

Effect of Sources and Storage Conditions on Quality of Sorghum Seeds

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Abstract

A study was conducted in three agro-ecological zones of Tanzania to investigate sources, status, quality and storage conditions of sorghum (*Sorghum bicolor* L.) seeds. Sorghum seed samples were collected from Kwimba (Lake zone), Chamwino (Central zone) and Kilosa (Eastern zone) districts. In surveyed districts 83.3 % of farmers were using farmer saved seeds while 16.7 % were using improved sorghum seeds. In surveyed areas, 85 % of seed samples were obtained from small scale farmers as farmer saved seeds, 1.7% from seed stockists and 13.3% from agriculture research institutions. Seeds were found stored in the households (86.7%) and in go-down in case of seeds stockists (13.3%). The laboratory purity analysis test results indicated that Kwimba had pure seeds of 94.4%, Chamwino 96.5% and Kilosa 99.0%. Inert matters; Kwimba 5.3%, Chamwino 1.8% and Kilosa 1.0%. The non-sorghum seeds observed were Kwimba 0.2%, Chamwino 1.8% and Kilosa 0%. The results were significantly different at $P < 0.001$ from one agro-ecological zones to another. The germination test of sorghum seeds varied highly significantly ($P < 0.001$) from Kwimba 74%, Chamwino 88% and Kilosa 85%. Seed-borne fungal species found in the samples from the study areas were *Fusarium moniliforme*, *Bipolaris sorghicola*, *Curvularia lunata*, *Colletotrichum graminicola* and *Phoma sorghina*. Samples collected from Eastern zone had the highest infection by fungi. Other pathogens *Aspergillus flavus*, *A. niger*, *Penicillium* spp., *Claviceps* spp. and *Rhizopus* spp. were found infecting seeds. Central agro-ecological zone is proposed to be better for sorghum seeds production for healthier seeds due to non-fungal infection observed in this study.

Key words: agro-ecological zones, seed, moisture content, purity, germination, seed-borne pathogens

Introduction

Seeds of inferior quality result into poor germination and vigour, or may contain seed-borne pathogens which may be transmitted to the developing crops (Abdusalaam and Shenge, 2011). Farmers incur financial and yield losses as a result of buying seeds of inferior quality (Setimela *et al.*, 2004). Poor seed germination has been identified as a fundamental constraint in sorghum production in Tanzania and it depends on the regions or agro-ecological zones of seed production (TOSCI, 2011). The average sorghum seed germination percentages of 68.2, 45.4 and 71.6 were recorded for the seed lots originated from Dodoma, Morogoro and Singida, respectively, from 2006 to 2010 (TOSCI, 2011). Moreover, among 39 sorghum seed samples tested at TOSCI which were produced from Morogoro region in 2006, 2007 and 2008, only 12 samples (30.8%) attained the

acceptable germination percent (75%) according to ISTA rules and Tanzania National Seed Quality Standards (ISTA, 2008a; TOSCI, 2011). The study conducted on sorghum quality declared seeds (QDS) in Morogoro and Dodoma regions also revealed poor sorghum seed germination (Mbega, 2007). Although according to the Ministry of Agriculture Food and Cooperatives, National Seed Policy (1994), 10% of farmers were found using improved (certified) seeds. Study by Temu and Mtenga (2001) revealed that only 4% of the total seed planted each year were certified, whereas informal seed systems supplied 96% of the seed used by smallholder farmers. Research conducted in Iringa, Morogoro and Dodoma regions in Tanzania in 2006 have reported serious seed germination problem caused by seed-borne pathogens including fungi, but it was on sunflower and finger millet (David, 2006). However, those previous studies

did not suggest the better site or agro-ecological zone where good quality and healthy sorghum seeds could be grown.

Seed testing is necessary in crop production for easy identification of seed-borne pathogens, determination of seed quality, moisture content, quality standards for certification purposes, seed grades and price and imposition of quarantines to avoid spread of seed-borne diseases, insect pests and weeds (Mathur and Kongsdal, 2003a). It is also known that, clear identification and proper management strategies of seed-borne pathogens are the most desirable way to control seed-borne diseases (Abdulsalaam and Shenge, 2011). Seed-borne pathogens may be found on the seed coat, endosperm or embryo and can be transmitted to the developing crop upon seed germination. Seed borne fungi limits production of sorghum in Tanzania (Nyambo, 2009).

Farmer saved seeds (FSS) are known to be rich in inert matters, weed seeds, higher moisture contents and are stored in poor facilities (Noble, 1971; David, 2006; Mbega, 2007). The poor storage facilities of FSS reduce seed quality, leading to low yield and incomes for small-scale growers (Syed *et al.*, 2012). The objective of this study was to determine how agro-ecological zones for production, classes and storage facilities affect the seed quality. In this study prevalence and incidence of seed borne fungi on sorghum seeds of various classes collected from three agro-ecological zones of Tanzania were determined and recommendation of preferential sites for healthy sorghum seeds multiplication were given.

Material and methods

Study area

Field survey was conducted from September to October 2012 and 60 sorghum seed samples of different classes from different sources were collected (Table 1 and Figure 1). The criteria used in selection of agro-ecological zones was based on differences in climatic factors, viz a viz Morogoro and Dodoma are located at low to medium altitude and medium rainfall, Mwanza; medium altitude high rainfall). These factors have influence on occurrence and severity of diseases. Seed samples were purchased from

farmers saved seeds, seed producers and seed merchants for improved or certified seeds. Selection of wards and ultimately villages to be surveyed for sorghum seeds samples was participatory. In each district, the District Agricultural and Livestock Officers (DALDO) were requested to suggest two wards and two villages with the highest sorghum production records. A structured questionnaire seeking information on household characteristics and knowledge on improved sorghum seeds production and usage including processing and utilization, was administered to a total of 60 purposively selected sorghum farmers and seed dealers.

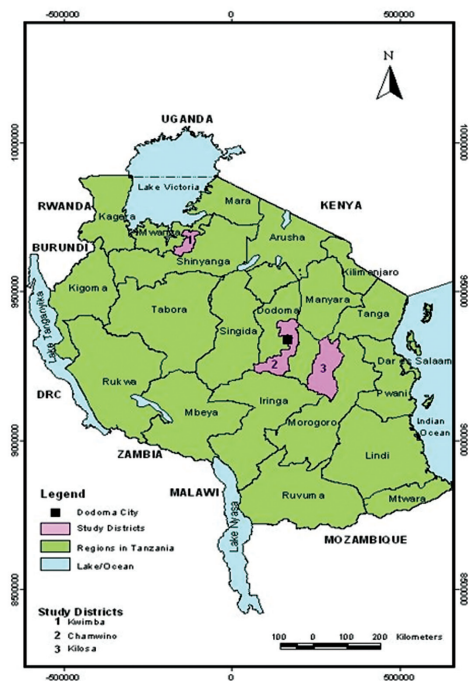


Figure 1: Map of Tanzania showing districts where the seed samples were collected

Laboratory seed quality tests

In the households, sorghum seeds and grains were found to be stored in shelled form in polythene sacks made of polyethylene materials. In the seed companies and stockists, sorghum seeds were found stored in the similar polythene sacks treated with some additives such as anti-blocks to prevent the plastic layers from sticking together and ultra-violet inhibitor to protect

Table 1: Characteristics of agro-ecological zones and source of sorghum seeds used in the study

Zone	Altitude (m.a.s.l)	Annual rainfall (mm)	Rainfall pattern	Regions	District	Ward	Villages
Lake Zone	500-1500	600-1400	Bimodal	Mwanza	Kwimba	Igongwa	Mwadubi Igongwa
Central Zone	500-1500	400-800	Unimodal	Dodoma	Chamwino	Buigiri	Buigiri Chamwino
Eastern Zone	200-800	750-1200	Bimodal	Morogoro	Kilosa	Chanzuru	Ilonga Chanzuru

the plastic from ultraviolet radiation which can weaken the plastic's strength and fade the colour. During sorghum seeds sampling, a grain trier was used to draw incremental samples from three points from each bag. The samples were taken only from containers meant for seeds. The incremental samples were thoroughly mixed to make a composite sample. In each household, one kilogram of the well mixed composite sample was packaged in a khaki paper bag. The label was inserted inside the bag while the other one stapled outside before sealing the bags.

The collected seed samples were taken to Tanzania Official Seed Certification Institute (TOSCI) and Plant Pathology Laboratory at Sokoine University of Agriculture (SUA) for seed quality tests which were purity analysis, moisture content, germination and health. At TOSCI, the working samples were obtained by pouring the composite samples in the conical Boerner divider (made in India by Kartar Scientific Industries) to mix and divide to obtain 90 g of working samples for seed quality testing of purity and germination tests according to International Seed Testing Association (ISTA) rules (ISTA, 2008b). The working samples for seed-borne fungal pathogen test were submitted to Plant Pathology Laboratory at SUA. At TOSCI and SUA laboratories the samples were stored in cold rooms maintained at 5°C to inhibit further growth of microorganisms and other storage insect pests.

Seed moisture content analysis

Ten grams of sorghum seeds were evenly distributed over the metal dishes with 8.5 cm

diameter. The weight was recorded before and after filling metal dishes with seeds, then placed in an oven maintained at 130°C and dried for 2 h (ISTA, 2008b). Percentage of moisture was calculated as follows:

$$MC = \frac{M_2 - M_3}{M_2 - M_1} * 100$$

Where; M1 = the weight (g) of empty container and its cover

M2 = the weight (g) of container plus cover and seeds before drying.

M3 = the weight (g) of container plus cover and seeds after drying.

MC = Moisture Content

Seed purity analysis

Composite samples were thoroughly mixed using a Boerner divider and after a thorough mixing, 90 g from each seed samples were taken for purity analysis according to ISTA Rules (ISTA, 2008b). The seed samples taken were then poured on a purity analysis table. Seed samples were analysed into pure seeds (seeds of *S. bicolor*), inert matter (chaffy materials, sand, soil particles, plant parts, live and dead insects and animal droppings and particles of any seed which is less than half) and other seeds (any crop or weed seeds other than *S. bicolor* and weed seeds). These components were then weighed separately using a precision balance (pioneer TM for working sample, DIKEY John for purity and pioneer OHAUS for inert matter) all from OHAUS corporation company, United States of America. The percentage by weight of each component fraction was calculated using the following formula:

$$\text{Component(\%)} = \frac{\text{Weight of each component fraction}}{\text{Total test sample weight}} \times 100$$

When percentages of all three components were added together, they were equal to 100 %. The percentage of pure seed was presented to one decimal place. In some cases where the sum did not equal to 100 %, 0.1 % was subtracted or added to from the pure seed fraction. Fractions of components less than 0.05 % were recorded as “trace”. The pure seed fraction was used for seed germination test.

Seed germination test

The pure sorghum seed portions obtained after purity analysis were used for germination test. Four hundred (400) seeds were taken from each sample using halving-method (ISTA, 2008a; 2008b). Halving method refers to procedure where seeds are poured evenly on to a smooth clean surface and thoroughly mixed into a mound using a spatula. The mound is then divided into ½ and each half is mound again and halved into 4 portions and halved again to get 8 portions. The halved portions were then arranged in rows and alternate portions were combined and retained. The process was repeated until the sample of required weight was obtained (400 seeds in this case) (ISTA, 2008a; 2008b). ISTA papers were used as substrate in the sorghum seeds germination test. The averages of 100 seeds per replicate (4 replications) were expressed as a percentage by number of normal seedlings (those which show potential for continued development into satisfactory plants when necessary conditions are provided), abnormal seedlings (those which did not show the potential to develop into normal plant when grown in good quality soil and under favourable conditions of moisture, temperature and light), hard seeds (those seeds which remained hard at the end of the test period because they could not imbibe water), fresh seeds (those seeds which fail to germinate under the condition of germination test but remain clear and firm and had the potential to develop into the normal seedling) and dead seeds (those seeds at the end of the test period were neither hard nor fresh nor have produced any part of a seedling). The percentages of normal, abnormal and dead seeds were calculated by using the formula:

$$\text{Component(\%)} = \frac{\text{number of each component counted}}{100}$$

The percentages were calculated to the nearest whole number after calculation of tolerance for germination test (ISTA, 2008a; 2008b).

Seed health testing

For detection of seed infection, four hundred (400) pure seeds from each sample were plated in potato dextrose yeast agar (PDYA) in Petri dishes of 90 mm diameter at the rate of 20 seeds per dish and incubated for 7 days (Mathur and Kongsdal, 2003b) to detect seed infestation and infection. Before plating, sorghum seeds were first surface sterilized using 70% ethanol for 1 min, then immerse into 2% sodium hypochlorite (NaOCl₂) solution for 5 min followed by three rinses in sterile distilled water for 3 min. Twenty seeds from each sample were then plated in Petri dish containing PDYA (pH 5.5) and incubated at 25°C for 24 h of alternating cycle of light and darkness for 7 days. After 7 days seeds were examined using a stereomicroscope to determine the presence or absence of fungal growth.

The observed fungal conidia and conidiomata were placed on microscope slides and observed by compound microscope. Various magnifications were used to examine spores and mycelia produced by each group of fungi. This experiment was laid out in RCBD with three replications; each region was regarded as block.

Data analysis

Data from survey were analysed by SPSS 16 edition for windows computer software. Descriptive statistical analysis was carried out by using a sub-programme “Frequencies” for univariate analysis to obtain variability of dependent and independent variables to determine means and frequencies. Chi-square was used to test for the variable relationships and to determine mean differences. These were rejected or accepted on the basis of the Chi-square values computed for the dependency between the variables. Significance levels of 0.05 and 0.001 were selected as the criterion for determining a significant difference. Data obtained from purity test, seed germination tests and seed-borne fungal growth was analysed

using GenStat computer package 14th edition. The calculated value (F-value) was compared with tabulated value at 0.05 level of significance. Mean separation test was done using Least Significance difference for seed moisture content, purity and germination tests; and Turkey's tests for seed fungal growth incidence.

Results

Rainfall pattern of agro-ecological zones under sorghum seed production and characteristics of seeds producers

The study areas of Kwimba and Kilosa were characterized by bimodal rainfall pattern while Chamwino had unimodal (Figure 2). The bimodal is indicated by two peaks from mid-February to end of April for long rain season and mid-November to mid-January for short rains. The central zone's rain is from mid-November to March. In all agro-ecological zones sorghum seeds were produced during long rain seasons. In surveyed districts 83.3 % of farmers were using FSS while 16.7% were using certified sorghum seeds. Most small scale farmers had age ranging between 30 to 50 years (65%). The sorghum seeds producers and dealers had different levels of education from no formal education, primary, secondary and college with percentages of 15.0%, 51.7%, 20.0%, and 13.3% respectively. In all surveyed areas 85.0% of sorghum seed producers were small scale farmers, 1.7% were stockist and 13.3% were institutions dealing with plant breeding and seed multiplication. Purpose for sorghum production differed among individuals whereby 85% were for household consumption and other uses, while 15% were for sell as seeds. In all districts seeds were found stored in the house (86.7%) and in storage facility (13.3%) (Table 2).

Laboratory sorghum seeds testing results

Seeds from all three agro-ecological zones had a highly significantly difference ($P < 0.001$) moisture contents from one sample to another across location (Table 3). The recorded average of moisture contents were Kwimba 11.8%, Chamwino 11.1% and Kilosa 11.5%. However, some samples had moisture content as high as 14.3% (Fig. 3). This study also indicated the relationship between the seed moisture content, incidence of seed-borne pathogen and seed

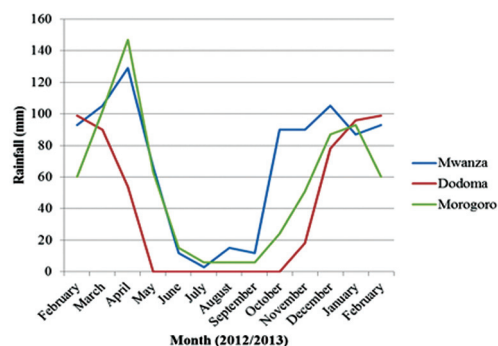


Figure 2: Distribution of rainfall in Kwimba, Chamwino and Kilosa for the year 2012/2013

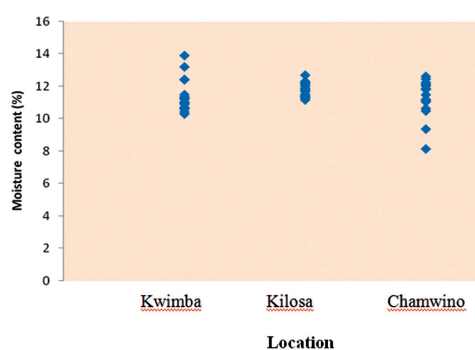


Figure 3: Seed moisture contents of the collected samples in three districts (Kwimba, Chamwino, Kilosa). One dot represents more than one sample.

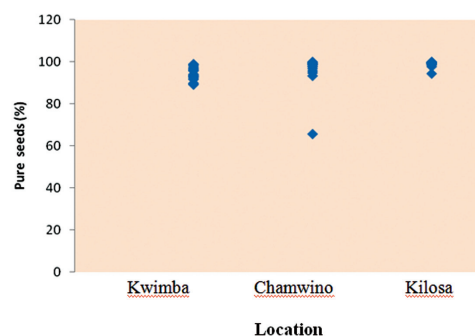


Figure 4: Seed purity status of the collected samples in three districts (Kwimba, Chamwino, Kilosa). ISTA and National recommended pure seeds for certified sorghum is 98%. A national recommended pure seed for QDS sorghum is 98%. One dot represents more than one sample.

Table 2: Characteristics of sorghum seeds producers in Kwimba, Chamwino and Kilosa

Parameter	Category	Kilosa		Kwimba		Chamwino		Mean	Chi-square
		N	%	N	%	N	%		
Gender	Male	16	80	10	50	19	95	75	15.000*
	Female	4	20	10	50	1	5	25	
Age	Youth (<20)	1	5	4	20	4	20	15	52.133**
	Adult 1 (30-50)	11	55	13	65	15	75	65	
	Adult 2 (51-64)	4	20	3	15	1	5	13.33	
Education	Old (>65)	4	20	0	0	0	0	6.67	23.333**
	Adult education	0	0	0	0	0	0	0	
	Primary	11	55	13	65	7	35	51.67	
	Secondary	6	30	3	15	3	15	20	
	Collage	0	0	0	0	8	40	13.33	
	Standard 4 or 8	0	0	0	0	0	0	0	
Sorghum	No formal education	3	15	4	20	2	10	15	85
	Sorghum farmer	19	95	20	100	12	60	85	
Seed	Stockist	1	5	0	0	0	0	1.67	73.300***
Ownership	Research Institutes	0	0	0	0	8	40	13.33	
Sorghum seed	FSS ¹	20	100	19	95	11	55	83.33	
Classes	Certified	0	0	1	5	9	45	16.67	26.667
Storage Facility	House	20	100	20	100	12	60	86.67	
	Go-down	0	0	0	0	8	40	13.33	32.267*

¹Farmer saved seeds;

ns = not significant, * = significant at $p < 0.05$, ** = highly significant at $p < 0.01$,

*** = very highly significant at $p < 0.001$.

germination. The high amount of moisture content of individual seed lot resulted into low germination percentage and high incidence of seed infection by seed-borne pathogens. For instance, seven individual samples from Kwimba, two from Kilosa and one from Chamwino had the moisture contents of 13.1, 14.3, 14.3, 13.2, 14.7, 14.1, 10.9, 12.8, 12.8 and 12.3% respectively and germination were 56, 38, 52, 63, 38, 5, 71, 70, 72 and 70% (Fig. 3).

The samples collected from three districts also had highly significantly difference ($P < 0.001$) purity specifically on pure seed and inert matter components (Table 3). The pure seeds were from Kwimba 94.4%, Chamwino 96.5% and Kilosa 99.0% (Fig. 4). Inert matters were Kwimba 5.3, Chamwino 1.8 and Kilosa 1.0 while non-sorghum seeds were Kwimba 0.2, Chamwino 1.8 and Kilosa 0 (Table 3).

The germination percentages of sorghum seeds

Table 3: Sorghum seed moisture content, purity and germination

District	MC (%) ³	Seed purity (%) ^{1,3}			Seed germination (%) ^{2,3}		
		PS	IM	OS	NS	AS	DS
Kwimba	11.81b	94.39a	5.32b	0.21a	74.40a	4.90a	20.70a
Chamwino	11.10a	96.51ab	1.79a	1.81a	87.90b	3.55a	8.55a
Kilosa	11.54ab	99.01b	0.99a	0.00a	85.00ab	4.25a	10.75a
F-test _{0.05}	***	***	***	Ns	***	Ns	Ns
LSD _{0.05}	0.67	3.01	2.81	2.70	6.02	0.28	5.60
S.E	0.33	4.75	0.99	0.99	2.16	0.78	2.01
C.V (%)	9.20	4.90	79.10	66.10	20.40	50.20	116.10

¹PS= pure seeds, IM= inert matter, OS= other seeds, MC= Moisture content.

²NS= normal seedlings,

AS= abnormal seedlings,

DS= dead seedlings.

ISTA and National recommended germination for certified sorghum seeds is 75%. The National recommended germination for QDS is 70%. ISTA and National recommended 98% and the National recommended purity for QDS is 98%.

³Means followed by the same letter (s) within the column are not significantly different at 5% level based on least significant difference (LSD) test.

S.E = standard error,

CV =coefficients of variation,

ns = not significant,

* = significant at $p < 0.05$,

** =highly significant at $p < 0.01$,

*** = highly significant at $p < 0.001$.

varied highly significantly ($P < 0.001$) from one location (agro-ecological zone) to another (Table 3 and Fig. 5). The average seed germination

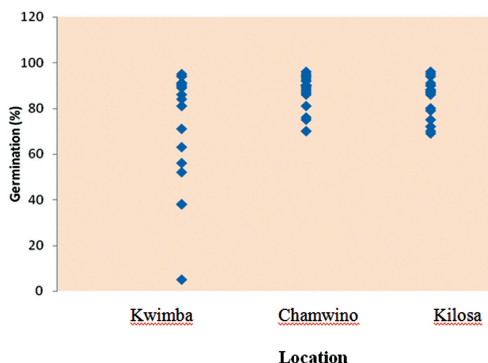


Figure 5: Seed germination percentages of the collected samples in three districts (Kwimba, Chamwino, Kilosa). ISTA and National recommendation germination for certified sorghum seeds is 75%. National recommendation for QDS of sorghum is 70%. One dot represents more than one sample.

from Kwimba, Chamwino and Kilosa were 74, 88 and 85% respectively. There were 10 samples (7 from Kwimba, 2 from Kilosa and 1 from Chamwino districts) with very low average germination percentage as low as 16.7% (Fig. 5).

Location-wise the average incidences of fungal seed-borne infection from Kwimba, Chamwino and Kilosa were 10.5, 30.5 and 50.5% respectively (Table 4). About five seed-borne fungal species were identified on sorghum seed samples: *Fusarium moniliforme*, *Bipolaris sorghicola*, *Curvularia lunata*, *Colletotrichum graminicola* and *Phoma sorghina*. Most samples collected from Eastern zone (Kilosa) were highly infected by fungi (Fig. 6). Other microbes such as *Aspergillus flavus*, *A. niger*, *Penicillium* spp., *Claviceps* spp. and *Rhizopus* spp. were found infecting sorghum seed samples (Table 4). The high incidence of fungal seed-borne infection in Kilosa was associated with higher rainfall which created favourable microclimate for fungal growth (Fig. 2 and 6).

Table 4: Sorghum seed infestation and infection in Kwimba, Chamwino and Kilosa

District	<i>Fusarium moniliforme</i>	<i>Bipolaris sorghicola</i>	<i>Curvularia lunata</i>	<i>Colletotrichum graminicola</i>	<i>Phoma sorghina</i>	<i>Rhizopus</i> spp.	<i>Penicillium</i> spp.	<i>Claviceps</i> spp.	<i>Aspergillus flavus</i>	<i>Aspergillus niger</i>
Kwimba	17.50a	0.00a	14.00a	0.00a	1.5a	9.00a	4.20a	0.00a	6.25a	0.00a
Chamwino	7.75a	4.75ab	2.75a	5.25a	5.25a	10.50a	6.00a	0.00a	3.85a	3.85a
Kilosa	12.00a	19.25b	10.75a	5.00a	1.25a	17.25a	5.25a	5.00a	4.70a	9.00a
F-test _{0.05}	ns	***	ns	ns	ns	ns	ns	ns	ns	ns
LSD _{0.05}	14.66	11.22	11.67	6.12	4.65	7.80	3.894	2.844	3.416	4.287
S.E	5.18	3.96	4.12	2.16	1.64	2.75	1.375	1.004	1.206	1.514
C.V (%)	186.5	221.4	201.1	282.9	275.3	100.6	121.4	269.5	108.3	158.1

Means followed by the same letter (s) within the column are not significantly different at 5% Turkey's test.

S.E = standard error, CV = coefficients of variation, ns = not significant, * = significant at $p < 0.05$, ** = highly significant at $p < 0.01$, *** = very highly significant at $p < 0.001$.

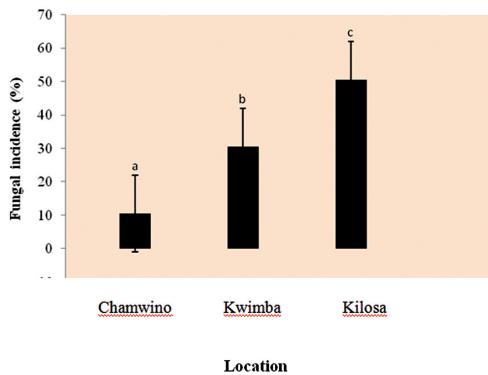


Figure 6: Incidence of seed-borne fungi on the collected sorghum seed samples from Chamwino, Kwimba and Kilosa districts

Discussion

The results from this study indicated that about 17% of farmers who grow sorghum used certified seeds. About 11 years ago Temu and Mtenga (2001) found that, the use of certified seeds in Tanzania was about 4%. These results show the increase in use of certified seeds. However, it was obvious that most of small scale farmers still depended on FSS of low purity and germination percentage from local varieties as a source of planting materials. This correlates to the conclusion made by ECARSAM (2012) that

most small scale farmers in Tanzania prefer local varieties of sorghum seeds due to its palatability and low attack by bird pests. Most farmers were storing the seeds in the house where household activities were also taking place. According to Bonner and Karrfalt (2008) control of storage environment is essential in order to increase viability period of seeds through metabolism reduction; hence conservation of the nutritional reserves. Marcos-Filho (2005) outlined several desirable categories of packaging materials which are: porous or permeable (do not prevent the air exchange between the seeds and the environment as screens of cotton and cardboard), semi-permeable (resistant to circulation of water vapour and of exterior air as bags of multi-layered Kraft paper type and polyethylene) and hermetic or impermeable (do not allow for water vapour exchanges as metal and glass containers). However, Ezequiel *et al.* (2007) stated that after seed drying process, storage conditions can be handled by the type of packaging material, which may be partial or completely hermetic in order to delay atmospheric moisture re-absorption. Owolade *et al.* (2011) proposed air tight aluminium can containers as the best storage option for farmers living in rural areas under ambient condition (28 - 32°C) with no modern day storage facilities.

Some samples from the study area had as high moisture contents ranging from 14.1% to 14.7%. According to Abdusalaam and Shenge (2011) these moisture contents are mostly favourable for growth and development of seed-borne fungi and other microbes. This relationship was also mentioned by Dejene (2004) that high temperature and concomitant result in high relative humidity in the store which finally reduce seed viability due to increased degree of invasion by seed-borne or storage fungi. The study found that, with the exception of research centres and Agriculture Seed Agency, small scale farmers store sorghum seeds in warm and humid environments which increase the rate of moisture absorption until it gets to equilibrium (Owolade *et al.*, 2011). This situation was encountered in this study where 86.7% of the surveyed FSS producers stored their seeds in houses whereby temperature could be accelerated to higher extent because most small scale farmers cook in the same house where seeds are stored. Increase in temperature normally favours survival and development of seed-borne pathogens, storage insects and cause seed deterioration.

The purity analysis of samples also shows that most samples from Lake Zone had high contents of inert matters which may increase the moisture contents and temperature of stored seeds. Most samples rich in inert matters had also high moisture contents and finally high incidence of seed-borne fungi. For instance samples with very high moisture contents collected from Kwimba district with moisture contents of 14.3, 14.3, 14.7 and 14.1% had also high disease incidence. The purity analysis of sorghum seeds from the surveyed areas also correlates to the one stated by the previous research conducted by Mbega (2007) in Morogoro and Dodoma regions and by David (2006) in Iringa and Morogoro regions who encountered seed samples with high amount of inert matters. According to Carvalho and Nakagawa (2000), the increase in respiration rate of seed either due to inert matter or any other cause may lead into release in its composition water to environment hence the increase in relative humidity within packaging material. When this happens seeds will adjust themselves to the new relative humidity and then acquire more elevated moisture content

than initial amount. Sorghum seed samples from Kwimba district had purity as low as 94.4% which was below the TOSCI standard of 98%. The other districts of Chamwino and Kilosa had seed purity of 96.5% and 99.0% respectively.

The germination percentages of sorghum seeds varied from location to location and were Kwimba 74%, Chamwino 88% and Kilosa 85%. While TOSCI germination recommendations are 75% for certified seed grades, 70% for QDS and 65% for standard seed class, other seeds from the study areas expressed as low seed germination as 16.7%. Seed germination test is normally conducted in the laboratory in order to determine the percentage of live seeds in a sample (Ali and Kose, 2011; Panchal and Dhale, 2011). The viable seed is capable of producing normal seedlings under favourable germination conditions. This test is necessary for seeds which are produced for commercial use within a country or abroad (Garay and Gatch, 2011).

Seed-borne fungal species from sorghum seed samples of various designation from the study area were such as *Fusarium moniliforme*, *Bipolaris sorghicola*, *Curvularia lunata*, *Colletotrichum graminicola* and *Phoma sorghina* while other non-seed-borne infection were caused by *Aspergillus flavus*, *A. niger*, *Penicillium* spp., *Claviceps* spp. and *Rhizopus* spp. Most samples collected from Eastern zone (Kilosa) had higher infected seeds than other two locations under the same study. The sorghum seed-borne fungi were also reported in the previous research work by Mbega (2007) on QDS of sorghum seeds in Morogoro and Dodoma regions. Also the similar fungi were reported on sorghum seeds by Syed *et al.* (2012) and Owolade *et al.* (2011) but in different locations and climate. Several species of fungi are known to cause diseases in sorghum at vegetative growth in Tanzania which include *Cercospora fusimaculans* (ladder leaf spot), *Ramulispora sorghi* (sooty stripe), *Gleocercospora sorghi* (zonate leaf spot), *Exserohilum turcicum* (leaf blight), *Puccinia purpurea* (leaf rust), *Colletotrichum graminicola* (anthracnose) and *Cercospora sorghi* (grey leaf spot) (Nyambo, 2009). The study conducted in Dodoma and Morogoro regions in 2007 on stored QDS showed presence of *Fusarium moniliforme*, *Acremonium*

strictum, *Phoma sorghina*, *Bipolaris sorghicola*, *Curvularia lunata*, *Colletotrichum graminicola* and *Cercospora sorghina* (Mbega, 2007). Some fungal species attacking sorghum crops at vegetative growth continue to infect seeds at storage as well. About 90 % of planting material and germplasm are supplied as seeds (Schwinn, 1994). Despite the importance of seeds in agriculture and other sectors like business, they are the most carriers of seed-borne pathogens and the source of plant diseases (Noble, 1971). Most diseases caused by seed-borne pathogens are known to reduce yields and quality of crops (Syed *et al.*, 2012). Therefore, the production and supply of health and improved planting materials is very important (Mathur and Kongsdal, 2003a; 2003b; Nyambo, 2009).

Conclusion

From the study majority of small scale sorghum farmers are using un-improved sorghum seeds. Storage of sorghum seeds in the house of farmers with no required storage conditions for sorghum seed contributed to seeds deterioration. Capacity building on post-harvest processing of sorghum seeds and proper storage facilities and conditions should be delivered to small scale farmers to improve quality of stored seeds. From this study, the Central agro-ecological zone is the most preferred for production of sorghum seeds to minimize seed-borne infections. High germination percentages and low disease incidence in most samples from central agro-ecological zone might be due to climatic factors such as low of humidity and low rainfall which does not favour survival and dissemination of fungal seed-borne pathogens. More emphasis should be made on the production and distribution of sorghum QDS to provide small scale farmers with improved seeds. No QDS was reported to be available in the study area. More emphasis is needed on the use of certified sorghum seeds in all surveyed areas and other districts at large.

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