybean cv. Gazelle farm-saved seed sampled at UM2 (Upper midland II (UM2), Upper Midlands III (UM3, Lower Midland III (LM3) and Lower Midland IV (LM4) agro-ecologies of Meru South

This showed that the cooler UM2, UM3 and LM3 agro-ecologies with annual mean temperatures of less than 23°C provided favourable conditions for production of soybean seeds with high germination. Similar findings was reported by Padua *et al.*, (2014) that the favourable agroclimatic zone for production of high quality soybean seed in Minas Gerais state of Brazil were areas with average temperatures of $\leq 23.5^{\circ}\text{C}$. Costa *et al.* (2005) also reported that for high quality soybean seed production, maturation and harvesting phases should occur under mild temperatures and dry conditions. From the physiologically view point, higher temperatures experienced more in the LM4 agro-ecological zone may have accelerated degradation processes, such as peroxidation of polyunsaturated fatty acids, and damage of cell membranes and DNA, causing germination to decrease (Bewley and Black, 1994). In addition, because seed moisture from all the agro-ecologies (Fig. 1) was below 12% safe moisture for storage reported by

Thomas, (1980) probably fungal diseases (Mamiro and clement 2014; Ibrahim 2015) may also have played a role in variations of germination across agro-ecologies. In our experiment, however, we did not explore the role of pathogens in answering variations in germination of seed lots from different agro-ecologies, but which may have partly contributed to it. Overall, due to conducive environmental conditions of temperature during crop maturation and ambient storage, significantly highest germination was realized in farm-saved soybean seed from cooler higher agroecologies of Chuka and Magumoni (UM2, UM3 and LM3) than seed from warmer lower altitudes of Igamba'ngombe (LM4) of Meru South Sub-county.

Correlation between germination percent and seed leachate conductance: The correlation between seed leachate conductance and percent germination of seeds sourced from various agro-ecologies in Meru South sub-county is shown in Figure 4.

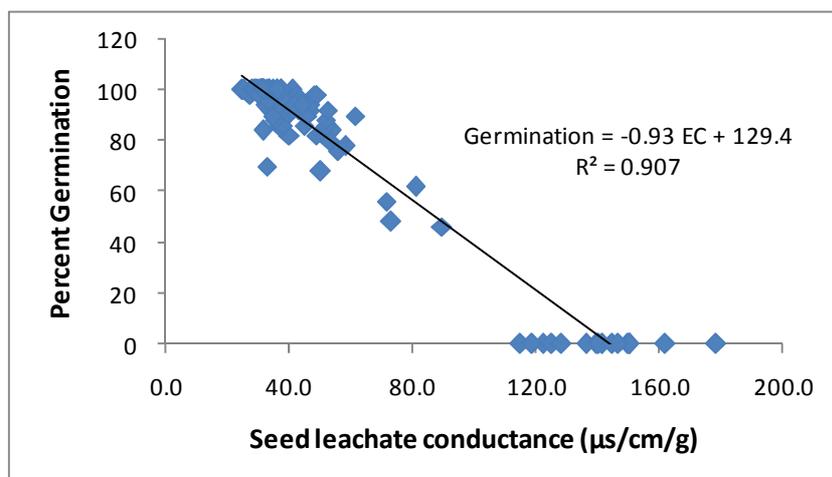


Figure 4: Correlation between seed leachate conductance and percentage germination of seeds sourced from UM2 (Upper midland II (UM2), Upper Midlands III (UM3, Lower Midland III (LM3) and Lower Midland IV (LM4) agro-ecologies of Meru South

The study revealed a very strong negative correlation ($R^2=0.91$) of germination percent with leakage of electrolytes from soybean farm-saved seed. This revealed that seed with reduced germination had increased levels of electrolytes leaked from them (seed leachate conductance). Similar correlations have been reported in Soybean by Panobianco and Vieira (1996) and Salinas *et al.* (2010) as well as in wheat by Tabjakksh (2000). Kumar *et al.* (2011) also reported that

electrical conductivity of seed leachates and lipid peroxidation increased significantly with seed deterioration. The likely reason for this is that deteriorated seed are likely to leak more electrolytes due to loss in ability of seed to re-organize seed membranes completely during early imbibitions (Abdul-Baki and Anderson 1970; Heydecker 1972; Vande Henter and Gobbelaar 1985). This has very strong bearing on germination, which reduced with increased leachates in the current study.

CONCLUSION

The study examined the viability and vigor of farm saved seed of soybean cv. Gazelle obtained from Meru South Sub-county, Tharaka Nithi County of Kenya. Data revealed that soybean farm-saved seed quality was influenced by production and storage agro-ecology's environmental conditions. The higher altitude cooler agroecological zones (UM2, UM3; LM3) maintained seed

of higher germination and Vigor than seed from the warmer lower zones (LM4). Consequently, farmers should source better quality soybean farm-saved seed from the cooler higher agroecological zones (UM2, UM3 and LM3) of Meru South Sub-County. These results also validate the need for ecological zoning of suitable areas for the production of high quality soybean seed in Kenya.

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