Evaluation of Seed Quality Attributes of Sorghum Germplasm Accessions from Eastern, Coastal and Nyanza Regions, Kenya

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Abstract

Sorghum (Sorghum bicolor L.) is an important cereal grain used in Kenya. Despite the crop’s importance, the yields attained by farmers in Eastern, Coastal and Nyanza regions of Kenya remain low. Access to good quality seeds of sorghum is one of the constraints facing the subsistence farmers. Good quality seed is important for increasing yield to attain food security. The aim of this study was to evaluate quality attributes of the seed used by farmers. A total of 108 germplasm accessions were obtained from 76 farmers. The seeds were tested for time and percentage of germination, seed vigour index, shoot and root dry weight. Data collected was subjected to analysis of variance. Means were separated using Fisher’s Least Significance Difference test at p ≤ 0.05. Seed samples of 26 accessions attained germination percentage below stipulated standards by Seeds and Plant Varieties Act CAP 326. Majority of seeds showed longer mean germination time with only nine accessions germinating in less than ten days. Seed vigour index was relatively high in most of the accessions, while biomass accumulation varied from high to very low among accessions. Though most of the seeds attained a high germination percentage, about 92% of seeds showed longer mean germination time. The environmental conditions in the fields, pre and post harvest handling practices impact on the seed quality hence the wide variability in germination percentage, germination time, seed vigour index and dry matter accumulation. Therefore the need to improve quality of seeds used by subsistence farmers by providing extension services on best pre and post harvest handling practices. Increasing production of sorghum in these regions will contribute significantly towards realizing food security. Further analysis could be carried out on genetic and sanitary quality aspects of the seeds planted by farmers in Eastern, Nyanza and Coastal regions.

Keywords: attributes, germplasm, seed quality, Sorghum bicolor

1. Introduction

Sorghum (Sorghum bicolor (L.) Moench) is an important cereal grain used and grown in semi-arid areas as food for many families due to its nutritive value (Rao et al., 2016; FAO, 2018). The ability of sorghum to adapt to drought, salinity and high temperatures makes it a critical crop in the dry regions where other cereal crops produce low yields (Mamoudou, 2006). In Kenya, the crop is cultivated and highly consumed in semi-arid regions with low annual rainfall of about 300mm which include Eastern (1385m ASL, 76mm month⁻¹), Coast (185m ASL, 87mm month⁻¹) and Nyanza (1190m ASL, 130mm month⁻¹) (Grieser et al., 2006). With its utilization closely related to maize, sorghum can be an alternative crop in marginal areas (Swigonova et al., 2004). The crop has got a large germplasm which could provide opportunities for a sustainable crop production for food security (Kange et al., 2014).

Sorghum production is mainly by subsistence farmers in marginalized regions in Kenya. Despite the many benefits associated with sorghum its production is still low (Muui et al., 2019). Farmers obtain seed from informal seed system which include retaining seed on-farm from previous harvests to plant the following season.
and farmer-to-farmer seed exchange networks (Ochieng et al., 2011; Muui et al., 2013, 2019). Where formal seed is available, the farmers cannot afford due to high seed prices. The informal seed supply system consists of farmer-managed seed production activities and is based on indigenous knowledge and local diffusion mechanisms. Maintaining crop production in terms of yield and quality grains which give the farmer maximum return requires good seed which carries the genetic, physiological, and physical quality aspects (Muasya et al., 2008; Ahmed et al., 2009). Good seed requires constant care to prevent loss of quality and to ensure high yield for farmers. Seed deterioration usually commences at physiological maturity and continues during harvest, processing and storage and is governed by the genetic constitution, environmental factors during seed development and storage conditions (McDonald, 1999; Muasya et al., 2008).

Seed quality is considered as an important factor for increasing yield unit area to attain food security (Badigannavar et al., 2016). Quality seeds have the ability for efficient utilization of available inputs such as fertilizers and moisture eventually maximizing yields (Jisha et al., 2013). Use of poor quality seed is one of the constraints to sorghum production in Kenya where majority of the farmers rely on the informal seed supply sources resulting to low yields (Ochieng et al., 2011). Poor seed quality at farm level is caused by poor drying of harvested grains, threshing practices, storage conditions (Harrison and Perry, 1976; Songa et al., 1995). Also, many subsistence farmers in Sub-Saharan Africa do not apply fertilizers to their farms (Jama et al., 1998; Ochieng et al., 2011; Muui et al., 2019). This is attributed to the fact that sorghum is often grown under marginal rainfall conditions and fertilizer prices are unfavourably high in relation to sorghum grain price. This practice of using little or no fertilizer affects both seed quality and yield of the crop negatively (Swinkels et al., 1997).

Sorghum landraces germplasm provides a great genetic variability with high preferences based on unique characteristics (Ng’uni et al., 2012). Sorghum being a food crop with the potential of alleviating the problem of food insecurity, there is need for using quality seeds for sustainable production by the subsistence farmers (Mwadalu and Mwangi, 2013). This study aimed at assessing the quality of on farm saved sorghum seeds used by farmers at eastern, coastal and nyanza regions of Kenya. A total of 108 germplasm accessions were collected from farmers to determine germination percentage, germination time, seed vigour index, seedling shoot and root dry weight.

2. Materials and Methods

2.1 Description of experimental Site

The experiment was carried out in Kenyatta University situated in Nairobi County about 20 Km from Nairobi city along Nairobi-Thika road between August and October 2018. The county is characterized by a warm climate with temperatures varying between 12°C and 18.7°C. The rainfall aggregate for the county is 1,000 mm per year. Its geographical coordinates are 1° 10’ 0” S, 36° 50’ 0” E with an elevation of 1,720m above sea level (ASL). The area has a bimodal rainfall pattern with an average of 1,000 mm per annum. The long rains occur between March and May while the short rains set in between October and December. The soils are acrisols, alisols, lixisols and luvisols (Shisanya et al., 2006).

2.2 Experimental Treatments and Design

2.2.1 Experimental Layout and Data Collection

The experiment was carried out in the laboratory and in a greenhouse. The two experiments were arranged in a Complete Randomised Design. A total of 108 sorghum germplasm accessions obtained from farmers comprising of 41 accessions from Eastern, 25 from Nyanza and 42 from Coastal regions of Kenya were used. The sorghum germplasm was collected from farmers in 2018 while conducting a baseline survey to assess the production systems for sorghum in the three regions (Muui et al., 2019).

2.3 Crop Management and Data Collection

Germination percentage and mean germination time experiments were carried out in the laboratory while seed vigour index, shoot and root dry weight was done in the greenhouse.

2.3.1 Germination Percentage

From each of the 108 sorghum germplasm accessions, a sample of 400 seeds was selected at random from the 1,000-seed weight lot and grouped into four replicates of 100 seeds (ISTA, 2012). Each of the four replicates was placed in a germination tray with sterilized filter papers moistened with distilled water as a growth medium. The trays were illuminated with light during the whole period and temperatures maintained at 25±5°C. Distilled water was added as necessary to maintain the correct moisture content. Germination count was done at the end of the fourth day and seedling evaluation at the end of the tenth day. Germination percentage was calculated as
follows:
Germination percentage (%) = (Number of seeds germinated/Number of seeds sown) x100

2.3.2 Mean Germination Time (Days)

The seeds used for testing germination percentage were also used in the determination of mean germination time. Emerged seedlings in each container were counted daily at an interval of 24 hours from the first day to the day no more germination occurred. The mean germination time was calculated using the method described by Khan et al. (2010) as follows:

Mean germination time = (No. of germinated seedlings/Total no. of seeds sown) x Days after sowing

2.3.3 Seed Vigour Index

From the 108 sorghum germplasm accessions, a sample of 200 seeds was selected at random from 1,000-seed weight lot (same seed lot used for germination) and grouped into four replicates of 50 seeds. The fifty seeds were placed in plastic containers (pots) with sterilized forest soil as a growth medium for 21 days. Number of germinated seeds was recorded every 24 hours. Watering was done on daily basis and pots kept weed free throughout the experimental period. After 21 days, the seedlings were uprooted, soils washed off and a ruler used to measure the seedling height. Seed vigour index determination was done using the equation cited by Zhu et al., (2010) as follows:

Seed vigour index (SVI) = Seedling height × ∑ (number of germinated seedlings by end of test period/days after sowing)

2.3.4 Shoot and Root Dry Weight (Grams)

Seedlings used for seed vigour index were also used for dry weight measurement. A random sample of twenty five seedlings was taken and separated into shoot and root, dried in a forced-air oven at 72°C for 48 hours. The samples were fully dried such that no significant changes occurred before the tests were done. The dried shoots and roots were weighed using an electronic balance (model 6354) and recorded in grammes.

2.4 Data Analysis

The data collected on germination percentage, germination time, seed vigour index, shoot and root dry weight were managed in the Ms excel spreadsheet and subjected to one-way analysis of variance (ANOVA) using Statistical Analysis Software (SAS) version 9.1. Means were separated using Fisher’s Least Significance Difference (LSD) test at p≤0.05.

3. Results

3.1 Germination Percentage

There were statistical differences (p≤0.05) in the germination percentage of the germplasm accessions evaluated across the three regions of Kenya; Eastern (41), Nyanza (25) and coast (42). In the Eastern region, thirty-eight of the tested accessions had more than 70% while three accessions had less than 70% with local102 having the lowest germination (18.67%) (Table 1). On the other hand, 29 of the tested accessions from coastal region had 70% germination whereas 13 accessions showed less than 70% germination with the lowest, 18%, from local accession gaddamssp38. In Nyanza, 15 of the tested accessions had 70% germination. A relatively lower than 70% germination percentage was observed in ten germplasm accessions, but Ngware spp2 recorded the lowest germination percentage of 18.0%.
Table 1. Germination percentages for sorghum germplasm accessions obtained from Eastern, Coastal and Nyanza regions in 2018

| Germplasm accessions | Eastern region (%) | Coastal region (%) | Nyanza region (%) |
|----------------------|---------------------|--------------------|-------------------|
| Local Variety 68     | 97.67^ab            | Gadam Spp68        | 60.33^ab          |
| Local Variety 69     | 84.67^def           | Gadam Spp69        | 66.67^def         |
| Local Variety 70     | 77.67^hi            | Local Variety 70   | 93.30^h           |
| Kivila Kyaivui71     | 84.33^def           | Local Variety 22   | 33.33^d           |
| Kidomo72             | 93.33^bcd           | Mixed30            | 26.67^d           |
| Rasta73              | 86.67^bdef          | Gadam Spp31        | 86.67^bdef        |
| Kilala74             | 71.00^ij            | Gadam Spp32        | 80.00^ij          |
| Local Variety 75     | 71.00^ij            | Gadam Spp33        | 86.67^bcd         |
| Kitaa Kyaivui76      | 84.33^bcddef         | Gadam Spp34        | 58.00^hi          |
| Kari Mtama-177       | 95.67^abc           | Local Variety 35   | 29.00kl           |
| Local Variety 78     | 82.33^efgh          | Gadam Spp68        | 86.30^bcd         |
| local Variety Red79  | 80.00^efgh          | Kautimbi sps37     | 93.30^ab          |
| local variety 80     | 97.67^ab            | Gadam Spp38        | 18.00f            |
| Katengu81            | 100.00^a            | Gadam Spp39        | 97.67^n           |
| local Brown82        | 100.00^a            | Kingundu spp40     | 95.33^a           |
| local Red83          | 86.67^bdef          | Local Variety 41   | 100.00^a          |
| Rasta spp84          | 100.00^a            | Local Variety 42   | 97.67^n           |
| Muruge spp85         | 97.67^ab            | Gadam Spp43        | 93.00^n           |
| Muveta spp86         | 100.00^a            | Local Variety 44   | 95.33^ab          |
| Muveta spp87         | 100.00^a            | Local Variety 45   | 75.67^cdef        |
| Mugeta spp88         | 100.00^a            | Gadam Spp46        | 100.00^a          |
| Local Red89          | 66.67^gh            | Local Variety 47   | 60.00^hi          |
| Local Red90          | 100.00^a            | Local Variety 48   | 93.30^ab          |
| Ciambichi91          | 71.00^ij            | Local Variety 49   | 69.00^efgh        |
| Vaansa92             | 64.67^l             | Local Variety 50   | 86.67^bdef        |
| local brown93        | 100.00^a            | Kitaakayi IV VII51 | 87.00^bcd         |
| Rasta94              | 97.67^ab            | Gadam Spp52        | 75.33^cdef        |
| Muvuta spp95         | 91.3^abcde          | Local Variety 53   | 29.00^d           |
| Seren96              | 100.00^a            | Local Variety 54   | 84.33^bde         |
| Langi wa Mbesa97     | 100.00^a            | Kivilakyaivui55    | 93.00^ab          |
| Rasta98              | 100.00^a            | Local Variety 56   | 49.00^i           |
| Kaguru spp99         | 100.00^a            | Local Variety 57   | 73.33^efgh        |
| Rasta spp100         | 97.67^ab            | Local Variety 58   | 100.00^a          |
| Light brown101       | 100.00^a            | Local Variety 59   | 100.00^a          |
| Local102             | 18.67^e             | Gadam Spp60        | 97.70^e           |
| Local103             | 100.00^a            | Local Variety 61   | 100.00^a          |
| Repaetaed104 Cultivar| 97.67^ab            | Local Variety 62   | 97.70^a           |
| Local brown105       | 86.67^bdef          | Local Variety 63   | 62.33^bi          |
| Local Red106         | 100.00^a            | Local Variety 64   | 95.67^ab          |
| Local107             | 71.00^ii            | Local Variety 65   | 75.66^defg        |
| Local Red108         | 73.00^ii            | Kitaakayi IV VII66 | 91.33^abc         |

LSD 11.74 16.24 17.47

Means followed by the same letter within the same column are not significantly different according to Fisher’s Least Significance Difference (LSD) test at p≤0.05.

3.2 Mean Germination Time (Days)

The mean germination time (MGT) revealed statistical differences (p≤0.05) for the germplasm accessions evaluated across the three regions: Eastern, Nyanza and Coast. From Eastern region, local red83, ciambichi91 and local102 had the shortest MGT of 8.40, while Katengu81, local variety 75, Kitaakyaivui 7,
Rasta 73 and Rasta spp 100 had the longest MGT of 21.00 (Table 2). At the Coastal region, mixed30 and local variety35 accessions had the shortest MGT of 5.60 while, local variety28, local variety41, local variety44, kitaakyavili51, kita kya ivui66 and Kavilakyavui55 exhibited the longest MGT of 21.00 respectively (Table 2). In Nyanza Othiwa spp18, Nyakabala spp9 and Gadam spp25 had the shortest MGT of 11.20 while Ngware spp12, Ochutis spp15, Oyundiwi-Joleho23 and Seredo spp24 had the longest MGT of 21.00 respectively (Table 2).

Table 2. Mean germination time (days) of sorghum germplasm accessions obtained from Eastern, Coastal and Nyanza regions in 2018

| Eastern region | Coastal region | Nyanza region |
|----------------|----------------|---------------|
| Germplasm accessions | MGT (days) | Germplasm accessions | MGT (days) | Germplasm accessions | MGT (days) |
| Local Variety68 | 16.80<sup>cd</sup> | Gadam Spp26 | 18.20<sup>abc</sup> | Nyakatos spp1 | 18.20<sup>ab</sup> |
| Local Variety69 | 16.80<sup>cd</sup> | Gadam Spp27 | 16.80<sup>cd</sup> | Ngware spp2 | 19.60<sup>ab</sup> |
| Local Variety70 | 14.00<sup>e</sup> | Local Variety28 | 21.00<sup>a</sup> | Ngware spp3 | 19.60<sup>ab</sup> |
| Kivila Kyaiyui71 | 18.20<sup>bc</sup> | Local Variety29 | 19.60<sup>ab</sup> | C-26 spp4 | 19.60<sup>ab</sup> |
| Kikomo72 | 18.20<sup>bc</sup> | Mixed30 | 5.60<sup>f</sup> | Nyadundo5 3 | 16.80<sup>bc</sup> |
| Rasta73 | 21.00<sup>e</sup> | Gadam Spp31 | 16.80<sup>cd</sup> | Sered6 | 19.60<sup>ab</sup> |
| Kilala74 | 16.80<sup>cd</sup> | Gadam Spp32 | 18.20<sup>abc</sup> | Nyakabala spp7 | 15.40<sup>ef</sup> |
| Local Variety75 | 21.00<sup>e</sup> | Gadam Spp33 | 16.80<sup>bc</sup> | Nyakatos spp8 | 19.60<sup>ab</sup> |
| Kitaayaiyui76 | 21.00<sup>e</sup> | Gadam Spp34 | 12.60<sup>efg</sup> | Nyakatos spp9 | 11.20<sup>f</sup> |
| Kari Mtama-177 | 18.20<sup>bc</sup> | Local Variety35 | 5.60<sup>f</sup> | Ngware spp10 | 16.80<sup>bc</sup> |
| Local Variety78 | 16.80<sup>cd</sup> | Gadam Spp36 | 19.60<sup>ab</sup> | Ngware (white)spp11 | 18.20<sup>abc</sup> |
| local Variety Red79 | 18.20<sup>bc</sup> | Kautimbi spp37 | 19.60<sup>ab</sup> | Ngware spp12 | 21.00<sup>c</sup> |
| local variety80 | 15.40<sup>de</sup> | Gadam Spp38 | 8.40<sup>ijk</sup> | Nyakabala spp13 | 16.80<sup>bc</sup> |
| Katengu81 | 21.00<sup>e</sup> | Gadam Spp39 | 18.20<sup>abc</sup> | Nyakabala spp14 | 19.60<sup>ab</sup> |
| local Brown82 | 19.60<sup>b</sup> | Kingundu spp40 | 18.20<sup>abc</sup> | Ochuti spp15 | 21.00<sup>c</sup> |
| local Red83 | 8.40<sup>f</sup> | Local Variety41 | 21.00<sup>a</sup> | Nyakabala spp16 | 15.40<sup>ef</sup> |
| Rasta spp84 | 15.40<sup>de</sup> | Local Variety42 | 18.20<sup>abc</sup> | Nyakabala spp17 | 26.80<sup>bc</sup> |
| Muruage spp85 | 19.60<sup>b</sup> | Gadam Spp43 | 19.60<sup>ab</sup> | Othiwa spp18 | 11.20<sup>f</sup> |
| Muveta spp86 | 16.80<sup>cd</sup> | Local Variety44 | 21.00<sup>a</sup> | Gadam Spp19 | 12.60<sup>de</sup> |
| Muvula spp87 | 16.80<sup>cd</sup> | Local Variety45 | 9.80<sup>ef</sup> | Nyakabala spp20 | 19.60<sup>ab</sup> |
| Mugeta spp88 | 16.80<sup>cd</sup> | Gadam Spp46 | 18.20<sup>abc</sup> | Andiwo spp21 | 15.40<sup>ef</sup> |
| Local Red89 | 19.60<sup>e</sup> | Local Variety47 | 19.60<sup>ab</sup> | Ngware spp22 | 16.80<sup>bc</sup> |
| Local Red90 | 19.60<sup>e</sup> | Local Variety48 | 15.40<sup>cd</sup> | Oyundiwi-Joleho23 | 21.00<sup>c</sup> |
| Ciimbich91 | 8.40<sup>f</sup> | Local Variety49 | 16.80<sup>bcd</sup> | Seredo spp24 | 21.00<sup>c</sup> |
| Vaasya92 | 15.40<sup>de</sup> | Local Variety50 | 15.40<sup>de</sup> | Gadam Spp25 | 11.20<sup>c</sup> |
| local brown93 | 19.60<sup>b</sup> | Kitaakyavili71 | 21.00<sup>ab</sup> |
| Rasta94 | 16.80<sup>cd</sup> | Gadam Spp52 | 18.20<sup>abc</sup> |
| Mavuta spp95 | 16.80<sup>cd</sup> | Local Variety53 | 8.40<sup>ijk</sup> |
| Serena96 | 16.80<sup>cd</sup> | Local Variety54 | 18.20<sup>abc</sup> |
| Langi wa Mbasa97 | 19.60<sup>b</sup> | Kivilakyavui55 | 21.00<sup>a</sup> |
| Rasta98 | 21.00<sup>e</sup> | Local Variety56 | 8.40<sup>ijk</sup> |
| Kaguru spp99 | 14.00<sup>de</sup> | Local Variety57 | 15.40<sup>de</sup> |
| Rasta spp100 | 21.00<sup>e</sup> | Local Variety58 | 21.00<sup>a</sup> |
| Light brown101 | 19.60<sup>b</sup> | Local Variety59 | 19.60<sup>ab</sup> |
| Local102 | 8.40<sup>f</sup> | Gadam Spp60 | 19.60<sup>ab</sup> |
| Local103 | 19.60<sup>b</sup> | Local Variety61 | 21.00<sup>ab</sup> |
| Repaed104 Cultivar | 19.60<sup>b</sup> | Local Variety62 | 15.40<sup>cde</sup> |
| Local brown105 | 12.60<sup>b</sup> | Local Variety63 | 12.60<sup>d</sup> |
| Local Red106 | 14.00<sup>de</sup> | Local Variety64 | 16.80<sup>bcd</sup> |
| Local107 | 12.60<sup>b</sup> | Local Variety65 | 11.20<sup>f</sup> |
| Local Red108 | 15.40<sup>de</sup> | Kita ikya iv vii66 | 21.00<sup>a</sup> |

LSD 3.312 2.98 3.08

Means followed by the same letter within the same column are not significantly different according to Fisher’s Least Significance Difference (LSD) test at p≤0.05.
3.3 Seed Vigour Index (SVI)

Different germplasm accessions exhibited significant differences (p≤0.05) in seed vigour index (SVI) in Eastern, Nyanza and Coastal regions (Table 3). Local103 accession was superior with an SVI of 3499.3 from Eastern region, while local102 had the lowest SVI of 322.3. At Coastal region, SVI superiority was exhibited by accession localvariety41 that recorded 4392.0 followed by the localvariety42 with 4044.3, while Gadam spp38 had the lowest SVI of 507.5. At Nyanza, Nyakabala spp9 and Ochuti spp15 were the superior accessions with a high SVI of 4080.9 and 4060.0 respectively, while Serodo spp24 had the least SVI of 2119.8.

Table 3. Seed vigour index (SVI) for sorghum germplasm accessions obtained from Eastern, Coastal and Nyanza regions in 2018

| Germplasm accessions | SVI | Germplasm accessions | SVI | Germplasm accessions | SVI |
|----------------------|-----|----------------------|-----|----------------------|-----|
| Eastern region       |     | Coastal region       |     | Nyanza region        |     |
| Local Variety68      | 3196.6 ab | Gadam Spp26          | 2759.2 bijk | Nyaktos spp1        | 3570.8 abcde |
| Local Variety69      | 2503.9 gh | Gadam Spp27          | 1713.3 b c | Ngware spp2         | 3794.4 b c |
| Local Variety70      | 1874.0 k lm | Local Variety28      | 3083.9 defghi | Ngware spp3        | 3340.4 b cdef |
| Kivila Kyaiyuvi71    | 1287.2 no | Local Variety29      | 1271.5 d | C-26 spp4          | 3065.4 d e |
| Kikomo72             | 1644.5 v k mol | Mixed30             | 1321.2 c | Nyadundo5 3        | 2849.2 d efg |
| Rasta73              | 2001.0 a | Gadam Spp31          | 2994.5 efgijk | Seredo6           | 3004.5 d efg |
| Kilala74             | 1264.2 h | Gadam Spp32          | 2416.3 g | Nyakabala spp7     | 3161.9 b cdef |
| Local Variety75      | 1877.1 k l m | Gadam Spp33         | 2689.6 j | Ngware spp8        | 3028.1 d e f |
| Kitaa Kyaiyuvi76     | 2008.5 jk | Gadam Spp34          | 1908.9 g | Ngware spp9        | 4080.9 b |
| Kari Mtama-177       | 1977.6 jk | Local Variety35      | 624.7 p | Ngware spp10       | 3893.3 b cdefgh |
| Local Variety78      | 1742.5 km | Gadam Spp36          | 2823.6 de fjk | Ngware (white)spp11 | 3499.2 ab cdef |
| local variety Red79  | 1767.7 k ln m | Kautimbi spp37   | 3017.8 i j | Ngware spp12       | 3351.1 b cdef |
| local variety80      | 2643.8 eg fh | Gadam Spp38         | 507.5 l | Nyakabala spp13    | 3640.1 ab cdefgh |
| Katengu81            | 2613.3 eg fh | Gadam Spp39         | 3864.7 ab c | Nyakabala spp14    | 3270.6 b cdef |
| local Brown82        | 2292.7 hij | Kingundu spp40      | 3224.0 d e fgh | Ochuti spp15      | 4060.0 b cdefgh |
| local Red83          | 2605.4 eg fh | Local Variety41     | 4392.0 o | Nyakabala spp16    | 3499.2 ab cdefgh |
| Rasta spp84          | 1723.3 in m | Local Variety42     | 4044.3 b | Nyakabala spp17    | 3096.4 ab cdef |
| Muruge spp85         | 3036.0 bcde f | Gadam Spp43         | 2907.5 hijk | Othiwa spp18       | 3536.5 abcde |
| Muveta spp86         | 2960.0 bcdef | Local Variety44     | 3566.6 cdef g | Gadam spp19        | 2769.1 b cdef |
| Muvela spp87         | 2273.3 hijk | Local Variety45     | 2787.5 hijk | Nyakabala spp20    | 2906.9 cdefghi |
| Mugeta spp88         | 2666.7 cdefghi | Gadam Spp46       | 3781.7 ab c | Andiwon spp21      | 3273.4 abcdefgh |
| Local Red89          | 1790.3 km | Local Variety47     | 2248.4 l m | Ngware spp22       | 3485.5 abcdefgh |
| Local Red90          | 3271.0 ab | Local Variety48     | 3320.9 ab cdefgh | Oyundiwi-Jolejo23 | 2615.8 b cdefgh |
| Cumbichia91          | 2526.8 eg fh | Local Variety49     | 2917.4 gh k | Seredo spp24       | 2119.8 b cdefgh |
| Vaasya92             | 2823.7 bcdefghi | Local Variety50   | 3299.1 ab cdefghi | Gadam spp25       | 13331.0 b abcde |
| local brown93        | 2978.7 bcdefghi | KitaakyaIV VII15 | 3619.2 b cdefghi | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Rasta94              | 2708.5 cdefghi | Gadam Spp52        | 2607.3 hijk | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Muvuta spp95         | 3143.3 abcd | Local Variety53     | 1107.5 pq | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Serena96             | 3167.0 abcde | Local Variety54     | 2634.8 b cdefghi | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Langi wa Mbasa97     | 2286.0 hij | Kivilakaiyuvi55     | 3174.4 cdefghi | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Rasta98              | 2708.5 cdefghi | Local Variety56     | 1321.3 b cdefghi | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Kaguru spp99         | 2275.0 hijk | Local Variety57     | 2783.1 hijk | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Rasta spp100         | 2677.0 de fghi | Local Variety58     | 3299.1 ab cdefghi | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Light brown101       | 2405.6 gh lu | Local Variety59     | 3545.7 bcde fghi | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Local102             | 322.3 h | Gadam Spp60          | 3610.9 bcdef | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Local103             | 3499.3 a | Gadam Spp61          | 3131.7 de fghi | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Repaeted104 Cultivar | 3201.6 ab | Local Variety62     | 3198.3 cdefghi | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Local brown105       | 2406.5 gh lu | Local Variety63     | 2440.0 b cdefghi | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Local Red106         | 1835.0 km | Local Variety64     | 3736.3 abcde | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Local Red107         | 1854.7 jk l km | Local Variety65    | 3078.1 e ghijk | KitaakyaIV VII15 | 3619.2 b cdefghi |
| Local Red108         | 1436.9 mno | Kitaaka Kyiv vii66 | 3289.8 b cdefghi | KitaakyaIV VII15 | 3619.2 b cdefghi |
| LSD                   | 486.96 | 758.15 | 816.13 |

Means followed by the same letter within the same column are not significantly different according to Fisher’s Least Significance Difference (LSD) test at p≤0.05.
3.4 Shoot Dry Weight (SDW)

There was a significant difference (p<0.05) in shoot dry weight among various germplasm accessions from Eastern, Nyanza and Coastal regions (Table 4). In Eastern, Ciumbichi91 accession had the highest shoot dry weight of 0.046g, mixed30 accession from Coastal region was the leading in shoot dry weight of 0.073g while, at Nyanza, Ochuti15 was superior, recording 0.075g. Germplasm accessions with the least shoot dry weight were Gadam spp 27 (0.0137g) and Seredo spp 24 (0.0180g) from Coastal and Nyanza regions respectively.

Table 4. Shoot dry weight (SDW) (grams) of sorghum germplasm accessions obtained from Eastern, Coastal and Nyanza regions in 2018

| Eastern region | SDW (g) | Coastal region | SDW (g) | Nyanza region | SDW (g) |
|----------------|---------|----------------|---------|---------------|---------|
| Germplasm accessions | Gadam spp 26 | 0.0470 | Nyakabala spp 7 | 0.0590 |
| Local Variety 68 | 0.0241 | Gadam spp 31 | 0.0354 | Nyakabala spp 10 | 0.0540 |
| Local Variety 69 | 0.0297 | Gadam spp 37 | 0.0290 | Nyakabala spp 11 | 0.0640 |
| Local Variety 70 | 0.0162 | Local Variety 28 | 0.0202 | Nyakabala spp 12 | 0.0530 |
| Kivila Kyaiwuvi 71 | 0.0071 | Local Variety 29 | 0.0340 | Gardama spp 13 | 0.0410 |
| Kikombo 72 | 0.0122 | Mixed 30 | 0.0190 | Gardama spp 15 | 0.0750 |
| Rasta 73 | 0.0320 | Gadam spp 32 | 0.0234 | Gardama spp 16 | 0.0530 |
| Kilala 74 | 0.0098 | Gadam spp 33 | 0.0350 | Gardama spp 17 | 0.0350 |
| Local Variety 75 | 0.0260 | Gadam spp 36 | 0.0290 | Gardama spp 18 | 0.0440 |
| Kitaa Kyaiwuvi 76 | 0.0181 | Local Variety 35 | 0.0220 | Gardama spp 20 | 0.0310 |
| Kari Mtmpa 177 | 0.0235 | Local Variety 37 | 0.0340 | Gardama spp 21 | 0.0340 |
| Local Variety 78 | 0.0133 | Kautimbi spp 37 | 0.0340 | Gardama spp 22 | 0.0380 |
| local Variety Red 79 | 0.0173 | Local Variety 38 | 0.0190 | Gardama spp 23 | 0.0260 |
| local variety 80 | 0.0228 | Gardam spp 39 | 0.0470 | Gardama spp 24 | 0.0180 |
| Katengu 81 | 0.0207 | Gardam spp 40 | 0.0289 | Gardama spp 25 | 0.0380 |
| local Brown 82 | 0.0190 | Kingundo spp 40 | 0.0289 | Gardama spp 26 | 0.0300 |
| local Red 83 | 0.0262 | Local Variety 41 | 0.0430 | Gardama spp 27 | 0.0340 |
| Rasta spp 84 | 0.0136 | Local Variety 42 | 0.0360 | Gardama spp 28 | 0.0420 |
| Muruge spp 85 | 0.0263 | Gadam spp 43 | 0.0370 | Gardama spp 29 | 0.0380 |
| Muvuta spp 86 | 0.0242 | Local Variety 44 | 0.0328 | Gardama spp 30 | 0.0320 |
| Muvela spp 87 | 0.0171 | Local Variety 45 | 0.0453 | Gardama spp 31 | 0.0340 |
| Mugeta spp 88 | 0.0214 | Gardam spp 46 | 0.0540 | Gardama spp 32 | 0.0340 |
| Local Red 89 | 0.0301 | Local Variety 47 | 0.0500 | Gardama spp 33 | 0.0380 |
| Local Red 90 | 0.0230 | Local Variety 48 | 0.0045 | Gardama spp 34 | 0.0260 |
| Ciumbichi 91 | 0.0460 | Local Variety 49 | 0.0510 | Gardama spp 35 | 0.0260 |
| Vaasya 92 | 0.0450 | Local Variety 50 | 0.0430 | Gardama spp 36 | 0.0380 |
| local brown 93 | 0.0274 | Kitaakyayi V 171 | 0.0560 | Gardama spp 37 | 0.0360 |
| Rasta 94 0.0230 | Gadam spp 52 | 0.0456 | Gardama spp 38 | 0.0350 |
| Muvuta spp 95 | 0.0380 | Local Variety 53 | 0.0390 | Gardama spp 39 | 0.0430 |
| Serana 96 | 0.0297 | Local Variety 54 | 0.0260 | Gardama spp 40 | 0.0300 |
| Langi wa Mbesa 97 | 0.0200 | Kaiyaiayi V 55 | 0.0383 | Gardama spp 41 | 0.0380 |
| Rasta 98 | 0.0230 | Local Variety 56 | 0.0211 | Gardama spp 42 | 0.0340 |
| Kagaru spp 99 | 0.0180 | Local Variety 57 | 0.0517 | Gardama spp 43 | 0.0360 |
| Rasta spp 100 | 0.0237 | Local Variety 58 | 0.0330 | Gardama spp 44 | 0.0340 |
| Light brown 101 | 0.0216 | Local Variety 59 | 0.0382 | Gardama spp 45 | 0.0340 |
| Local 102 | 0.0088 | Gadam spp 60 | 0.0452 | Gardama spp 46 | 0.0350 |
| Local 103 | 0.0280 | Local Variety 61 | 0.0280 | Gardama spp 47 | 0.0390 |
| Repaeted 104 Cultivar | 0.0260 | Local Variety 62 | 0.0271 | Gardama spp 48 | 0.0300 |
| Local brown 105 | 0.0200 | Local Variety 63 | 0.0380 | Gardama spp 49 | 0.0360 |
| Local Red 106 | 0.0120 | Local Variety 64 | 0.0440 | Gardama spp 50 | 0.0300 |
| Local 107 | 0.0163 | Local Variety 65 | 0.0490 | Gardama spp 51 | 0.0340 |
| Local Red 108 | 0.0144 | Kitaa Kya iv vii 66 | 0.0487 | Gardama spp 52 | 0.0380 |
| LSD | 0.014 | 0.016 | 0.111 |

Means followed by the same letter within the same column are not significantly different according to Fisher’s Least Significance Difference (LSD) test at p≤0.05.

3.5 Root Dry Weight (RDW) (Grams)

Root dry weight exhibited significant differences (p≤0.05) among germplasm accessions from Eastern, Coastal
and Nyanza regions (Table 5). Vaasya92 (0.0152g), Nyakabala spp9 (0.0188g) and local variety45 (0.039g) from Eastern, Nyanza and Coastal regions respectively had more root dry weight. Kilala74 in Eastern recorded the least root dry weight of 0.0020g while in Nyanza Seredo spp 24 had the least weight of 0.0036g.

Table 5. Root dry weight (RDW) (grams) of sorghum germplasm accessions obtained from Eastern, Coastal and Nyanza regions in 2018

| Germplasm accessions | RDW (g) | Eastern region | Germplasm accessions | RDW (g) | Coastal region | Germplasm accessions | RDW (g) | Nyanza region |
|----------------------|---------|----------------|----------------------|---------|----------------|----------------------|---------|---------------|
| Local Variety68      | 0.0052  | Gadam Spp26    | 0.014c               | Nyakakos spp1 | 0.0074        |
| Local Variety69      | 0.0121  | Gadam Spp27    | 0.004c               | Ngware spp2 | 0.0070        |
| Local Variety70      | 0.0056  | Local Variety28 | 0.006c              | Ngware spp3 | 0.0053        |
| Kivila Kyavui71      | 0.0024  | Local Variety29 | 0.009c              | C-26 spp4  | 0.0081        |
| Kikomo72             | 0.0037  | Mixed30        | 0.010c              | Nyadundo5 3 | 0.0052        |
| Rasta73              | 0.0037  | Gadam Spp31    | 0.01c                | Seredo6    | 0.0060        |
| Kilala74             | 0.0020  | Gadam Spp32    | 0.007c               | Nyakabala spp7 | 0.0068    |
| Local Variety75      | 0.0102  | Gadam Spp33    | 0.0077c              | Nyakakos spp8 | 0.0051        |
| Kitata Kyavui76      | 0.0060  | Gadam Spp34    | 0.014c               | Nyakabala spp9 | 0.0188        |
| Kari Mtama-177       | 0.0039  | Local Variety35 | 0.005c              | Ngware spp10 | 0.0071        |
| Local Variety78      | 0.0053  | Gadam Spp36    | 0.006c               | Ngware (white) spp11 | 0.0080       |
| local Variety79      | 0.0026  | Kautimbi spp37 | 0.010c              | Ngware spp12 | 0.0072        |
| local variety80      | 0.0087  | Gadam Spp38    | 0.0004c             | Nyakabala spp13 | 0.0076        |
| Katengu81            | 0.0058  | Gadam Spp39    | 0.016bc              | Nyakabala spp14 | 0.0073        |
| local Brown82        | 0.0110  | Kingundu spp40 | 0.007               | Ochuti spp15 | 0.0120        |
| local Red83          | 0.0050  | Gadam Spp41    | 0.011c              | Nyakabala spp16 | 0.0091        |
| Rasta spp84          | 0.0125  | Local Variety42 | 0.117c              | Nyakabala spp17 | 0.0080        |
| Muruge spp85         | 0.0110  | Gadam Spp43    | 0.010c              | Othiwa spp18  | 0.0068        |
| Muveta spp86         | 0.0097  | Local Variety44 | 0.009c              | Gadam Spp19  | 0.0074        |
| Muvela spp87         | 0.0045  | Local Variety45 | 0.039a              | Nyakabala spp20 | 0.0083        |
| Mugeta spp88         | 0.0065  | Gadam Spp46    | 0.011c              | Andiwii spp21 | 0.0071        |
| Local Red89          | 0.0106  | Local Variety47 | 0.014c              | Ngware spp22 | 0.0086        |
| Local Red90          | 0.0049  | Local Variety48 | 0.010c              | Oyundwi-Jolejo23 | 0.0038        |
| Ciumbichich         | 0.0058  | Local Variety49 | 0.014c              | Seredo spp24 | 0.0036        |
| Vaasya92             | 0.0152  | Local Variety50 | 0.007c              | Gadam Spp25 | 0.0089        |
| local brown93        | 0.0029  | Kitaaka111VII51 | 0.015c             |            |               |
| Rasta94              | 0.0085  | Gadam Spp52    | 0.009               |            |               |
| Muvuta spp95         | 0.0065  | Local Variety53 | 0.010c              |            |               |
| Serena96             | 0.0079  | Local Variety54 | 0.006c              |            |               |
| Langi wa Mbasa97     | 0.0048  | Kivilakayavui55 | 0.010c              |            |               |
| Rasta98              | 0.0085  | Local Variety56 | 0.010c              |            |               |
| Kagaru spp99         | 0.0054  | Local Variety57 | 0.012c              |            |               |
| Rasta spp100         | 0.0106  | Local Variety58 | 0.007c              |            |               |
| Light brown101       | 0.0045  | Local Variety59 | 0.008c              |            |               |
| Local102             | 0.0034  | Gadam Spp60    | 0.011c              |            |               |
| Local103             | 0.0138  | Local Variety61 | 0.005c              |            |               |
| Repaaedt104          | 0.0058  | Local Variety62 | 0.006c              |            |               |
| Cultivar             | 0.0054  | Local Variety63 | 0.011c              |            |               |
| local brown100       | 0.0090  | Local Variety63 | 0.011c              |            |               |
| local Red100         | 0.0030  | Local Variety64 | 0.031ab             |            |               |
| local Red107         | 0.0067  | Local Variety65 | 0.014c              |            |               |
| Local Red108         | 0.0035  | Kitaa Kya iv vii66 | 0.010c            |            |               |
| LSD                  | 0.005   |                 | 0.015               | 0.003      |

Means followed by the same letter within the same column are not significantly different according to Fisher’s Least Significance Difference (LSD) test at p≤0.05.
4. Discussions

In this study, there was a high variability in the germination percentages for the sorghum seeds obtained from Eastern, Coastal and Nyanza regions of Kenya. A majority of the seeds exhibited a high germination percentage of 70% which is within the set standards by the Seeds and Plant Varieties Act of CAP 326 of the Kenyan constitution for sorghum varieties. However, part of the germplasm had low germination percentages indicating presence of low quality seeds used by farmers. Previous studies have reported that farmers obtain sorghum seeds from previously saved seeds, local markets, borrow from neighbors (Ochieng et al., 2011; Catherine et al., 2013; Kange et al., 2014; Muui et al., 2019). Majority of subsistence farmers in semi arid areas produce crops without fertilizers (Jama et al., 1998; Muui et al., 2013). Results of a baseline survey assessing production systems at coastal, Nyanza and eastern regions revealed that most farmers do not use fertilizers (Muui et al., 2019). This results to low yields and poor quality seeds since most soil nutrients have already been depleted (Songa et al., 1994; Craine et al., 2018). High humidity under elevated temperatures in these regions may have contributed to rapid deterioration of the seeds. There is evidence that elongated exposure to high temperatures and moisture would significantly reduce seed germination potential in many crops (Nagel et al., 2016). Besides, post-harvest seed handling and packaging also influence the rate of seed deterioration and hence has a direct impact on seed germination potential (Kange et al., 2014). Studies conducted in eastern, coast and Nyanza reported that most farmers have low education and therefore do not understand the best agronomic and post harvest handling practices which could help increase the quality of seed (Muui et al., 2013; 2019).

The mean time of germination for a seed indicates the time taken by a seed to develop critical structures crucial for germination success, survival, and for faster and uniform establishment. In this study, the mean germination time observed ranged from short, moderate to long. The shorter the mean germination time, the greater the seed vigour. A prolonged MGT may be an indication of deteriorated seed quality as a result of exposure of the seeds to harsh or unfavourable conditions in the field and after harvesting (Bewley and Black, 2012). Such conditions slows the rate of emergence and growth of the seedlings (Amirmoradi and Feizi, 2017); and eventually limits the seedlings from taking advantage of the available nutrients and resources for maximum yield within a short time (Bradford, 2002).

The seed vigour index variation in this study could be attributed to the diverse conditions during production, source of seeds and post harvest handling practices. Increased seedling vigour is an indication of effective germination, seedling emergence early seedling growth and improved grain yield (Lamichhane et al., 2018). Harsh conditions during the late stage of seed development might have also contributed to hormonal imbalance within the seeds which promotes physiological seed dormancy (Cotado and Munné-Bosch, 2020). Longer storage is associated with deterioration of seed stored microRNAs and other important proteins that have a role in the maintenance of high seed viability (Sahu et al., 2017; Sano and Rajjou, 2020).

The shoot biomass of seedlings varied from high to low attributed to pre and post harvest handling practices. A high shoot biomass is an indicator of increased seed vigour and subsequent crop growth cycles (Maucieri et al., 2016). Rapid development of the shoot is associated with the development of more leaves, which is important for the interception of photosynthetic active radiation that enhances rates of photosynthesis resulting in high biomass accumulation (Ceotto et al., 2013). Furthermore, genotypes with higher shoot dry matter have the capability of withstanding drought due to improved water and nutrient use efficiency (Verma et al., 2018). Majority of the germplasm displayed moderate to low root dry matter. Low root biomass has been reported to be as a result of reduced root growth in germplasm consisting of low quality seeds (Joshi et al., 2017). According to Blaha and Pazderu (2013), high seed quality leads to development of seedling with roots of greater biomass an indication of ability to withstand stress condition and also facilitate formation of high quality grains for the subsequent generations.

5. Conclusion and Recommendations

The ability of sorghum to perform well in semi arid areas makes it an important cereal crop to achieve food security. Farmers in Eastern, Nyanza and Coastal regions plant sorghum seeds obtained from diverse informal sources. The environmental conditions in the field and, pre and post harvest handling practices impact on the seed quality hence the wide variability in germination percentage, germination time, seed vigour index and dry matter accumulation in seedlings. This shows the need to improve and monitor the quality of seeds used by subsistence farmers. The quality of sorghum seeds could be improved by providing extension services on best pre and post harvest handling practices. Increasing production of sorghum in these regions will contribute significantly towards realizing food security. Further analysis could be carried out on genetic and sanitary quality aspects of the seeds planted by farmers in Eastern, Nyanza and Coastal regions.
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