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SORGHUM [*Sorghum bicolor* (L.) Moench] SEED QUALITY AS AFFECTED BY VARIETY, HARVESTING STAGE AND FERTILIZER APPLICATION IN BOMET COUNTY OF KENYA

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ABSTRACT

A set of laboratory experiments were conducted to evaluate the physiological quality of *Sorghum bicolor* (L.) Moench seeds subjected to different field cultural management practices. The main aim of this study was to contribute towards improved production of *Sorghum bicolor* (L.) Moench through better understanding of the crop's agronomy. The experimental design was a three factorial split-split block design in the rain fed *Sorghum bicolor* (L.) Moench producing areas of Bomet County of Kenya. Treatments within the block were randomized. There were three factors which included variety at two levels (improved and local varieties); fertilizer application at two levels (with and without fertilizer); and seed selection at three levels (continuous, from booting stage and at harvest). Percentages of crop emergence and days to 50% physiological maturity were determined. The following seed quality tests were carried out: 1000-seed weight, standard germination, mean germination time and electrical conductivity. The improved variety had a field emergence of 100% while that of the local variety ranged from 60 - 97%. In regard to field emergence and maturity, there were significance differences ($P \leq 0.001$) between plots with fertilizer and those without regardless of the variety. Those plots with fertilizer outperformed those without. Germination and vigour tests indicated that seed selection time did not influence seed vigour, viability and yield ($P \leq 0.05$). However, there were significant differences ($P \leq 0.001$) between the improved variety (E1291) and local (*Ochuti*) variety. In relation to this, variety E1291 showed better seed vigour, viability and yield as compared to *Ochuti*. Similarly, there were significant differences ($P \leq 0.001$) between plots to which fertilizer was applied and those without. Fertilizer application led to an increase in seed yield, seed weight, seed vigour and viability. It was therefore concluded that (i) E1291 was more adapted to the study area as compared to *Ochuti* and hence should be adopted by farmers; (ii) farmers should apply optimal phosphate and nitrogenous fertilizers to their soils so as to increase the quality and yield of their seed; and (iii) farmers could continue selecting their seed using their indigenous knowledge.

Key words: Seed, *Sorghum bicolor*, viability, vigour, yield

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is an important staple cereal crop that contributes immensely to domestic food supply and rural household income. Generally, total Sorghum [*Sorghum bicolor* (L.) Moench] production in Kenya is low. Statistics show that by the year 2011, the total yield was 0.6291 metric ton ha^{-1} [1]. Seed production is at 0.02 t ha^{-1} [1]. In Kenya, sorghum [*Sorghum bicolor* (L.) Moench] is ranked third after maize and wheat as a food crop and is adapted to drought environments [2]. *Sorghum bicolor* (L.) Moench production in Bomet County is low and this can be attributed to the low quality seed planted by farmers [3]. Farmers who cultivate *Sorghum bicolor* (L.) Moench face a number of problems in trying to improve the yield of the crop [4]. Most of these problems result from lack of knowledge regarding effective cultural practices for this crop.

Seed selection is an important aspect of seed management and farmers have developed methods of selecting their seeds [5]. Seed harvesting is done when the crop is ready for sale/consumption and not necessarily when the seeds have reached physiological maturity [4]. More so, the majority of the small-scale farmers never grow the crop with fertilizer [4]. 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. As a result, the effect of the use of fertilizer on the quality of seeds in Bomet County has not been known. This practice of using little or no fertilizer on crops may negatively affect both seed quality and yield of the crop [6, 7].

Since *Sorghum bicolor* (L.) Moench is a potential food crop, more information is needed on the good cultural practices of the crop. Such information will help to develop appropriate management practices that will increase the seed quality and contribute to high yields. The aim of this study was to contribute towards better understanding of sorghum crop agronomy and thus improved productivity.

MATERIALS AND METHODS

On-farm trials were carried out on two farmers' fields in Bomet County of Kenya between December 2005 and August 2006. One trial was set up in the upper parts of Bomet Central Division. This is a high production zone with moderate to high fertile loam soils, well distributed rainfall and high altitude [8]. Another trial was set up in the lower parts of Longisa Division of Bomet County. This is a lower production zone that receives low and erratic rainfall with infertile soils [8]. The entire District is divided into three agro-ecological zones. These are the Lower Highland, Upper Midland and Upper Highland [9]. The general altitude varies between 1800m asl in the south and 3000m asl in the north [9]. Longisa Division is located in the lower highland while Bomet Central Division is located in the upper highland region [9].

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The study was conducted using two sorghum varieties, E1291 and *Ochuti*. Variety E1291 is an improved type, cold tolerant and dual-purpose, suitable for both human food and livestock feed [10, 11]. It produces high yields of both grains (6 t ha^{-1}) and forage (has dry matter of 18 t ha^{-1}) [10, 11]. The grains of E1291 are sweet, brown in colour and mature in 160 days [11]. The grains of E1291 are vulnerable to bird damage because of the sweetness in taste [10, 11]. *Ochuti* on the other hand is relatively high yielding; drought tolerant, lodges, late maturing, has brown grains that are bitter in taste, hence not vulnerable to bird damage, and resistant to weevil damage. Before sowing the seeds in the fields, a sample was drawn from both seed lots and subjected to quality tests mainly germination and vigour. E1291 seed lot had a germination percentage of 96%; a mean germination time of 1.0 day and an electrical conductivity of 0.30 μ S cm^{-1} g^{-1} while *Ochuti* seed lot had 88% (germination percentage); 1.2 days (mean germination time) and 0.46 μ S cm^{-1} g^{-1} (electrical conductivity).

Experimental design

The experiment was set up as a 2 x 2 x 3 factorial fitted in a split-split plot design. The factors under test were fertilizer application at two levels, variety at two levels and time of seed selection at three levels. This resulted in 12 treatments in a block and each treatment replicated thrice.

Cold tolerant dual-purpose sorghum cultivar (E1291) and a local variety (*Ochuti*) were sown in the two sites described earlier before the on-set of the long rains of 2006. The sites were ploughed, harrowed and finally hand leveled to ensure a fine tilth. Each site had a total of 36 plots. Each plot size measured 3 x 2 m with 0.5 m and 1.0 m alleys between the plots in a block and between blocks, respectively. The spacing between the rows was 60 cm resulting in 5 rows. Diammonium phosphate (DAP) was thinly applied in the furrows of half of the plots per site (18 plots) at a rate of 225 g $plot^{-1}$ (45 g row^{-1}). This achieved a rate of 69 kg ha^{-1} of P and 27 kg ha^{-1} of N. The seeds of both varieties were sown in furrows of all the 36 plots per site and later thinned to a spacing of 60 x 20 cm $plot^{-1}$. Immediately after thinning, each of those 18 plots per site that had been fertilized with DAP were then top-dressed with 112.5 g of calcium ammonium nitrate or CAN (2.25 g $plant^{-1}$). This achieved a rate of 19.5 kg of N ha^{-1}.

Selection criterion of plants from which seed was to be harvested

Seed selection was done at three levels in accordance with plant development stages. As a result, in one-third of the total plots (12 plots), the plants from which seed was going to be harvested were continuously selected and marked with tags from two weeks after thinning up to harvest maturity time; in another one-third of the plots (12 plots), selection was done from 50% crop booting stage up to harvest maturity time; in the last one-third of the plots (12 plots), selection was done at harvest (this is the farmers usual practice). At all levels, the identification of the plant was by use of plant morphological characteristics.

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Data collection

The field data were obtained from the net plot area which had a total of 12 plants. The parameters measured included percent seedling emergence, days to 50% physiological maturity and grain yield at 11% moisture.

Laboratory experiments

1. Germination percentage

Four hundred seeds from each plot were sown on filter papers, put in petri -dishes and placed in germination chambers at a temperature of 25^0C (± 5) [12]. The seedlings were evaluated as normal seedlings; abnormal seedlings; hard seeds; rotten seeds; or diseased seedlings in accordance with the protocol described in International Rules for Seed Testing handbook [12]. The percent germination was determined by the proportion of normal seedlings on the tenth day.

2. Mean germination time

Four hundred seeds from each plot were sown on filter papers, put in petri -dishes and placed in a germination cabinet at 25^0C (± 5) [12]. The count of emerged seedlings was taken every 24 hours until the tenth day from the sowing date. The mean germination time was then calculated using the following method [13].

$$\text{Mean germination time } = \frac{\Sigma(fx)}{\Sigma(f)}$$

Where: f is the number of newly germinated seeds at a given time
x is the number of days or hours counted from the day of sowing.

3. Electrical conductivity

Four replicates of 100 seeds from each plot were weighed to three decimal places before being soaked in 250 ml -distilled water in plastic containers and incubated for 24 hours at 20^0C. The plastic containers were covered with aluminium foil to reduce evaporation and avoid contamination by dust. The electrical conductivity of the water with seeds was measured using a Fieldlab-LF conductivity Meter and LF 513T electrode dip-type cell (Schott Gerate Glass Company, Mainz, Germany). An equivalent quantity of distilled water was also measured as control. The conductivity per gram of seed in μ S/cm at 12% moisture content in 250ml of water was then calculated [12].

Statistical analysis

Data sets were analyzed using SPSS version 12.0.1. The data were subjected to analysis of variance (ANOVA). Levels of significance, means and standard errors were obtained for various data sets. Separation of means was done by the least significant differences (LSD) method.

RESULTS

The influence of site, variety and fertilizer on percent seedling emergence (SE %)

E1291 with or without fertilizer was not affected by site and hence 100% seedling emergence recorded (Table 1). The SE % of *Ochuti* was significantly (P≤0.001) influenced by site with or without fertilizer. The SE % of *Ochuti* was significantly (P≤0.001) higher in Longisa Division (LD) than in Bomet Central Division (BCD) with or without fertilizer (Table 1). In BCD, Variety *Ochuti* with no fertilizer gave the lowest value of 60.65%, implying low vigour (Table 1).

The influence of site, variety and fertilizer on days to 50% physiological maturity (PM)

The time taken by the sorghum crop to attain 50% PM was influenced by site for both E1291 and *Ochuti*, regardless of fertilizer application (Table 2). In LD, both E1291 and *Ochuti*, with or without fertilizer, took a significantly (P≤0.001) shorter time period to attain 50% PM than those in BCD (Table 2). Applying fertilizer to sorghum significantly (P≤0.001) reduced the number of days to 50% PM in both divisions (Table 2). Sorghum grown without fertilizer took significantly (P≤0.001) more days to attain 50% PM as compared to the sorghum crop with fertilizer. E1291 supplied with fertilizer in both divisions took a significantly (P≤0.001) shorter period to attain 50% PM than *Ochuti* when supplied with fertilizer (Table 2). In BCD, E1291 (without fertilizer) took a significantly (P≤0.001) shorter period to attain 50% PM as compared to *Ochuti* without fertilizer application (Table 2). In LD, there was no significant (P≤0.001) difference between E1291 (without fertilizer) and *Ochuti* (without fertilizer) in relation to the number of days taken to attain 50% PM (Table 2).

Influence of site, variety and fertilizer on percent germination (GMN %)

Percent germination of seeds harvested from both E1291 and *Ochuti* (with or without fertilizer) was influenced by site (Table 3). This was because the soils and climate in the two sites were different [8, 9] and (Table 7). In LD, the GMN % of seeds harvested from both E1291and *Ochuti* grown (with or without fertilizer) was significantly (P≤0.001) higher than those grown in BCD with the same treatment (Table 3). In LD, the GMN % of the sorghum seeds (harvested from both E1291 and *Ochuti*) increased significantly (P≤0.001) with fertilizer application (Table 3). In BCD, the GMN % of the sorghum seeds harvested from *Ochuti* increased significantly (P≤0.001) with fertilizer application (Table 3). In BCD, fertilizer application did not significantly (P≤0.001) affect the seeds harvested from E1291 (Table 3). Seeds harvested from E1291 (with or without fertilizer) significantly (P≤0.001) outperformed seeds harvested from *Ochuti* (with or without fertilizer) grown in BCD and seeds harvested from *Ochuti* (without fertilizer) grown in LD in relation to GMN % (Table 3). The GMN % of seeds harvested from E1291 (without fertilizer) grown in LD did not differ significantly (P≤0.001) from those harvested from E1291 (with fertilizer) grown in BCD and those harvested from *Ochuti* (with fertilizer) grown in LD (Table 3). In accordance with the guidelines stipulated in The Seeds and Plant Varieties Act of CAP 326 of the laws of Kenya [14], the minimum

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germination capacity percent requirement for sorghum is 70. Therefore, seeds harvested from *Ochuti* (without fertilizer) grown in BCD did not meet this standard (Table 3), implying poor quality.

Influence of site, variety and fertilizer on mean germination time (MGT) in days

The MGT of seeds harvested from E1291 and *Ochuti*, with or without fertilizer application was influenced by site (Table 4). This was because the soils and climate in the two sites were different [8, 9] and (Table 7). Seeds harvested from both E1291 and *Ochuti* (with or without fertilizer application) in LD took a significantly (P≤0.001) shorter time to germinate as compared to seeds harvested from the two varieties grown in BCD with the same treatment (Table 4). In both divisions, the application of fertilizer significantly (P≤0.001) shortened the MGT of seeds harvested from E1291 as compared to the seeds harvested from the same variety with no supplied fertilizer (Table 4). In both divisions, seeds harvested from *Ochuti* supplied with fertilizer took a significantly (P≤0.001) shorter MGT as compared to the seeds harvested from the same variety with no supplied fertilizer (Table 4). Seeds harvested from E1291 grown in LD significantly (P≤0.001) took the shortest MGT while seeds harvested from *Ochuti* in BCD significantly (P≤0.001) took the longest MGT (Table 4).

Influence of site, variety and fertilizer on electrical conductivity (EC)

Seeds of both E1291 and *Ochuti*, with or without fertilizer were influenced by site as revealed by the EC test (Table 5). Seeds of both E1291 and *Ochuti*, with or without fertilizer grown in LD had significantly (P≤0.001) lower EC values as compared to the seeds of the same treatment grown in BCD (Table 5). Therefore, seeds obtained from LD were considered to be of higher vigour than those obtained from BCD. Seeds obtained from sorghum crop supplied with fertilizer gave significantly (P≤0.001) lower EC values than those obtained from sorghum crop with no fertilizer in both divisions (Table 5). Seeds obtained from E1291, with or without fertilizer gave significantly (P≤0.001) lower EC values and thus were of high vigour as compared to those obtained from *Ochuti*, with or without fertilizer (Table 5). Seeds obtained from E1291 with fertilizer gave a significantly (P≤0.001) lower EC values as compared to seeds of E1291 without fertilizer (Table 5). Seeds harvested from *Ochuti* supplied with fertilizer had significantly (P≤0.001) lower EC values as compared to seeds harvested from *Ochuti* with no fertilizer supplied (Table 5).

Influence of site, variety and fertilizer on seed yield (SY)

Seed yield from E1291 and *Ochuti*, with or without fertilizer was influenced by site (Table 6). Applying fertilizer to sorghum crop significantly (P≤0.001) increased SY as compared to sorghum crop with no fertilizer in both divisions (Table 6). The seed yield of E1291 supplied with fertilizer grown in both divisions was significantly (P≤0.001) higher than the SY of E1291 with no fertilizer (Table 6). *Ochuti*, (with or without fertilizer) recorded significantly (P≤0.001) lower SY as compared to E1291 (supplied with fertilizer) grown in both divisions (Table 6). The SY of E1291 with no fertilizer grown in LD was significantly (P≤0.001) higher than the SY of E1291 (with

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no fertilizer supplied) grown in BCD and the SY of *Ochuti* (with or without fertilizer) grown in both divisions (Table 6). The SY of *Ochuti* (with fertilizer) grown in LD was not significantly (P≤0.001) different from that of E1291 grown in BCD with no fertilizer supplied (Table 6).

DISCUSSION

(i) Sorghum seed vigour and viability

(a) Influence of variety on vigour and viability

The seeds harvested from E1291 had significantly (*P*≤0.001) higher vigour and viability than those harvested from *Ochuti*. This could be due to two possible reasons. First, it is possible that variety E1291 had some superior genes adapted to the cold semi-arid conditions as a result of gene introgression by breeders [15, 16]. Breeders at Kenya Agricultural Research Institute (KARI) bred the improved variety with great considerations on its adaptability to cold semi-arid environments unlike the *Ochuti* variety. Therefore, there is a possibility that after the interaction between the varieties and the environment, the cell membranes of the seeds of variety E1291 retained their good integrity hence the seeds experienced minimal electrolyte leakage during the electrical conductivity test. Seed vigour is usually influenced by genetic constitution during seed development [17]. Some of these genotype qualities of the seed that influence seed vigour include mechanical integrity, protein content, resistance to disease and seed size. Another possible reason may be related to the observation that usually the quality of the seed produced will always depend on the quality of the seed sown, assuming all other factors are favourable [18]. The improved variety had higher quality than the local variety (as indicated by the initial quality tests).

(b) Influence of fertilizer on vigour and viability

Effect of fertilizer nutrients on seed vigour is not direct but has been attributed to their influence on seed maturation and seed chemical composition [19]. Fertilizer treatment of mother plants has been known to exert significant influence on resultant seed quality in relation to emergence, germination, growth and survival [19]. In this study, fertilizer application to sorghum led to an increase in seed vigour (as measured by both the electric conductivity and mean germination time tests) and viability (as measured by germination test). This could have been caused by increased photosynthates channeled within the seeds as a result of fertilizer application. Fertilizer application usually increases photosynthates being channeled to the developing seed, enabling it to attain higher seed weight [20].

The germination and vigour of seeds supplied with fertilizer was higher than that of seeds not supplied with fertilizer because seeds treated with fertilizer contained larger food reserves, which enable them to nourish the embryo longer during germination [21]. These seeds nourished with fertilizer have got big embryos that germinate vigorously as compared to those that have not been supplied with fertilizer and therefore stressed [22]. Furthermore, seeds supplied with fertilizer have got sufficient nitrogen that is essential for the production of enzymes, which play an important role

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in metabolic processes of germination and growth [23]. Seeds produced under conditions of nutrient stress have their chemical compounds such as carbohydrates and proteins stored and not utilized in the provision of energy and biochemical building blocks of the seed to enhance germination [22].

(c) Influence of site on vigour and viability

Seed vigour is usually influenced by environmental factors during seed development [17, 24]. These environmental factors include soil moisture, soil fertility and post maturation/ pre-harvest environment [24]. Vigour and viability of seed is usually high when a crop is planted in ideal growing conditions [24]. This means that an environment with stressful conditions will result in the production of a less vigorous and viable seed lot [24]. In Longisa Division (LD), both E1291 and *Ochuti* seeds were significantly ($P \leq 0.001$) of higher vigour and viability than those obtained from Bomet Central Division (BCD). This was caused by different ago-ecological factors (like soils and climate) exhibited in the two sites [8, 9]. Generally, many sorghum varieties are well adapted to a warm environment [16]. Therefore, the growing environment in LD was more ideal for the crop growth as compared to that of BCD [8, 9].

(ii) Sorghum seed yield

(a) Influence of variety on sorghum grain yield

Seed yield harvested from E1291 was significantly ($P \leq 0.001$) higher than that harvested from the *Ochuti* in both divisions. It is possible that, the genetic constitution of E1291 is more cold tolerant than that of *Ochuti* [25]. This is because E1291 was specifically bred to tolerate the harsh climatic conditions experienced in the cold semi-arid highlands while *Ochuti* was not [25]. The seed yield results obtained in this study are similar to those obtained earlier, which ranged between 3.0 to 7.5 t ha^{-1} [26].

(b) Influence of fertilizer on sorghum grain yield

Fertilizer treatment of mother plants has been known to exert significant influence on resultant seed quality in relation to seed weight [19]. Seed yield of both E1291 and *Ochuti* varieties irrespective of site increased with fertilizer application. In this study, the increase of seed yield in plots supplied with fertilizer was attributed to the availability of phosphorous and nitrogen from the DAP and CAN fertilizers applied [16]. Generally, DAP fertilizers are rich in both nitrogen and phosphorus while CAN fertilizers are rich in calcium and nitrogen nutrients. It is, therefore, assumed that the role played by these fertilizers in this study was to add to the soils some phosphorus, nitrogen and calcium nutrients. Increase in nitrogen leads to an increase in the sorghum seed yield [27]. For instance, sorghum seed yield increased from 2.92 to 5.61 t ha^{-1} in the plots that were treated with 90 kg N $ha^{-1,}$ compared with the control plots with 0 kg N ha^{-1} [27]. This increase in seed yield with nitrogen levels was attributed to the gradual increase in seed number and seed weight [27]. In addition, plants require adequate phosphorus from the very early stages of growth for optimum crop production [28].

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(c) Influence of site on sorghum grain yield

It has been reported that dry matter yields are directly correlated to rainfall or differences in temperature, which is expected to occur at temperature changes of about 6.5°C or at altitude change of 1000 m [29]. As pointed out earlier, Longisa Division (LD) is located in the lowlands while Bomet Central District (BCD) is located in the highlands thereby resulting in an ecological difference in terms of temperature and rainfall. It is expected that in the highlands temperatures are cooler than in the lowlands and this can adversely affect the production of sorghum considering that it is a warm season crop. Many sorghum varieties are usually adapted to drought prone environments that receive little rainfall [16, 29]. This is true in relation to the results obtained in this study because sorghum seed yield of both improved and local varieties (with or without fertilizer) in LD were significantly ($P \leq 0.001$) higher than those harvested from BCD.

CONCLUSIONS

During production of sorghum seeds, farmers should consider planting the improved variety if they are to optimize the seed quality and yield since the improved variety proved to be superior over the local variety in terms of seed quality and yield characteristics.

Sorghum positively responds to both nitrogen and phosphorous application. High grain yield and high seed quality can be achieved by the availability of phosphorus and nitrogen at the desired time and in optimal amounts. In this study, 69 kg ha^{-1} of phosphorus and 27 kg ha^{-1} of nitrogen was used. This indicates that farmers in Bomet County could produce high grain yield and high quality seeds if they applied fertilizer in optimal amounts.

Sorghum is more adapted to low rainfall regimes. The improved variety (*E1291*) is adapted to areas with less rainfall. Therefore, following the results of this study, farmers in Longisa Division can be encouraged to use the E1291 variety which is well adapted to the Division so as to alleviate poverty and improve the food security situation. Farmers in Bomet Central Division are encouraged to diversify and grow other food crops that are well adapted to the region other than sorghum so as to alleviate food insecurity.

The findings of this study did not show any significant difference in the different times of seed selection (continuous selection; selection from booting stage; and selection at harvest) in all parameters measured (Table 8). This indicates that seed selection time is not an important factor to consider in finding solutions to improving the low sorghum seed production in Bomet County. Therefore, farmers could continue with their indigenous way of selecting seed until a better selection method is developed.

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Table 1: Effect of site, variety and fertilizer on percent seedling emergence of on-farm sorghum produced seeds

Seedling emergence (%) [r]			
		Fertilizer (F)	
Variety (V)	**Site (S)**	With fertilizer	Without fertilizer
Improved	Bomet Central	100a	100a
	Longisa	100a	100a
Local	Bomet Central	85.18d	60.65e
	Longisa	97.22b	90.74c

CV (a)=48.71% CV (b)=20.88% CV (c)=4.08%

S.E. of V x F x S=0.32 L.S.D $_{(0.001)}$ of V x F x S=1.59

[r] Average of three replications

Means with the same letters are not significantly different from each other according to LSD test

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Table 2: Effect of site, variety and fertilizer on days to 50% physiological maturity of on-farm sorghum produced seeds

Days to 50% Physiological maturity [r]			
		Fertilizer (F)	
Variety (V)	**Site (S)**	With fertilizer	Without fertilizer
Improved	Bomet Central	170.8d	186.6b
	Longisa	135.2g	154.2e
Local	Bomet Central	180.3c	204.4a
	Longisa	141.8f	152.9e

CV (a)=14.22% CV (b)=10.38% CV (c)=0.61%

S.E. of V x F x S=0.3 L.S.D $_{(0.001)}$ of V x F x S=1.5

[r] Average of three replications

Means with the same letters are not significantly different from each other according to LSD test

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Table 3: Effect of site, variety and fertilizer on percent germination of on-farm sorghum produced seeds

Percent sorghum seed germination [r]			
		Fertilizer (F)	
Variety (V)	**Site (S)**	With fertilizer	Without fertilizer
Improved	Bomet Central	83.64bc	81.86c
	Longisa	88.00a	84.26b
Local	Bomet Central	74.12d	62.83e
	Longisa	84.16b	83.33d

CV (a)=18.49%   CV (b)=3.25% CV (c)=1.38%

S.E. of V x F x S=0.36   L.S.D $_{(0.001)}$ of V x F x S=1.79

[r] Average of three replications

Means with the same letters are not significantly different from each other according to LSD test

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Table 4: Effect of site, variety and fertilizer on mean germination time (days) of on-farm sorghum produced seeds

Mean Germination Time (days) [r]			
		Fertilizer (F)	
Variety (V)	**Site (S)**	With fertilizer	Without fertilizer
Improved	Bomet Central	1.4e	1.5d
	Longisa	1.0h	1.1g
Local	Bomet Central	1.6c	2.0a
	Longisa	1.3f	1.9b

CV (a)=30.25%   CV (b)=21.39% CV (c)=2.14%

S.E. of V x F x S=0.01   L.S.D $_{(0.001)}$ of V x F x S=0.05

[r] Average of three replications

Means with the same letters are not significantly different from each other according to LSD test

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Table 5: Effect of site, variety and fertilizer on electrical conductivity (µS cm^{-1}) of on-farm sorghum produced seeds

Electrical conductivity (µS cm^{-1}) [r]			
		Fertilizer (F)	
Variety (V)	**Site (S)**	With fertilizer	Without fertilizer
Improved	Bomet Central	0.45f	0.51e
	Longisa	0.34h	0.40g
Local	Bomet Central	0.82b	1.05a
	Longisa	0.54d	0.76c

CV (a)=52.0% CV (b)=20.0% CV (c)=2.0%

S.E. of V x F x S=0.002 L.S.D $_{(0.001)}$ of V x F x S=0.01

[r] Average of three replications

Means with the same letters are not significantly different from each other according to LSD test

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Table 6: Effect of site, variety and fertilizer on yield (t ha^{-1}) of on-farm sorghum produced seeds

Yield (t ha^{-1}) ^{r}		Fertilizer (F)	
Variety (V)	**Site (S)**	With fertilizer	Without fertilizer
Improved	Bomet Central	5.79b	5.11d
	Longisa	7.16a	5.40c
Local	Bomet Central	3.03e	1.51g
	Longisa	5.02d	2.43f

CV (a)=30.60% CV (b)=20.08% CV (c)=2.3%

S.E. of V x F x S=0.02

L.S.D $_{(0.001)}$ of V x F x S=0.1

^{r} Average of three replications

Means with the same letters are not significantly different from each other according to LSD test

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Table 7: Monthly rainfall observation in millimeters as observed from December 2005 to December 2006 at Longisa and Bomet Central Divisions of Bomet County of Kenya

Month	**Amount of rainfall (mm)**		**Number of days rained per month**		**Mean monthly rainfall (mm)**	
	Longisa Division	Bomet Central Division	Longisa Division	Bomet Central Division	Longisa Division	Bomet Central Division
December 2005	14.2	17.5	3	4	0.46	0.56
January 2006	33.3	50.2	8	10	1.07	1.62
February 2006	74.8	100.3	8	10	2.67	3.58
March 2006	321.3	195.0	20	21	10.36	6.29
April 2006	254.0	237.8	15	23	8.47	7.93
May 2006	58.2	226.4	8	19	1.88	7.30
June 2006	27.8	34.1	5	6	0.93	1.14
July 2006	28.3	22.9	4	4	0.91	0.74
August 2006	95.0	52.2	6	6	3.06	1.78
September 2006	38.2	64.3	6	11	1.27	2.14
October 2006	32.3	31.6	4	6	1.04	1.02
November 2006	219.3	325.3	18	23	7.31	10.84
December 2006	315.4	360.2	16	28	10.17	11.62

Source: [30]

Mean annual rainfall of Longisa Division= 4.13 mm

Mean annual rainfall of Bomet Central Division= 4.71 mm

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Table 8: A summary of results of percent seedling emergence; days to 50% physiological maturity (pm); germination percentages; mean germination time; electrical conductivity; and yield in Longisa and Bomet Central Divisions

Mean squares

Source	df	% seedling émergence	Days to 50% PM	Germn. (%)	MGT (days)	Electrical Conductivty (μS cm^{-1} g^{-1})	Yield (t ha^{-1})
Site (S)	1	567.2*	28084.5*	837.8*	1.6*	0.7*	23.4*
Replication	2	53.6 ns	0.4 ns	0.6 ns	0.0 ns	0.0 ns	0.0 ns
Variety (V)	1	4931.1*	1200.5*	2110.3*	3.1*	2.4*	147.9*
S x V	1	1996.6*	555.6*	213.6*	0.2*	0.1*	1.8*
CV (%)		48.7	14.2	18.5	30.3	52.0	30.6
Fert. (F)	1	1082.3*	5512.5*	859.7*	1.6*	0.3*	48.0*
F x S	1	366.9*	107.6*	2.5 ns	0.0*	0.0 ns	5.2*
F x V	1	1082.3*	0.2 ns	309.2*	0.6*	0.1*	3.1*
F x V x S	1	366.9*	296.1*	6.6*	0.1*	0.0*	0.0 ns
CV (%)		20.9	10.4	3.3	21.4	20.0	20.8
Selec. (T)	2	1.0 ns	3.9 ns	14.1 ns	0.0 ns	0.0 ns	0.0 ns
T x S	2	1.0 ns	03. ns	1.8 ns	0.0 ns	0.0 ns	0.0 ns
T x V	2	1.0 ns	0.9 ns	0.5 ns	0.0 ns	0.0 ns	0.0 ns
T x F	2	1.0 ns	0.4 ns	0.3 ns	0.0 ns	0.0 ns	0.0 ns
T x V x S	2	1.0 ns	0.4 ns	0.3 ns	0.0 ns	0.0 ns	0.0 ns
T x V x F	2	1.0 ns	0.1 ns	0.3 ns	0.0 ns	0.0 ns	0.0 ns
T x F x S	2	1.0 ns	1.0 ns	0.2 ns	0.0	0.0 ns	0.0 ns
TxVx F x S	2	0.0 ns	0.2 ns	1.4 ns	0.0 ns	0.0 ns	0.0 ns
Error	46	14.022	1.012	1.194	0.001	0.001	0.003
CV (%)		4.1	0.6	1.4	2.1	2.0	2.3

* significant ns = Not significant cv = coefficient of variation Alpha = 0.05

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