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RESEARCH ARTICLE

Assessment of the quality status of farm-saved maize (*Zea mays* l.) seeds in a lake zone, Tanzania

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ABSTRACT

A study was conducted to assess the quality of farm-saved maize seeds in the Lake Zone of Tanzania in relation to the seeds' source (regions), drying methods, and packaging materials used by farmers. Seed samples were collected during the 2021/22 planting season. During seed sampling, information on seed source, drying method, and packaging materials was recorded and submitted to the TOSCI seed laboratory for seed quality analysis. Seed quality analysis was performed in the laboratory according to ISTA standards procedures. A factorial experiment with three factors: source of seeds, drying methods, and packaging materials 6 x 2 x 2 was used in RCBD. Results showed that all collected samples had moisture content that met the required standards (≤ 13%) for commercial seed classes, 85% of samples collected did not meet the germination percentage as per Tanzanian standard, 54% of samples collected met the required seed purity as per Tanzanian standards. There was a highly significant variation (P<.001) across production areas and treatment combinations on all seed quality attributes. Seeds that were dried on tarpaulins and packed in hermetic bags were high quality compared to those that were dried on bare ground and packed in polypropylene bags. Conclusively, very few samples reached the required minimum quality standards as per Tanzanian regulations. This signifies that farmers are limited in the production of quality seeds. It is recommended that, in order to have quality seeds, farmers should improve their seed management techniques or methods when saving the seeds.

Keywords: Packaging materials, seed purity, germination, moisture contents, drying methods

INTRODUCTION

The root of successful agricultural production is the use of quality seeds. This requires careful production, processing, and storage of the seed. Planting seeds of high-quality spurs growth and yield of the crop. Using good or improved technology and agricultural inputs, including quality seeds, can improve crop yield (Finch-Savage, 2020). Key seed quality attributes are health, physiological, physical, and genetic aspects (Powell, 2009). It is estimated that 70% of maize producers in third-world countries, including Tanzania, use farmer-saved seeds. Farmers produce these seeds using their traditional expertise (Wambugu et al., 2012; Kahwili, 2020). In Tanzania, farmer-saved seeds are used across all agroecological zones, though at different magnitudes (Wasseh & Nie, 2016; Lyimo et al., 2014). Currently, the Lake Zone of Tanzania is reported to have low adoption of improved varieties compared to the southern highlands zone (Lyimo et al., 2014). A significant feature of farmer-saved seeds is their dominance in areas where subsistence farming is practiced (Mulesa et al., 2021). Saving seeds is also influenced by the economic circumstances of farmers (Mutanyagwa et al., 2018). For millions of farmers in Tanzania, the informal seed system is the primary seed source for cereal production (Kahwili, 2020). It is the pivot for staple food production in Tanzania since the majority of farmers source their seeds from this system through observation, selection, breeding, and saving (Westengen et al., 2014).

The informal maize seed system remains important as seed security for more than 70% of farmers in Tanzania. This is facilitated by the formal seed system, which unfortunately supplies inadequate, expensive seeds and sometimes distantly from farmers' settlements (Kahwili, 2020; Westengen et al., 2014). Accessibility, availability, cost, and distance from the source cause the formal seed system to be less used by most farmers in developing countries and in Tanzania. Several initiatives to create seed security in Tanzania have been established, for example, the introduction of the Quality Declared Seeds (QDS) system, which was inaugurated in the 2000s to increase quality seed availability to farmers, Production of maize seeds using the QDS in Tanzania, however, is less than 1% of the seed needed, resulting in small-scale farmers still depending on the informal seed system (URT, 2020).

The quality of seeds obtained from the informal seed system is considered low according to the required standards in Tanzania (Wambugu et al., 2012). The poor quality of these seeds is facilitated by a lack of quality control in the informal system during production, processing, and storage. Seeds in the informal system are produced using farmers' expertise, and some production practices facilitate seed deterioration (Asiedu et al., 2007; Koes & Arief, 2020). Seed management practices have a significant effect on seed quality. Production area (source), drying methods, and packaging materials have all been found to have influences on maize seed quality (Asiedu et al., 2007; Girma, 2018). In the Lake Zone of Tanzania, farmer-saved seed management is practiced using traditional methods (Obura et al., 2021). In the zone, farmers do differ in seed management practices such as drying methods (bare ground, mats or tarpaulin, rocks, dry-off in the field, and house rooves), packaging materials (smoking, hanging out sides, plastic containers, traditional cribs, hermetic bags and polypropylene bags), and source of seeds (regions) (Mwanza, Mara, Kagera, Simiyu, Geita, and Shinyanga). There is limited information on the quality of farmer-saved seeds with respect to production areas in the Lake zone of Tanzania, dominating seed drying methods and packaging materials. Despite the role played by maize farm-saved seeds in Tanzania and in the study area, little is documented on the quality status of the seed in relation to bare ground and tarpaulin drying methods and packaging materials (polypropylene and hermetic packaging bags). This study assessed the quality of maize farm-saved seeds in relation to relevant production regions in the Lake zone of Tanzania, dominating seed packaging materials and drying methods.

MATERIALS AND METHODS

Study area

The collected samples from Lake Zone regions (Mwanza, Kagera, Mara, Simiyu, Geita, and Shinyanga) were analyzed for quality in the laboratory during the 2021/22 planting season. The zone is located at latitude 2°41′ 21.48′′ south and longitude 32°50′ 12.48′′ east, has an altitude of 950–1850 meters above sea level and receives rainfall ranging from 850–1500 mm annually (Mafuru et al., 1999).

Sampling procedure

Mixed sampling techniques (multi-stage and purposive) were used to select areas and farmers involved in seed sampling respectively. Six regions were involved: two districts per region, two wards per district, two villages per ward, and two farmers per village were selected which make a total of 12 districts, 24 wards, 48 villages, and 96 farmers purposively on the basis that the farmers were using farm-saved seed. The dominating drying methods (bare ground and tarpaulin methods) and packaging materials (polypropylene and hermetic bags) were regarded as treatment in combination with seed sources. Each farmer collected 1 kg of maize seed after an interview on the seed management practices used while saving the seeds. Seed sampling was done according to ISTA rules for seed sampling (ISTA, 2004). After sampling, the sample was packed in moisture-proof packaging material to prevent absorption of moisture from the environment or loss of moisture to the environment during transportation. After a field survey, samples were transported to Morogoro's Tanzania Official Seed Certification Institute (TOSCI) laboratory for seed quality assessment.

Laboratory tests

All samples (96) collected were analyzed for seed quality attributes: physical purity, germination, moisture content, and seed vigour. All laboratory tests were conducted according to ISTA (2021) procedures. Samples were analyzed by referring to the source of seeds (production area), and the drying method, and the packaging materials used by farmers were captured during the field survey for each sample. Overall seed quality analysis was done, then analysis for quality in relation to areas seed sourced, dying methods, and packaging materials regarded as treatments.

Moisture content determination

Moisture content was determined using the constant high-temperature oven method according to ISTA (2021). The 96 submitted seed samples were thoroughly mixed by placing the opening of the nylon container against the side of a similar empty container and pouring the seeds back and forth between the two containers for about 1 minute. Three subsamples were drawn from different parts of the sample and then mixed to form a working sample of 5 g. The process was repeated to obtain a duplicate working sample.

The obtained samples were ground on an electrical grinder to a fine powder for about 2 minutes and then sieved with a 0.5-mm mesh. Containers and their lids were weighed and recorded as M_1, then containers were filled with ground samples and labeled M_2. After filling and weighing the containers and their lids with samples, they were rapidly placed into an oven maintained at 130 ºC for 4 hours. After a 4-hour drying period, The containers with their lids were placed into a desiccator for thirty minutes to cool; the container with lids and dried sample were weighed and recorded as M_3. The moisture content was calculated as. $\text{Moiture content (M.C)} = \frac{\text{Loss of weight}}{\text{Initial weight}} \text{X } 100 = \frac{\text{M2}-\text{M3}}{\text{M2}-\text{M1}} \text{ X } 100$

hereby M_1 Weight in grams of the container and its cover.

M_2 Weight in grams of the container, its cover, and its contents before drying, M_3 Weight in grams of the container, its cover, and its contents after drying.

Physical purity analysis

A soil divider (riffle divider) mixed and divided a seed sample. The working sample was obtained by repeating halving and adding using a divider until the minimum prescribed amount, which is 900 g for maize seeds, was obtained, according to ISTA (2021). The working sample was divided into three components: pure seeds, inert matter, and seeds of other species. The components were weighed and recorded to one, two, or three decimal places depending on their weight. The physical purity of seeds was calculated by dividing the weight of pure seed by the sum of components obtained from the working sample (ISTA, 2021).

Germination test

The pure maize seeds, after purity analysis, were used for the germination test. The halving method obtained 400 seeds (ISTA 2021) from each of the 96 collected samples. The halving process involved pouring seeds on the table and thoroughly mixing them into a mound. After mounding, the sample was divided into two equal parts, one of which was discarded, and the remaining part was then further divided into four portions, each containing 100 seeds. The experimental design was completely randomized for each managerial practice used by farmers. Four hundred seeds in four groups of 100 seeds each were regarded as replicates (ISTA, 2021). The sand was used as a planting medium, and 100 seeds were planted in a single plastic container. Seeds were planted in moist, heat-sterilized sand, and a layer of 10–20 mm of uncompressed soil was used to cover the seeds. The bottom layer was raked before the seeds were sown. Then, containers were incubated in the room with artificial light at a temperature of 25 ºC for 7 days after the final seedling evaluation was done. Calculation and expression of the results as a percentage by the number of normal germinated seedlings according to ISTA (2021) procedures.

Vigour test of the seedling

The vigour test used the germination speed (germination index) from a standard seed germination test. Since the vigour test was done along with the standard germination test, the number of seedlings germinating on the first counting day was recorded. Then the number of seedlings increased per day up to the final counting day, the seventh day of the test, and was counted and recorded daily. The germination index was calculated by dividing the number of germinated seedlings by the number of days they germinated (Gupta, 2004).

Germination Index (G.I) = Sum of number of germinated seedlings at day D /number of days since planting = N/D.

RESULTS

Overall seed quality of collected farm-saved maize seeds in the Lake zone of Tanzania

The overall quality status of 96 samples of maize farm-saved seeds (seed moisture contents, purity, and germination percentages) collected from the lake zone of Tanzania was presented in **Table 1**. It was found that overall average seed moisture content, purity, germination percentage, and germination index ranged from 9.3% to 12.8%, 97.8% to 99.9%, 70% to 91.2%, and 18 to 22.8 respectively, with means of 11%, 99.1%, 84.6% and 20.97 of the collected seed samples. These results revealed that all samples complied with the required moisture contents. In contrast, only 8.3% and 54% of seed samples met the minimum requirement for germination and physical purity according to Tanzanian standards, respectively. The seed germination index was at an average of 20.97. Seeds sourced from Kagera region had the lowest (81%) mean germination percentage, whereas seeds samples from Simiyu region had the highest (84%) germination percentage. Seed samples sourced from Kagera region had the lowest (10.8%) moisture content, whereas seeds sourced from the Simiyu region had the highest (11.5%) mean moisture content. Seed samples collected from the Mwanza region had the highest (99.4%) mean seed purity, whereas those from Kagera, Shinyanga, and Geita regions scored the lowest (98.9%) mean seed purity. Seed samples collected from the Mara region scored the highest (21.5) germination index, and those sourced from Kagera region scored the lowest (20.21) germination index. Seed samples collected from Kagera region scored the lowest (81%) germination percentage, whereas seed samples collected from the Simiyu region scored the highest (84%) germination percentage.

Data analysis

Analysis of variances (ANOVA) where relevant was used to analyze using the GenStat computer package, 16th edition. Treatment arrangement was done in a factorial way whereby seed source from six regions (Mwanza, Mara, Kagera, Simiyu, Shinyanga, and Geita regions), two dominating seeds drying methods (bare ground and tarpaulin methods), and two dominating packaging materials (polypropylene and hermetic bags). Then, the treatment combination was 6 x 2 x 2 = 24 treatments and replicated thrice. A complete randomized block design was used as an experimental design. Analysis of variance (ANOVA) and mean separation were computed using GenStat 16th edition software. Separation of means was performed using DMRT at 5% level of significance.

Seed quality attributes in relation to the seed source (Regions)

Results of quality attribute components of the collected farm-saved maize seed samples in relation to the seed source (area) show significant variation in germination percentage and physical purity. Findings show highly significant variation (<.001) between regions on germination percentage, germination index, and seed purity (**Table 2**). Mean germination, germination index, moisture content, and seed purity were found to be 84.6%, 21.3, 11%, and 99.1% respectively. It was observed that the Simiyu and Shinyanga regions scored the highest germination percentage (85.3%) whereas Geita scored the lowest germination percentage (83.7%). The rest regions' mean germination percentage ranged from 83.9% to 85.9%.

The germination index observed that the Simiyu region scored the highest (21.91) germination index, whereas the Kagera region scored the lowest (20.74) germination index. It was also observed that the Mara region had the highest (11.7%) mean moisture content compared to other regions, whereby Kagera region had the lowest (9.79%) mean moisture content. The mean moisture contents for other regions ranged from 10.39% to 11.21%. The physical seed purity results revealed that Mwanza had the highest (99.3%) mean physical purity, whereas Geita region had the lowest mean physical purity 98.9%. Physical purities for other regions were similar, which scored 99.1%.

Table 1. Germination, purity, and moisture contents of the farm-saved maize seeds collected across Lake zone regions of Tanzania

		MARA				MWANZA				GEITA				SIMIYU				KAGERA				SHINYANGA			
	S/N	GER%	M.C	G.I	SP %	GER%	M.C	G.I	SP %	GER%	M.C	G.I	SP %	GER%	M.C	G.I	SP %	GER%	M.C	G.I	SP %	GER%	M.C	G.I	SP %
	1	84.7	10.6	21.4	98.3	87	11.5	20.4	98.8	84.6	10.8	21.6	98.2	86	11.3	21.1	99.4	81	10	19.4	99.2	82	11.2	19.3	99.5
	2	85.5	10.4	21.5	98.4	84	11.4	20.2	99.8	83.9	10	21.7	98.4	87	10	21.1	99	82.3	10	19.5	99.2	84	10.9	19.3	99.2
	3	86	10	21.3	98.2	83.9	11	20.3	98.8	85	11	20.9	98.6	85.9	11.5	21.3	99	82	10.3	19.3	99.2	82.8	10.8	19	99
	4	83	11.6	22	99.5	82	11.7	20.7	99.8	80	10.8	21.2	98.8	84	12.1	22.6	98.7	80	10.3	22	98.7	87	11.1	22.3	99.7
	5	81.9	12	22	99.4	81.8	11.6	20.6	98.9	79	10.6	21	98.7	84	12.8	22.6	98.8	79.9	9.9	21.9	98.7	85	11	22.4	98.5
A	6	83	11.7	21.9	99.3	82.1	11.4	20.7	99.9	81	11.1	21.1	99.2	83.9	11.9	22.8	98.9	82.1	9.8	22.7	98.7	86.9	11.2	22	98.7
	7	85.8	11.9	22.4	99.9	86	11.1	22.8	99.1	86.7	11.9	21.9	99.7	89	11.9	22	99.6	91.2	10.7	22.6	99.9	90	11.2	22.5	99.9
	8	86	12	22.2	99.8	87	11	22.6	98.9	87	11.3	21.8	99.5	89	12	21.9	99.9	90.7	10.9	22.5	99.9	88.8	11.2	22.2	99.3
	9	85.9	11.7	22.2	99.6	86.9	10.9	22.8	99.1	88	11.7	21.7	99.1	88.9	11.8	21	99.8	89.8	11	22	99.9	87.8	11	22	99.2
	10	83.8	12.3	21.5	98.5	85	11.5	22	99.7	82	11.6	20.2	98.7	81	12	22.6	98.8	82.6	9.8	19.2	98.6	79.8	9.8	20.8	99.2
	11	85	12.1	21.1	98.9	84.5	11.2	21.8	98.9	81.9	11.5	20	98.6	80.8	11.8	22	98.8	81.5	9.5	19	98.6	80.9	10	20.5	98.7
	12	84	11.9	21.1	99	85	10.9	21.4	99.8	83	11.4	20	98.8	83	12	22	98.8	82.4	10	19	98.6	81.2	9.9	20.6	98.3
	13	89	9.3	22	98.8	87	10	22.1	99.6	86	11.1	21.1	98.7	90	11.1	22.4	99.4	71	12	18.8	98.3	81	9.8	20.8	98.7
B	14	91	10.7	22.6	99.9	70	11	18.4	99.9	73	11.2	19.1	98.4	85	9.7	21	99.2	81	12	20	98.4	79	11.2	19	98.8
	15	71	10.4	18.8	98.8	71	10.2	19.7	99.9	90	10.9	21.9	99	77	11.2	19.3	99.6	70	11.9	18.7	97.9	73	12	19.5	99.2
	16	75	10.5	20.5	99.8	90	11.1	21.9	99.8	77	11.2	19.2	99.9	75	11	19.4	99	79	10.9	18.1	99.1	84	11.2	21.3	97.8

S/N = Sample number, GER% = Germination percentage, SP = Seed purity, G.I = Germination index, M. C % = Moisture content in percentage (%), A; Either of the seeds dried on bare ground or tarpaulin and packed neither in polypropylene nor hermetic bags and B; Neither of the seeds dried on bare ground nor tarpaulin and packed neither in polypropylene nor hermetic bags. *Note,* each region had 16 samples.

Effect of farm-saved seed source (regions in Lake zone of Tanzania) and drying methods used by farmers

Table 3 presents results on germination percentage, germination index, moisture contents and seed purity in relation to the combination treatments of seed source and drying methods used by farmers. The results showed a highly significant difference (P<.001) between the treatment combination of source (area) of seed and seed drying method used on germination percentage, germination index, moisture contents, and seed purity. It was observed that seeds sourced from the Kagera region which were dried on bare ground scored the lowest (81.2%) germination percentage whereas seeds sourced from the Kagera region dried on tarpaulin scored the highest (86.8%) germination percentage. The treatment combination effect on mean germination ranged between 82 and 85.9% and the mean germination percentage was 84.6%. Despite such variation, all germination did not meet the minimum germination percentage (90%) as per Tanzania standards for commercial seed classes. The germination index observed that seeds sourced from the Mwanza region which dried on tarpaulin scored the highest index (22.21) whereas seeds sourced from Mwanza dried on bare ground scored the lowest (20.47) germination index and the overall mean was 21.31. The rest

Table 2. Seed quality across production areas (Seed source) regions in the Lake zone of Tanzania

Regions	Germ%	G. I	M.C (%)	S.P
Geita	83.7a	21.08b	11.14c	98.9a
Kagera	84b	20.74a	10.1a	99.1ab
Mwanza	84.4c	21.34c	11.27cd	99.3b
Mara	84.9d	21.7d	11.52de	99.1ab
Simiyu	85.3e	21.91d	11.76e	99.1ab
Shinyanga	85.3e	21.07b	10.77b	99.1ab
Probability	<.001	<.001	<.001	<.001
S. E	0.1872	0.2106	0.2385	0.2949
Mean	84.6	21.3	11.0	99.1
C.V (%)	0.2	1	2.6	0.3
LSD	0.1538	0.173	0.2385	0.2424

S.E = Standard error, LSD = Least Significant difference, C.V = Coefficient of variation and M.C = Moisture content, Germ% = Germination percentage, S.P = Seed purity.

Table 3. Influences of treatment combination of seed source and drying method used by farmers on seed quality

Treatment	Ger%	G. I	M.C	PS
Kagera x Bare ground	81.15a	20.8ab	10.06a	98.9ab
Geita x Bare ground	82b	21.24cd	10.72bcd	98.7a
Mwanza x Bare ground	82.97c	20.47a	11.43ef	99.3b
Mara x Bare ground	84.23d	21.66ef	11.05cde	98.9ab
Simiyu x Bare ground	85.13e	21.92fg	11.6ef	98.9ab
Shinyanga x Bare ground	85.18e	20.72ab	11.03cde	99.1ab
Geita x Tarpaulin	85.39e	20.92bc	11.57ef	99.1ab
Shinyanga x Tarpaulin	85.48e	21.42de	10.52abc	99.1ab
Simiyu x Tarpaulin	85.48e	21.91fg	11.92f	99.3b
Mara x Tarpaulin	85.5e	21.75ef	11.98f	99.3b
Mwanza x Tarpaulin	85.9f	22.21g	11.1de	99.2b
Kagera x Tarpaulin	86.8g	20.69ab	10.15ab	99.2b
Probability	<.001	<.001	<.001	<.001
S. E	0.1081	0.1216	0.1675	0.1703
Mean	84.6	21.31	11.1	99.1
C.V (%)	0.2	0.4	0.6	0.1
LSD	0.2176	0.2447	0.3372	0.3428

S.E = Standard error, LSD = Least Significant different, C.V = Coefficient of variation and M.C = Moisture content,

Germ% = Germination percentage, S.P = Seed purity

treatment combination effect on the germination index ranged from 20.69 to 21.92. The effect of treatment combination (seed source and drying methods) on seed moisture content was also highly variable (P<.001). Seeds sourced from the Kagera region dried on bare ground scored the lowest (10.06%) moisture content whereas seeds sourced from Simiyu dried on tarpaulin scored the highest (11.98%) moisture content. The mean moisture content based on the treatment combination between the source of seeds and the drying method was 11.1%. The other treatment combinations ranged from 10.15% to 11.92%. Also, it was found that seed purity for Simiyu and Mara regions combined with the tarpaulin drying method scored the highest (99.3%) whereas the treatment combination between Geita and bare ground drying method scored the lowest 98.7% seed purity. Seed purity for rest treatment combination (seed source x drying methods) ranged from 98.9% to 99.22%.

Effects of a combination of seed source and packaging materials on germination percentage, germination index, moisture content, and seed purity

Results on the influences of the combination effect of seed source and packaging materials used mostly by farmers in the Lake zone of Tanzania on seed quality attributes were presented in **Table 4**. Treatment combination between seed source (regions) and seed packaging materials used by farmers showed highly significant differences (P<.001) on all measured seed quality attributes (germination percentage, germination index, moisture content, and seed purity). The mean germination, germination index, moisture content, and seed purity were 84.6%, 21.2, 11.2%, and 99.1% respectively. It was observed that seeds sourced from the Simiyu region and packed in hermetic bags scored the highest (87.6%) germination percentage. In contrast, seeds sourced from the Geita region and packed in polypropylene bags scored the lowest (80.9%) germination percentage. The rest of the treatment combination between seed source and packaging materials' effect on germination percentage ranged from 81.4% to 86.7%. All mean germination percentages on the treatment combination between the seed source and packaging materials did not meet the Tanzanian minimum germination percentage standard. It was also found that the germination index for seeds sourced from the Mara region and packed in hermetic bags scored the highest (21.8) germination index. In contrast, seeds sourced from the Simiyu region and packed in polypropylene bags had the lowest (20.5) germination index. The germination index for the rest of the treatment combination (seeds source and packaging materials) ranged between 20.6 and 21.6. It was also observed that seeds from the Simiyu region packed in polypropylene bags had the highest (12.1%) moisture content. In contrast, seeds sourced from Kagera region packed in hermetic bags had the lowest 10.49% moisture content. Moreover, it was observed that seed purity across regions in the lake zone in combination with packaging materials showed that seed samples sourced from Kagera region packed in hermetic bags scored the highest (99.6%) seed purity. In contrast, seeds samples sourced from Kagera region packed in polypropylene scored the lowest (98.7%) seed purity; the rest treatment combinations ranged between 98.8% and 99.5% seed purity.

Table 4. Influences of the combination of seed source and packaging materials used by farmers on seed quality attributes

Treatment	Germ%	G. I	M.C%	S.P
Geita x Polypropylene bags	80.9a	20.5a	11.17c	98.8ab
Kagera x Polypropylene bags	81.4b	20.6a	10.72b	98.7a
Simiyu x Polypropylene bags	82.9c	21.5e	12.1e	98.8ab
Mwanza x Polypropylene bags	83.4d	21.2bc	11.38cd	99.5cd
Mara x Polypropylene bags	83.9e	21.6cd	11.93de	99.1a-d
Shinyanga x Polypropylene bags	84.0e	21.4cd	10.5b	98.9ab
Mwanza x hermetic bags	85.4f	21.5cd	11.15c	99.1a-d
Mara x hermetic bags	85.8f	21.8d	11.1c	99.0a-d
Geita x hermetic bags	86.5g	21.6cd	11.12c	98.9abc
Kagera x hermetic bags	86.5g	20.9ab	10.49a	99.6d
Shinyanga x hermetic bags	86.7g	20.7a	11.05bc	99.4bcd
Simiyu x hermetic bags	87.6h	21.4c	11.42cd	99.5cd
Probability	<.001	<.001	<.001	<.001
S. E	0.1081	0.1216	0.1675	0.1703
Mean	84.6	21.2	11.2	99.1
C.V (%)	0.2	0.5	0.6	0.3
LSD	0.2176	0.2447	0.3372	0.3428

S.E = Standard error, LSD = Least Significant difference, C.V = Coefficient of variation and M.C = Moisture content, Germ% = Germination percentage, S.P = Seed purity.

Effect of treatment combination between seeds source, drying methods, and packaging materials used by farmers in the Lake zone of Tanzania

Table 5 presents seed quality results based on interaction between seed source (region), drying methods, and packaging materials used. It was observed that a combination of these treatments (seed source, seed drying method, and seed packaging materials used) showed highly significant variation (P<.001) on all seed quality attributes analyzed (Germination, germination index, moisture content, and seed purity). The overall mean for seed quality over different treatment combinations was 84.6%, 21.3, 11.09%, and 99.1% for germination, germination index, moisture content, and seed purity, respectively. It was observed that seeds sourced from Geita region, dried on bare ground, and packed in polypropylene bags scored the lowest 79% germination percentage. In contrast, seeds sourced from Kagera region, dried on tarpaulin, and packed in hermetic bags had the highest germination percentage of 91.1% and met the minimum germination as per Tanzanian standards. In contrast, the rest ranged from 80% to 89.8% germination percentage and failed to meet Tanzanian standards. The mean germination index over a combination of these treatments as per combination was 21.3. Seeds sourced from Mwanza dried on tarpaulin and packed in hermetic bags had the highest 22.7 germination index compared to others, whereas seeds sourced from Kagera region, dried on tarpaulin and stored in polypropylene bags, scored the lowest 19.04 germination index. In contrast, other germination indexes ranged from 19.34 to 22.6. It was also found that the mean moisture content was 11.09%. Seeds from the Simiyu region dried on bare ground and packed in polypropylene bags had the highest 12.27% moisture content. In contrast, seeds sourced from Kagera region dried on Tarpaulin and packed in hermetic scored the lowest 9.98% moisture content. The rest of the treatment combination ranged from 10% to 12.1% moisture content. Moreover, it was observed that the mean seed purity on three treatment combinations was 99.1%. The treatment combination of Kagera, tarpaulin, and hermetic bags scored the highest 99.9% seed purity. In contrast, the treatment combination between seeds sourced from the Shinyanga region, dried on bare ground, and packed in polypropylene bags had the lowest seed purity, 98.3%. The other seed purity for the rest of the treatment combination ranged from 98.4% to 99.8%. 54.2% of the treatment combination between area, drying method, and packaging materials was observed to meet the minimum seed purity standard as per Tanzanian.

Table 5. Seed quality attributes over combined effects of area (seed source), seed drying methods, and packaging materials used.

Treatment combination	Germ%	G. I	M.C	PS
Geita x Bare ground x Polypropylene bags	79a	21.09cd	10.83c-g	98.9a-e
Kagera x Bare ground x Polypropylene bags	80.3b	22.21g-i	10a-c	98.7a-d
Shinyanga x Tarpaulin x Polypropylene bags	81.1c	20.62bc	10a-c	98.7a-d
Mwanza x Bare ground x Polypropylene bags	81.9d	20.66bc	11.57g-m	99.5d-f
Simiyu x Tarpaulin x Polypropylene bags	82d	22.2g-i	11.93klm	98.8a-d
Kagera x Bare ground x Hermetic bags	82d	19.38a	10.11a-d	99.2a-f
Kagera x Tarpaulin x Polypropylene bags	82.5de	19.04a	9.43a	98.6abc
Geita x Tarpaulin x Polypropylene bags	82.8e	20.06b	11.5f-m	98.7a-d
Mara Bare ground Polypropylene bags	82.9ef	21.95f-h	11.77h-m	99.4c-f
Shinyanga x Bare ground x Hermetic bags	83.4fg	19.19a	10.97d-i	99.2b-f
Simiyu x Bare ground x Polypropylene bags	83.9g	22.67i	12.27m	98.8a-d
Mwanza x Bare ground x Hermetic bags	83.9g	20.28b	11.3f-l	99.1a-f
Mwanza x Tarpaulin x Polypropylene bags	84.8h	21.71de-h	11.2e-l	99.5c-f
Mara x Tarpaulin x Polypropylene bags	85hi	21.21c-e	12.1lm	98.8a-d
Geita x Bare ground x Hermetic bags	85hi	21.38d-f	10.6b-f	98.4ab
Mara x Bare ground x Hermetic bags	85.5ij	21.37d-f	10.33a-e	98.7a-d
Mara x Tarpaulin x Hermetic bags	86jk	22.28g-i	11.87i-m	99.8ef

Simiyu x Bare ground x Hermetic bags	86.3k	21.16c-e	10.93d-h	99.1a-f
Shinyanga x Bare ground x Polypropylene bags	86.9l	22.25g-i	11.1e-k	98.3a
Mwanza x Tarpaulin x Hermetic bags	86.9l	22.71i	11d-j	99.0a-f
Geita x Tarpaulin x Hermetic bags	88m	21.79e-h	11.63g-m	99.4c-f
Simiyu x Tarpaulin x Hermetic bags	88.9n	21.61d-g	11.9j-m	99.8ef
Shinyanga Tarpaulin x Hermetic bags	89.8o	22.21g-i	11.13e-k	99.5c-f
Kagera x Tarpaulin x Hermetic bags	91.1p	22.35hi	9.98a	99.9f
Probability	<.001	<.001	<.001	<.001
S. E	0.1529	0.1719	0.2369	0.2408
Mean	84.6	21.30	11.09	99.1
C.V (%)	0.2	0.5	0.6	0.1
LSD	0.3077	0.3461	0.4769	0.4848

S.E = Standard error, LSD = Least Significant difference, C.V = Coefficient of variation; M.C = Moisture content, Germ% = Germination percentage, S.P = Seed purity.

DISCUSSION

Overall seed quality of collected farm-saved maize seeds in the Lake zone of Tanzania

With these results, all collected samples met the required maize storage moisture content according to Tanzanian standards, which is < 13% (Table 1). This could be due to the long period of storage (more than five months) up to the planting time, which could cause seeds to lose moisture content in a drier environment. Also, it could be due to pre-storage practices such as drying and cleaning before storage, and for those who used moisture-proof materials, the suitability of the storage packaging materials such as hermetic bags and plastic containers. These results correlated with a study by Bekele et al. (2019), which reported that seed samples collected from different areas (regions) of production in Ethiopia met moisture content requirements according to Ethiopian standards. Physical purity results revealed that 54% of samples met the minimum purity standard for certified seed classes in Tanzania, which is 99%. This means that about 46% of samples did not comply with the required standard for certified seeds classes since they scored below 99% purity. Seed samples that complied with the physical purity required per national standards might be due to farmers' need for seeds with good physical qualities. These results correlate with studies by Zewdie et al. (2012), and Bekele et al. (2019) reported that the majority (93% and 87%) of farm-saved maize seeds and wheat collected from different regions in Ethiopia met the minimum purity standard for certified seed classes. The germination percentage results revealed that the majority (91.7%) of samples did not meet the minimum requirements for commercial seed classes, which is a 90% germination percentage. Failure of the majority of samples to meet the required standard might be due to a lack of quality control in seed production and processing and inadequate knowledge of seed management practices by farmers. Bishaw et al. (2012) and Shengu (2019) reported comparable results for farm-saved seeds of wheat and maize, respectively, sourced from different production areas in Ethiopia that were below the Ethiopian minimum germination standard for commercial seed classes. Lack of quality control practices and good knowledge of post-harvest seed management could also be why some farm-saved seeds failed to comply with the quality standards set.

Effects of seed source on maize farm-saved seeds germination percentage, germination index moisture content, and seed purity

The discrepancy in the quality of farmer-saved maize seeds across regions in the study area could be due to differences in farmers' seed management practices and weather conditions. This means that farmers' practices on seed handling influence seed quality attributes (moisture contents, physical purity, germination, and germination index). Variations in seed germination percentage, moisture contents, and germination index of the seeds could be influenced by different areas (regions) where seeds are produced (Table 2). Variability in weather conditions and seed management between regions where seeds were sampled could be among the factors influencing variability in seed attributes. Therefore, different environments, such as harvesting time and seed management practices, influenced seed quality. Since seed management practices are not harmonious across all regions, this could also be a source of variability among the quality attributes of the collected seed samples. These results imply that most farm-saved maize seeds used in the Lake zone of Tanzania are variable in terms of qualities. These results correlate with studies by Zewdie et al. (2012); Shengu (2019) reported significant differences in seed quality attributes of farm-saved maize seeds obtained from different regions and districts in Ethiopia. Their studies showed highly significant differences in seed quality attributes for seeds sourced from farmers saving wheat and maize seeds. Moisture content meant to be in the acceptable range of ≤ 13% across all regions could be due to the long storage period (more than six months) in which most farmers stored seeds up to the planting time. Likely, the source of physical purity variability of the farm-saved seeds in the study areas could be attributed to different shelling and cleaning methods farmers use. These findings correlate with studies by Zewdie et al. (2012); Shengu (2019); Mamiro (2015); Njonjo et al. (2019) who both reported a highly significant difference in seed purity between barley, wheat, sorghum, and maize farm-saved seeds from different regions in Ethiopia, Tanzania and Kenya respectively.

Effect of combination between seed source (regions) and drying methods used on seed quality

Treatment combinations between areas and drying methods had shown significant differences in seed quality attributes (Table 3). Variations in seed quality attributes might be due to variations in seed management practices across regions in the study area. Variation of moisture released and absorbed by the seeds depends on the drying methods. It was observed that seeds dried on bare ground had lower moisture content compared to seeds dried on tarpaulin materials. This means dried seeds on bare ground lose much moisture compared to those on tarpaulin. This also influences other seed quality attributes such as germination percentage and germination index. Also, cultural practices on seed management and sub-agroecological zones from respective regions influenced variability in seed quality. Seeds sourced from different regions were observed to have different seed quality attributes. Despite such variability, all moisture content met the required standard as per Tanzanian (< 13%). It was also observed that 8 out of 12 treatment combinations met the seed purity, and none of the treatment combinations met the minimum germination percentage as per Tanzanian standards. These results correlate to the study by Khazaei et al. (2016), who reported highly significant differences between treatment combinations (seed source and drying methods) on wheat farm-saved seed quality attributes for seeds sourced from different regions in Iran. seeds dried on the bare ground showed the lowest moisture content compared to those dried on tarpaulin.

Effect of combination between areas (region) and packaging materials used on seed quality

Variation in seed quality based on seed source combined with packaging materials. The differences among quality attributes could be due to seed management practices used by farmers, weather conditions, and quality properties of the packaging materials. Most of the seeds packed in hermetic bags were better than those packed in polypropylene bags. This could be because hermetic bags had high efficiency on seed protection from contact with seed deteriorating agents (humidity, oxygen, and moisture from the environment) compared to polypropylene bags. Variations in seed quality across areas where seed is sourced could be due to differences in agroecological among regions. Differences in seed quality could also be influenced by the soil where seeds are produced and the time farmers take for the seeds to be packed after harvest. These results mean that hermetic bags are good for seed storage by farmers since they show a good quality of seeds compared to polypropylene bags. Also, it was observed that some high-quality treatment-produced seeds, such as seeds sourced from Simiyu packed in hermetic bags, had 87%, which is approaching the required germination percentage by Tanzanian standards. These results imply that most maize farm-saved seeds failed to meet the quality standard set. These findings are central to the study by Abass et al. (2018); and Hnin et al. (2021), who concluded that there was no significant difference in packaging material used to store seeds for less than six months on seed physiological properties. However, Afzal et al. (2020) reported that seeds stored in hermetic bags had a higher germination percentage than polypropylene bags and other common packaging materials (polypropylene bags) used by farmers. Furthermore, similar findings reported by Wambungu et al. (2009) also reported significant differences in germination index and viability for seeds packed in plastic containers and sack polypropylene bags after six months of storage. Girma (2018) reported central results that hermetic bags scored the lowest germination in (69%) compared to polypropylene bags (83.5%) and other traditional packaging materials in Ethiopia. Therefore, current research results are expected, and this will most likely be due to the probable presence of significant environmental variability impact, especially micro-climates of humidity and temperature within the storage containers.

Effect of combination between the source of seeds (region), drying methods, and packaging materials

The combination of the three treatments showed highly significant differences in the seed quality attribute analyzed. Farm-saved maize seeds sourced from different regions in the Lake zone of Tanzania, dried on either bare ground or tarpaulin and packed in either polypropylene or hermetic bags, did not achieve the minimum germination percentage of 90% as per Tanzanian standards. It was observed that seed quality attributes varied highly significantly over three treatment combinations. Farm-saved seeds varied in germination percentage and germination index. This could be due to differences in sub-agroecological zones existing in the study area. For example, the Kagera region experience different weather condition compared to other regions also, planting and harvesting time slightly vary among regions. Therefore, these situations could be the sources of seed quality variability among seed samples collected from the Lake zone. It was observed that most of the seeds dried on tarpaulin and stored in hermetic bags had the highest germination percentage and germination index compared to those dried on bare ground and packed in polypropylene bags. This could be due to deteriorating agents such as humidity, moisture, and contact with oxygen. In contrast, seeds dried on bare ground and packed in polypropylene bags are easily contacted with seed deteriorating agents and hence have lower seed qualities. These findings correlate with the study by Adetumbi et al. (2009), who reported significant differences in seed quality attributes packed in different packaging materials (hermetic and polypropylene bags) and sourced from different regions in Ghana.

The moisture content also varied significantly, although, across treatment combinations, all met the requirement as per Tanzanian standards. This could be due to drying methods practices used by farmers and the weather conditions in the Lake zone, which had minimum humidity compared to other zones. Also, packing seeds in polypropylene and hermetic bags reduces the ability of the seeds to come into contact with the external environment; hence, seeds remain with the required moisture content for long seed storability. Seed purity across treatment combinations varied significantly. Seeds dried on tarpaulin and packed in hermetic had the highest seed purity compared to seeds dried on bare ground and packed in polypropylene bags. This could be due to the reduced effects of pests, which bore grains and produce powdery seeds packed in hermetic bags. Also, variability in seed purity could be caused by practices used by farmers after threshing, such as cleaning methods. These results correlate with the study by Mutungi et al. (2019), who reported that seeds dried using tarpaulin and packed in containers (waterproof package) had lower moisture contents and had the highest germination percentage compared to seeds dried on bare grounds and packed in non-waterproof packaging materials (polypropylene bags). Also, storage duration could have contributed since it is approximately six months from harvesting to planting time. Thus, perhaps short-period exposure to deteriorating agents. It may also suggest that the study area environment was essentially the same uniformly dry during the storage period across the regions. These results contrast the study by Abass et al. (2018) and Hnin et al. (2021), who concluded that there was no significant difference in packaging material used to store seeds for less than eight months on seed physiological properties. These also correlate with the study by Mutungi et al. (2019), who reported that tarpaulin had lower moisture contents and germinated more vigorously than seeds dried on bare grounds from different areas.

CONCLUSION

Seed sources (regions), drying methods, and packaging materials used by farmers showed highly significant differences in the qualities of farmer-saved seeds. Most seed samples did not meet the minimum germination standard set for certified seed classes according to Tanzanian standards. In contrast, most samples attained the minimum physical purity and met the required storage moisture contents. Seeds collected from Kagera and Mwanza recorded the highest seed purity compared to other regions, while seeds collected from the Geita region recorded a higher germination percentage than others. Mats/tarpaulin drying method and hermetic storage were responsible for higher seed quality than others. Also, interactions of treatments showed highly significant differences over the seed quality attributes assessed. From these findings, it is recommended to enable farmers to use certified seeds or improve their seed management practices to improve the quality of their seeds. Improving seed management practices and parallel re-affirmation of landrace varieties could be the best strategy for improving the quality of farmers' saved seeds.

DISCLOSURE STATEMENT

The author declares no competing interests.

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