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Evaluation and improvement of the health status of farmer-saved okra (*Abelmoschus esculentus* (L.) Moench) seeds in the Ashanti Region of Ghana

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ABSTRACT

Farmer-saved seeds are major plant pathogen carriers, which serve as the primary source of inocula of many diseases leading to massive crop losses. In view of this, laboratory experiments to evaluate seed quality and prevalence of seed-borne fungi of farmer-saved okra seeds in 10 major okra growing communities in the Ashanti region were conducted. Two local okra varieties (Asontem and Asante Aba) were collected from farmers for the laboratory studies. Although the collected seeds were observed to be of high purity, their moisture contents were high. The germination percentage, percentage of normal roots, field emergence and establishment of seedlings derived from okra seeds were also low. The study moreover showed high total seed-borne fungi infection. Health testing of the okra seeds revealed the presence of eight seed-borne fungi namely *Fusarium sp*., *Colletotrichum sp*., *Aspergillus flavus*, *A. niger*, *Rhizopus sp*., *Mucor sp*., *Penicillium sp*. and *Curvularia sp*. Seeds of Asante Aba variety showed good quality characteristics over seeds of Asontem. Seeds of the two varieties placed in airtight plastic containers stored better than seeds placed in insecticide-treated mosquito nets. Treatment of okra seeds with Dresscare and *Senna siamea* wood ash resulted in a lower incidence of seed-borne fungi and better seed quality characteristics. Treating okra seeds with Dresscare and *Senna siamea* wood ash and storing in airtight plastic containers is therefore recommended.

Keywords: Okra**,** Inocula; seed-borne fungi; infection; dresscare

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Introduction

Genetic and physical purity, germination capacity, moisture content, vigor and health status are the essential quality parameters of a good seed (Kant *et al*., 1999). Diaz *et al*. (1998) have stated that a healthy seed is the foundation of a healthy plant which is an essential condition for good yields. Seeds are common carriers of plant pathogens, which serve as the primary source of inocula of numerous diseases (Rahman & Mia, 1998). Seed-borne diseases cause massive loss of crops worldwide. Mostly, the cultivation of poor quality seeds is responsible for such low yield (Mew, 1997).

About 80-90% of farmers in Ghana recycle seeds from previous cultivations for replanting (Danquah *et al*., 2004). Recycling of seed is a common practice to most Ghanaian farmers. These seeds may be obtained from farmer's own fields, family members or friends (Clottey *et al*., 2009). The recycling of seeds has a negative impact on seed quality, contributing to the build-up and proliferation of seed-borne fungal pathogens (GSSP Report, 2010). For Okra, it has been observed that farmer-saved seeds which are attainable in local markets are mostly of low quality due to poor handling and storage and are often collected from indigenous, contaminated and deteriorated varieties (Anonymous, 1995). An ISTA (1979) report showed that seed health is a significant factor in the management of crop diseases and further indicated that infected seeds are less viable, have low germination, reduced vigor and less yield.

According to Odofin (2010), seed quality declines during post-harvest storage due to pest infestation, pathogen infection and poor storage condition. Okra is primarily propagated using the seeds, hence to attain high yields, the seeds used in establishing fields must be healthy, pathogen and disease free. To guarantee planting of best quality seed by growers, an assessment of the health status and different quality attributes of okra seeds is essential. In view of this, the present study was conducted to determine the quality and health status of farmer-saved okra seeds from ten okra growing communities of the Ashanti region and also to determine the efficacy of synthetic fungicide-insecticide (Dresscare) and botanical (wood ash) in two storage containers for the management of seed-borne fungi of stored farmer-saved okra seeds.

Materials and Methods

Variety of okra seeds collected from farmers in the studied communities

The okra varieties Asontem and Asante Aba commonly grown by the farmers in the studied communities namely Mankranso, Mfensi-Adankwame, Beposo, Abompe, Kotokuom, Nkwanta-Kesse, Atwima Mim, Abaesua, Offinso and Nerebehi of Ashanti region were used for the study. The farmer-saved seed samples used for the study were collected per farmer interviewed in each community. Seeds were collected from 10 communities mentioned earlier. The cultural practices of the farmers across the study areas in respect of cultivation practices, crop protection, harvesting and processing methods, storage and seed treatments were the same and for these reasons, same variety of farmer-saved okra seeds obtained from the 10 farmers of each community was bulked together, labelled and put into brown paper bags which were sealed off and transported to the Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi, Ghana.

Percentage purity

Three 100 g sub-samples of each variety from each community was weighed using KERN electronic balance (KERN and Sohn GmbH, Germany). Physical qualities or parameters of the seeds were assessed and categorized as pure, shriveled, holed, broken, discolored seeds and inert matter (chaff, seeds of other crops and stones) by visual examination or dry seed inspection. All the, shriveled, holed,

broken, discolored seeds and inert matter were categorized as impurity of the seeds. Each parameter was weighed and recorded in percentage relative to the weight of the samples that were tested for purity.

Moisture content

Moisture contents of the seed samples were determined using the Hydromette G86 (GANN) digital electric moisture meter made in Germany. Three independent working samples of seeds were drawn from each variety obtained in each community. The moisture content (%) of each sample was determined using Hydromette G86 (GANN).

Germination percentage

The assessment was conducted at the plant house of the Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi Ghana. 300 pure seeds were randomly selected from the seed lots from the 10 communities. The selected seeds were sown using the germination tray method at 100 seeds per germination tray. Sterilized topsoil was used to fill the germination trays before seed sowing. Seven days after sowing, the number of seedlings that emerged in each tray was recorded. The germination capacity was expressed in percentage based on total seeds used in the test according to ISTA (2006). The data as calculated in percentage based on the total number of seeds sown was done using the following formula (ISTA, 2006);

$$\% \text{ Germination} = \frac{X_1}{X} \times 100$$

Where, X = Total number of seeds sown in all the germination trays

X_1 = Number of seedlings in all the germination trays

Normal and abnormal roots of seedlings after germination

Seedlings were thoroughly watered on the tenth day to make it easy to uproot seedlings from the germination trays. All the seedlings in the germination trays were gently uprooted and their roots were physically observed by visual inspection. Seedling roots that were not deformed or diseased were categorized as normal healthy roots, while deformed and diseased roots were categorized as abnormal roots. The number of normal and abnormal roots were recorded and expressed in percentages.

Field emergence and establishment of okra seedlings

300 okra seeds were drawn randomly from each sample of the 10 communities and sown manually on 2 m x 1 m beds and covered with fine soil. The beds were raised to a height of about 15 cm. 50 cm spacing was maintained between the beds. Seeds were sown uniformly to a depth of 2 cm. The spacing maintained between the seeds on the beds was 5 cm within and 20 cm between the rows. Watering was done regularly to maintain adequate soil moisture in the seed beds. The emergence count was taken on the 15th day after sowing and the establishment count was recorded on the 30th day after sowing. The normal healthy seedlings appearing on the surface of soil were considered as emerged and the healthy growing seedlings that were able to survive till the 30th day after sowing were considered established. The field emergence and establishment counts were expressed in percentages relative to the total number of seeds sown using the formula by Carlson & Clay (2016):

$$\% \text{ Emergence} = \frac{M_2}{M_1} \times 100$$

Where,

M_1 = Total number of seeds sown on beds

M_2 = Normal healthy seedlings appearing on the surface of beds at 15th day after sowing

$$\% \text{ Establishment } = \frac{Q_2}{M_1} \times 100$$

Where,

M_1 = Total number of seeds sown on beds

Q_2 = Normal healthy seedlings surviving on the beds at 30th day after sowing

Prevalence, isolation and identification of seed-borne fungi associated with farmer-saved okra seeds

The determination of the prevalence of seed-borne fungi and their infection percentage of okra seeds before storage and after storage for five months were conducted in the Plant Pathology Laboratory, Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Farmer-saved seed samples of each of the two different varieties of okra obtained from each of the 10 communities were surface-sterilized with 10% sodium hypochlorite solution for one minute and differently rinsed three times in sterile distilled water and dried on two-ply tissue paper for one minute (Gothier *et al*., 2001).

Five seeds of the sterilized samples were aseptically plated onto each Petri dish containing solidified PDA. Equal distances were maintained between seeds. The plates were incubated at 28±1°C with a photoperiod of 12h:12h (Light: Darkness) for seven days. The identification of fungal species was carried out under a ZEISS compound microscope Carl Zeiss Microscopy GmbH, Göttingen, and with the aid of fungi identification manuals (Barnett & Hunter, 1972; Watanabe, 2002). Occurrence of fungi on seeds was expressed in percentage based on the total number of seeds plated (Neergaard, 1979).

$$\% \text{ Infection of seed-borne fungi on seeds} = \frac{\text{Sum of infected seeds}}{\text{Total of seeds tested}} \times 100$$

Storage containers

The experiment comprised two containers for the storage of okra seeds as follows;

- Airtight plastic container, and
- Deltamethrin insecticide-treated mosquito net

Seed treatment

The experiment comprised of three different seed treatments which were non-treated seed (control), seed treated with Dresscare and seed treated with *Senna siamea* wood ash.

Dresscare

Dresscare is a systematic and broad spectrum fungicide-insecticide composed of Imidalcloprid 20% + Metalaxyl-M 20% + Tebuconazole 2% WS as active ingredients.

Preparation of Senna siamea wood ash

One kilogram of fresh *S. siamea* wood was collected from Abuakwa in the Ashanti Region of Ghana. The wood sample was cut into pieces of about 10 cm long. The wood was then washed with clean running tap water to remove dust particles. The wood was then heaped on a clean wooden table measuring one meter in height for the water to drain off and subsequently thinly spread out on a wooden bench to dry under room temperature for 16 days. The dried wood was burnt to ash on a clean cemented floor to prevent mixing of ash with dusts. The ash was allowed to cool and was packaged into a labelled clean and dry

airtight plastic container. The filled container was stored under room temperature until it was required for use.

Application of Dresscare and Senna siamea wood ash on okra seeds for storage

Dresscare was applied at 2.5 g per kg of okra seed as recommended by the manufacturer, while 5 g of *S. siamea* wood ash to 100 grams of okra seeds was admixed with the okra seed samples. The quantity of *S. siamea* per gram of okra seed was worked out on a weight of ash/weight of okra seeds, w/w basis. A KERN electronic digital balance (KERN and Sohn GmbH, Germany) was used for seed weighing. The seeds were placed in transparent plastic bags and shaken thoroughly to ensure a uniform spread of the dressing on all the seeds in the plastic bags. The treated seeds were gently transferred into the airtight plastic containers and the pieces of treated nets which were tied with rubber bands for storage. The treated seeds were placed on one meter high tables under normal room temperature in the Plant Pathology laboratory, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi. Ghana.

Experimental design and layout

The experiment comprised three factors (two okra varieties, three seed treatments and two storage containers). The experimental design used was factorial arranged in Completely Randomized Design (CRD) with three replications.

Data Analysis

Data for each seed-borne fungal prevalence or infection was transformed using Square Root transformation before analysis and the results presented in tables. GenStat 12th statistical package was used to analyze the data. Least Significant Difference (LSD) at 5% was used to separate means.

Results and Discussion

Determination of purity of okra seeds before storage

The purity of seeds of Asontem ranged from 75.0% to 92.0%. There were significant differences ($p < 0.05$) in the purity of seeds of Asontem and Asante Aba between towns. The highest purity of seeds of Asontem okra was recorded in seeds collected from Nkwanta-Kesse, while the lowest was recorded in seeds from Abompe.

Impurities found in seeds were shriveled, broken, holed, discolored and inert matter. The highest proportion (11.7%) of shriveled seeds was recorded in seeds collected from Beposo. The lowest proportion (2.1%) of shriveled seeds was recorded in seeds collected from Atwima-Mim. Seeds from Beposo and Abompe had the highest proportion (9.0%) of broken seeds, while those collected from Nerebehi had the least proportion (1.0%) of broken seeds. Seeds with holes were highest (7.0%) in the seed lot at Beposo and Abaesua, while the lowest (0.5%) was recorded at Atwima Mim. The highest proportion (6.0%) of discolored seeds was recorded in seeds collected from Abaesua. No discolored seeds were found in the seeds collected from Offinso, Mfensi-Adankwame and Nkwanta-Kesse. Compared to the seed lots from other areas, there were more inert materials (4.9%) in the seed lot collected from Kotokuom (Table 1).

Moreover, the pure seeds of Asante Aba okra ranged from 70.0% to 95.0%. The highest proportion of pure seeds of Asante Aba were recorded at Abaesua, while the

lowest was recorded at Mfensi-Adankwame. Shriveled seeds were recorded highest (12.0%) at Nkwanta-Kesse, while lowest (1.3%) at Kotokuom. Broken seeds were highest (4.1%) at Mfensi-Adankwame and least (0.9%) at Abaesua. Holed seeds were highest (9.3%) at Offinso and none at Abompe. Discolored seeds were highest (4.1%) at Mankranso and none was recorded at Beposo, Offinso, Abaesua and Nerebehi. The highest proportion (3.1%) of inert materials were found in seed lot collected from Nkwanta-Kesse, while none found at Abaesua, Mfensi-Adankwame, Beposo and Abompe (Table 1).

Averagely, seed purity percentage recorded for Asante Aba and Asontem seed samples were relatively high. Comparatively, seeds of Asante Aba variety had higher purity percentage over seeds of Asontem variety. Amongst the communities, Abaesua recorded the highest seed purity percentage, while the lowest seed purity found at Mfensi-Adankwame. In terms of impurity, the highest total average impurity was found in seed lot of Asontem. Seeds collected from Mfensi-Adankwame recorded the highest total impurity. The most common component of okra seed impurity was shriveled seeds followed by holed seeds. The high percentage of shriveled seeds could be attributed to improper physiological maturity of seeds, diseases and improper storage. The holed seeds could be due to the activities of insect pest which created holes to feed on the seeds.

Discoloration of the seeds could also be attributed to high prevalence of fungal pathogens infection. This confirms the report of Fakir (2001) that seed-borne fungi lead to discoloration of seeds. The result indicated that farmer-saved okra seed was not of good quality because of presence of inert matter and other seeds. Thus the presence of inert matter in farmer-saved seed poses risk as regard to contamination of seed lot by the propagules of pathogenic fungi.

TABLE 1
Seed purity status of farmer-saved okra seeds collected from 10 different communities

	Pure seed (%)		**Total seed impurity (%)**		**Component of seed impurity (%)**									
					Shrivelled		Broken		Holed		Discoloured		Inert matter	
Communities	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba
Mankranso	86.0b	81.0d	14.0c	19.0c	4.6e	8.4b	1.2f	2.8b	4.0cd	1.7ef	2.0de	4.1a	2.2c	2.3b
Mfensi-Adankwame	81.0c	70.0f	19.0b	30.0a	11.1b	5.0d	4.0c	4.1a	3.6d	2.7c	0.0f	1.2bc	0.5f	0.0f
Beposo	87.0b	93.0ab	13.0c	7.0ef	11.7a	4.0e	9.0a	1.3e	7.0a	1.7ef	2.3d	0.0d	0.0g	0.0f
Abompe	75.0d	94.0a	25.0a	6.0f	7.0d	2.6g	9.0a	2.2c	2.2f	0.0h	2.0de	1.2bc	4.8a	0.0f
Kotokuom	79.0c	90.0bc	21.0b	10.0de	7.0d	1.3h	2.0e	3.0b	4.1c	2.1d	3.0c	1.6b	4.9a	2.0c
Nkwanta-Kesse	92.0a	76.0e	8.0d	24.0b	3.0g	12.0a	1.9e	2.9b	3.1e	5.1b	0.0f	0.9c	0.0g	3.1a
Atwima Mim	89.0ab	88.0c	11.0cd	12.0d	2.1h	7.0c	3.0d	1.7d	0.5g	0.9g	4.0b	0.0d	1.4d	2.4b
Abaesua	80.0c	95.0a	20.0b	5.0f	4.0f	2.3g	1.9e	0.9f	7.0a	1.8e	6.0a	0.0d	1.1e	0.0f
Offinso	78.0cd	80.0d	22.0ab	20.0c	8.0c	7.0c	4.8b	3.0b	6.2b	9.3a	0.0f	0.0d	3.0b	0.7d
Nerebehi	91.0a	94.0a	9.0d	6.0f	2.3h	3.0f	1.0f	1.2ef	2.7e	1.5f	1.8e	0.0d	1.2de	0.3e
$LSD_{(0.05)}$	2.3	2.4	2.3	2.4	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.4	0.2	0.1
CV (%)	1.6	1.6	8.3	9.9	2.3	2.4	3.1	6.0	3.9	3.3	6.5	24.5	4.7	7.2

Moisture content of okra seeds before storage

Moisture content of seeds collected from the 10 communities varied significantly ($p < 0.05$) from 12.7% to 14.7 %, and 12.5% to 16.5% for Asontem and Asante Aba varieties respectively (Table 2). The highest moisture contents of 14.7% and 16.5 % respectively for Asontem and Asante Aba were recorded at Beposo and Atwima Mim. The lowest moisture content of 12.7% and 12.5% were recorded for Asontem seeds from Nkwanta-Kesse and Asante Aba seeds from Mfensi-Adankwame respectively (Table 2). The mean moisture content of the Asontem and Asante Aba farmer-saved okra seeds from the 10 different communities were above the recommended moisture content (10%) for okra seeds. Seeds with high moisture contents are vulnerable to infection by storage fungi and insects which mostly cause considerable losses through reduction in germination (Martín *et al*., 2022).

Germination percentage, normal roots of seedlings, field emergence and establishment of okra seeds before storage

Germination percentage of okra seeds varied significantly ($p < 0.05$) from 30.0% to 82.0% and 35.0% to 87.0% for Asontem and Asante Aba varieties respectively (Table 2). The highest germination percentage of seeds of Asontem (82.0%) was observed in seeds collected from Offinso, while the lowest (30.0%) was recorded in seeds collected from Atwima Mim (Table 2). The highest (87.0%) and lowest (35.0%) germination percentages of Asante Aba seeds were recorded in seeds collected from Mfensi-Adankwame and Abompe, respectively (Table 2). Percentage germination was highly variable ($p < 0.05$) between the communities. The differences could be attributed in part to genotypic differences among the two varieties as well as variations in the environment and farmer storage conditions.

The percentage of normal roots of okra seedlings varied significantly ($p < 0.05$) from 24.0% to 70.0% and 29.0% to 78.0% for seeds of Asontem and Asante Aba varieties respectively (Table 2). The highest (70.0%) and lowest (24.0%) percentages of normal seedlings of Asontem were observed at Offinso and Atwima Mim respectively (Table 2). Mfensi-Adankwame and Abompe recorded the highest (78.0%) and lowest (29.0%) percentages respectively of Asante Aba normal roots of seedlings (Table 2). The percentage of abnormal roots of seedlings also varied from 5.0% to 15.0% and 6.0% to 15% for Asontem and Asante Aba varieties respectively. The highest (15.0%) and lowest (5.0%) percentages of abnormal roots of Asontem seedlings were observed at Abaesua and Mfensi-Adankwame respectively (Table 2). In seeds of Asante Aba variety, the highest percentage (15.0%) of abnormal roots of seedlings was recorded at Beposo, while the lowest (6.0%) recorded at Abompe (Table 2).

Seed emergence varied significantly ($p < 0.05$) from 29.0% to 80.0% and 35.0% to 85.0% for Asontem and Asante Aba varieties respectively (Table 2). The highest and lowest seed emergence of Asontem variety were observed at Offinso and Atwima Mim respectively (Table 2). With regards to the seeds of Asante Aba variety, Mfensi-Adankwame recorded the highest (80.0%) field emergence, while the lowest (29.0%) was observed at Abompe (Table 2). Moreover, percentage of field establishment of seeds varied from 25.0% to 70.0% and 32.0% to 79.0% for Asontem and Asante Aba varieties respectively. The highest (70.0%) and lowest (25.0%) field establishment percentages of Asontem variety were observed

at Offinso and Atwima Mim respectively (Table 2). For Asante Aba variety, Mfensi-Adankwame recorded the highest percentage (70.0%) of field established seedlings, while the lowest (25.0%) observed at Mankranso (Table 2).

This study showed that Asante Aba was of good quality in terms of germination, normal roots of seedlings, field emergence and establishment. This may be due to the highest mean purity percentage observed in Asante Aba. It could therefore be asserted that high percentage purity of seeds is a major contributor to good germination, normal roots of seedlings, field emergence and establishment which agrees with the findings by Sarkar *et al*. (2015) that seed from research stations which had high purity gave high germination percentage.

TABLE 2

Moisture content, germination, normal and abnormal roots of seedlings, field emergence and establishment of okra seeds collected from 10 different communities before storage

Communities	**Moisture content (%)**		**Germination (%)**		**Normal roots of seedlings (%)**		**Abnormal roots of seedlings (%)**		**Field emergence (%)**		**Field establishment (%)**	
	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba
Mankranso	13.3d	15.1b	54.0cd	38.0g	48.0c	30.0e	6.0c	8.0cd	52.0cd	36.7f	48.0d	32.0f
Mfensi-Adankwame	13.8c	12.5f	68.0b	87.0a	63.0b	78.0a	5.0c	9.0bcd	66.0b	85.0a	62.0b	79.0a
Beposo	14.7a	14.5c	37.0e	72.0b	30.0c	57.0b	7.0bc	15.0a	37.0e	70.0b	28.0f	60.0b
Abompe	13.5cd	12.8ef	57.0c	35.0g	50.0c	29.0e	7.0bc	6.0d	56.0c	35.0f	55.0c	34.0f
Kotokuom	12.8f	14.3c	50.0d	65.0cd	41.0d	55.0b	9.0bc	10.0bcd	51.0d	65.0bc	44.0de	57.0bc
Nkwanta-Kesse	12.7f	14.1c	49.0d	62.0d	40.0d	50.0c	9.0bc	12.0abc	49.0d	61.0c	42.0e	52.0cd
Atwima Mim	13.7c	16.5a	30.0f	51.0f	24.0e	43.0d	6.0c	8.0cd	29.0f	51.0e	25.0f	44.0e
Abaesua	12.9ef	13.2de	67.0b	69.0bc	52.0c	58.0b	15.0a	11.0abc	65.0b	67.0b	57.0bc	59.0b
Offinso	13.2de	13.4d	82.0a	56.0ef	70.0a	47.0cd	12.0ab	9.0bcd	80.0a	55.0de	70.0a	48.0de
Nerebehi	14.3b	13.1de	49.0d	60.0de	42.0d	47.0cd	7.0bc	13.0ab	48.0d	60.0cd	43.0de	49.0de
$LSD_{(0.05)}$	0.2	0.3	3.0	3.2	3.1	3.3	3.4	3.4	2.7	3.3	3.2	3.1
CV (%)	0.9	1.3	3.2	3.1	3.9	3.9	24.1	19.6	3.0	3.3	4.0	3.5

Prevalence of seed-borne fungi on farmer-saved okra seeds collected from 10 different communities before storage

Eight seed-borne fungi in seven genera were found to be associated with the seeds of the okra varieties collected from the farmers in the 10 different communities. The isolated fungi were *Fusarium* sp., *Colletotrichum* sp., *Aspergillus flavus*, *Aspergillus niger*, *Rhizopus* sp., *Mucor* sp., *Penicillium* sp. and *Curvularia* sp. The total seed-borne fungal infections on the okra seeds varied significantly ($p < 0.05$) between Asontem and Asante Aba varieties (Table 3). The highest and lowest total seed-borne fungal infections on Asontem seeds were observed at Kotokuom and Mfensi-Adankwame respectively (Table 3). The highest and lowest total seed-borne fungal infections on Asante Aba seeds were also recouded at Mankranso and Mfensi-Adankwame respectively. (Table 3).

In Asontem seeds, *A. flavus* was highest and lowest at Beposo and Nerebehi respectively. *Colletotrichum* sp. on Asontem variety was

highest at Nerebehi, while no infection occurred on seeds at Mfensi-Adankwame, Nkwanta-Kesse, Atwima Mim and Abaesua. *A. niger* on Asontem variety recorded the highest infection at Kotokuom and no occurrence at Beposo, Abompe, Nkwanta-Kesse, Abaesua and Nerebehi. *Fusarium* sp. prevalence was highest at Atwima Mim and Kotokuom, while Beposo, recorded no prevalence in *Fusarium* sp. (Table 3). *Curvularia* sp. on Asontem variety was highly prevalent at Atwima Mim but was not found at Abompe, Nkwanta-Kesse and Offinso. The highest prevalence of *Penicillium* sp. on Asontem variety was recorded at Mankranso, while no prevalence of *Penicillium* sp. recorded at Abompe. With regard to *Rhizopus* sp., the highest prevalence was found at Nkwanta-Kesse, while none was found at Mankranso, Beposo, Abompe, Atwima Mim and Nerebehi. *Mucor* sp., on Asontem variety was recorded highest at Abaesua, while no prevalence at Mankranso, Beposo, Kotokuom Atwima Mim and Offinso (Table 4).

Considering Asante Aba variety, the highest total fungi prevalence was found at Makranso, while Mfensi-Adankwame recorded the least prevalence. Kotokuom recorded the highest prevalence of *A. flavus*, while no prevalence occurred at Beposo, Abompe, Nkwanta-Kesse and Nerebehi. The highest prevalence of *Colletotrichum* sp. on Asante Aba variety was recorded at Mankranso and no occurrence at Mfensi-Adankwame. For *A. niger* on Asante Aba variety, Nerebehi recorded the highest prevalence. Atwima Mim and Mankranso recorded no incidence of *A. niger*. Beposo recorded the highest prevalence of *Fusarium* sp. on Asante Aba variety, while no *Fusarium* sp. was found at Abompe, Atwima Mim and Nerebehi (Table 3). *Curvularia* sp. on Asante Aba variety occurred most at Abompe, while Mfensi-Adankwame, Atwima Mim and Nerebehi recorded no incidence of *Curvularia* sp. on Asante Aba variety. *Penicillium* sp. on Asante Aba variety was highly prevalent at Offinso but not prevalent at Mankranso, Abompe and Nkwanta-Kesse. *Rhizopus* sp. on Asante Aba variety was highest at Beposo, while Mankranso and Abompe recorded no incidence of *Rhizopus* sp. No incidence of *Mucor* sp. was recorded on Asante Aba seeds (Table 4).

The lowest mean percentage of total seed-borne fungal infections were observed in Asante Aba variety. This could be explained on the basis of the high percentage purity observed in seeds of that variety. This confirms the study by Sarkar *et al.* (2015) which reported that healthy seeds yielded lowest incidence of fungi and highest percentage of germination.

A considerable number of seed-borne fungal pathogens belonging to the genera of, *Fusarium, Aspergillus, Colletotrichum, Rhizopus* and *Penicillium* in okra have been reported by previous studies (Jamandar *et al.,* 2001). The present study revealed that *Fusarium* sp., *Colletotrichum* sp., *Aspergillus flavus*, *A. niger*, *Rhizopus* sp., *Mucor, Penicillium* and *Curvularia* sp. were associated with the tested okra seed samples and this significantly reduced percentage germination, increased abnormality of seedlings and reduced field emergence and establishment. Similar results were reported by *Sarkar et al*. (2015) who observed that the occurrence of the storage fungi *Aspergillus flavus, Macrophomina phaseolina, Colletotrichum dematium, Rhizopus* sp. and *Curvularia* sp. caused germination loss. Occurrence of the eight fungi species varied independently of each other with respect to the location of seed collection. This could be attributed to the differences in seed handling and storage practices.

TABLE 3

Prevalence of seed-borne fungal species in farmer-saved okra seed samples collected from 10 different communities before storage

Communities	**Frequency of fungi infection on okra seeds/Community**									
	TL fungi prevalence		***Aspergillus flavus***		***Colletotrichum* sp.**		***A. niger***		***Fusarium* sp.**	
	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba
Mankranso	9.2ab	10.0a	3.8d	4.4a	4.5bc	8.4a	4.5ab	0.0d	3.2c	2.2d
Mfensi-Adankwame	8.1c	7.4d	3.1de	2.2b	0.0d	0.0g	3.2bc	3.1bc	2.2cd	3.8b
Beposo	9.5a	8.7bc	6.7a	0.0b	3.9c	3.2f	0.0c	2.2c	0.0d	4.5a
Abompe	9.7a	8.1c	5.5b	0.0b	7.1a	6.3de	0.0c	3.1bc	3.2c	0.0e
Kotokuom	10.0a	9.5ab	3.8e	5.0a	5.0b	5.4e	5.4a	3.8b	3.8a	2.2d
Nkwanta-Kesse	9.7a	9.7a	3.1de	0.0b	0.0d	7.4bc	0.0c	3.2bc	3.7ab	2.2d
Atwima Mim	9.2ab	9.2ab	4.4cd	3.2ab	0.0d	7.7b	3.8bc	0.0d	3.9a	0.0e
Abaesua	8.4bc	9.5ab	1.8de	3.1ab	0.0d	6.3de	0.0c	3.7b	1.8c	2.2d
Offinso	9.2ab	9.2ab	5.9ab	3.8a	3.1cd	4.4ef	4.4ab	3.1bc	2.9bc	3.1c
Nerebehi	9.2ab	9.5ab	1.8de	0.0b	7.4a	7.1d	0.0c	4.5a	2.9bc	0.0e
$LSD_{(0.05)}$	0.4	0.6	1.6	0.7	0.7	0.7	0.6	1.2	1.2	0.6
CV (%)	2.8	3.9	22.9	18.8	12.9	7.5	17.1	25.7	27.0	18.6

TABLE 4

Prevalence of other seed-borne fungal species in farmer-saved okra bare seed samples collected from 10 different communities before storage

Communities	**Frequency of fungi infection on okra seeds/Community**							
	***Curvularia* sp.**		***Penicillium* sp.**		***Rhizopus* sp.**		***Mucor* sp.**	
	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba	Asontem	Asante Aba
Mankranso	2.2bc	2.2b	3.9a	0.0d	0.0e	0.0c	0.0c	0.0a
Mfensi-Adankwame	3.2b	0.0c	2.2b	3.8ab	4.5c	3.2b	2.2b	0.0a
Beposo	3.8ab	2.2b	3.8a	2.2c	0.0e	5.5a	0.0c	0.0a
Abompe	0.0d	3.8a	0.0d	0.0d	0.0e	0.0c	2.2b	0.0a
Kotokuom	2.2bc	2.2b	2.2b	2.2c	2.2de	2.2bc	0.0c	0.0a
Nkwanta-Kesse	0.0d	2.2b	3.1ab	0.0d	7.1a	4.5ab	3.1a	0.0a
Atwima Mim	4.4a	0.0c	3.8a	3.2b	0.0e	2.2bc	0.0c	0.0a
Abaesua	3.1b	3.0ab	2.2b	2.9bc	5.9b	0.0c	3.2a	0.0a
Offinso	0.0d	2.2b	1.8c	4.5a	3.2d	2.2bc	0.0c	0.0a
Nerebehi	2.2bc	0.0c	3.1ab	3.1b	0.0e	3.1b	2.2b	0.0a
$LSD_{(0.05)}$	0.6	0.8	1.2	0.7	0.5	0.9	0.4	0.0
CV (%)	17.7	25.4	26.5	18.9	11.5	22.7	20.0	0.0

Effects of variety, storage containers and seed treatments on the quality parameters of okra seeds after storage

From the preliminary studies of the quality parameters of the okra seeds, samples from the Kotokuom community was randomly selected for treatment and storage for five months. There were no significant interactions among treatments therefore only the main effects were presented. There was significant difference ($p < 0.05$) between the varieties for percent moisture content, germination, normal roots of seedlings, field emergence of seedlings and field establishment of seedlings. Asante Aba recorded the highest percentages of all the parameters measured. With regards to storage containers, no significant difference ($p > 0.05$) was observed for percentage germination, normal roots of seedlings, field emergence of seedlings and field establishment of seedlings except for moisture content where seeds stored in the airtight plastic container recorded the lower moisture content.

However, higher percentages of germination, normal roots of seedlings, field emergence of seedlings and field establishment of seedlings were recorded by seeds stored in the airtight plastic container. There was significant difference ($p<0.05$) between seed treatments in terms of moisture content, percentage germination, normal roots of seedlings, field emergence of seedlings and field establishment of seedlings. The highest percentages of all the parameters measured were recorded by seeds treated with Dresscare except for moisture content where seeds treated with Dresscare recorded the least percentage (Table 5). For quality attributes due to type of storage container, percentage germination, normal roots of seedlings, field emergence of seedlings, and field establishment of seedlings were not significantly affected except for moisture content.

The seeds stored in treated nets were highly affected by moisture than the plastic containers. This observation can be attributed to the easy permeability of moisture from the surroundings or the storage room through the nets. The plastic containers on the other hand significantly reduced the moisture content of seeds due to their impermeability to moisture from outside. Nonetheless, the moisture content of seeds stored in plastic container was higher than the recommended (10%) standard for okra (Sarkar *et al*., 2015). With regards to results on germination percentage, normal roots of seedlings, field emergence and establishment of seedlings, the highest percentages were recorded in the seeds stored in the airtight plastic container. This observation may be attributed to the lower moisture content of the seeds. It has been observed that lower moisture contents help to preserve seed quality during storage (Sultana, 2013; Aktaruzzaman *et al*., 2010).

TABLE 5

Moisture content, germination, normal roots of seedlings, field emergence and field establishment of the two okra varieties treated with Dresscare, S. siamea wood ash and control stored in airtight plastic container and treated net after storage

Factors	Moisture content (%)	Germination (%)	Normal roots of seedlings (%)	Field emergence (%)	Field establishment (%)
Variety					
Asontem	11.0b	50.0b	43.5b	48.3b	42.0b
Asante Aba	12.2a	62.5a	56.9a	61.5a	56.5a
$LSD_{(0.05)}$	0.4	2.4	4.3	2.9	4.7
CV (%)	4.9	6.4	12.7	7.9	14.0
Storage container					
Plastic container	11.2b	57.7a	51.5a	56.7a	50.0a
Mosquito net	11.9b	54.5a	48.9a	53.2a	48.5a
$LSD_{(0.05)}$	0.5	5.0	6.3	5.3	6.9
CV (%)	6.7	13.1	18.5	14.3	20.6
Seed treatment					
Dresscare	11.2ab	59.5a	56.8a	59.5a	56.8a
S. siamea wood ash	11.4a	55.8ab	50.9b	54.2ab	49.8b
Control	12.1b	53.0b	42.9c	51.0c	41.2c
$LSD_{(0.05)}$	0.6	5.9	6.2	6.1	6.7
CV (%)	6.7	12.6	14.9	13.3	16.0

Effect of variety, storage containers and seed treatments on fungi infection of okra seeds after storage

There were no significant differences ($p > 0.05$) between varieties and storage containers for percent total seed-borne fungi infection. However, the highest total seed-borne fungi infection in terms of variety was recorded in Asontem, while seeds stored in the airtight plastic container also produced the highest total seed-borne fungi infection in terms of storage containers (Table 6). There were significant difference ($p < 0.05$) between seed treatments for percent total seed-borne fungi infection. The highest total seed-borne fungi infection was produced by untreated (control) seeds, while the least was produced by seeds treated with Dresscare (synthetic-insecticide fungicide mix) (Table 6).

Similarly, there were no significant differences ($p > 0.05$) between varieties for *Aspergillus flavus, Colletotrichum* sp., *Fusarium* sp. and *Penicillium* sp. infection (Table 6). However significant ($p < 0.05$) differences were observed between varieties in *A. niger, Curvularia* sp. and *Rhizopus* sp. infection (Table 6). Asontem variety produced the highest infections of *A. niger, Colletotrichum* sp. and *Fusarium* sp., while Asante Aba produced the highest infections of *A. flavus, Penicillium* sp. and *Rhizopus* sp. (Table 6). From the present study it could be deduced that Asante Aba okra variety had better quality attributes over Asontem and this could be attributed to genotypic differences between the two varieties.

There was no significant ($p > 0.05$) difference between storage containers for *A. flavus, A. niger, Colletotrichum* sp., *Fusarium* sp., *Penicillium* sp., *Curvularia* sp. and *Rhizopus* sp. infection. However, seeds stored in the airtight plastic container produced

the highest infections of *A. flavus*, *A. niger, Penicillium* sp. and *Rhizopus* sp., while seeds stored in the insecticide treated net produced the highest infections of *Colletotrichum* sp. and *Fusarium* sp. (Table 6). The level of *Curvularia* sp. infection recorded between the airtight plastic container and the insecticide treated net was not significant.

This current study also revealed no significant differences between fungal infections except for *Rhizopus* sp. which showed a significant difference between the two storage containers. Seeds stored in the airtight plastic container produced the highest infections of *Aspergillus flavus, A. niger* and *Rhizopus* sp., whereas seeds stored in the treated net produced the highest infections only in *Fusarium* sp. and *Colletotrichum* sp. Both treated net and airtight plastic containers produced statistically the same infection of *Curvularia* sp.

There was significant ($p < 0.05$) difference between seed treatment for *A. flavus, A. niger, Colletotrichum* sp., *Fusarium* sp., *Curvularia* sp., *Penicillium* sp. and *Rhizopus* sp. infection. Okra seeds treated with Dresscare produced the least infections of *A. flavus, A. niger, Colletotrichum* sp., *Fusarium* sp., *Curvularia* sp., *Penicillium* sp. and *Rhizopus* sp., while untreated (control) okra seeds produced the highest infections of all the okra seed-borne fungi listed above (Table 6). There were significant differences in seed-borne fungal infections due to seed treatment. Dresscare produced the lowest incidences of *Aspergillus flavus, Colletotrichum* sp., *A. niger, Fusarium* sp., *Curvularia* sp., *Penicillium and Rhizopus* sp., whereas untreated (control) seeds produced the highest incidences of all the above listed seed-borne fungi. Dresscare's ability to protect the seeds better than the wood ash and control could be attributed to the active ingredients Metalaxyl-M (20%) and Tebuconazole (2%) contained in Dresscare which have high fungicidal effects.

TABLE 6

Effect of variety, storage containers and seed treatment on fungal growth of okra seeds after storage

Factors	Total fungi infection	*A. flavus*	*Colletotrichum* sp.	*A. niger*	*Fusarium* sp.	*Curvularia* sp.	*Penicillium* sp.	*Rhizopus* sp.
Variety								
Asontem	7.4a	2.4a	3.7a	3.6a	2.7a	2.7a	2.2a	2.5b
Asante Aba	7.2a	2.5a	3.2a	2.7b	2.5a	2.1b	2.4a	3.2a
$LSD_{(0.05)}$	0.8	0.3	0.6	0.6	0.4	0.4	0.3	0.5
CV (%)	16.1	19.5	26.1	28.4	24.4	22.8	16.1	24.5
Storage container								
Plastic container	7.5a	2.5a	3.3a	3.4a	2.5a	2.4a	2.2a	3.0a
Mosquito net	7.4a	2.3a	3.7a	2.9a	2.7a	2.4a	2.3a	2.7a
$LSD_{(0.05)}$	0.8	0.3	0.6	0.7	0.4	0.4	0.3	0.5
CV (%)	16.4	19.4	26.7	30.1	24.4	26.0	16.1	26.4
Seed treatment								
Dresscare	6.3c	2.2a	3.1b	2.3b	2.2b	2.0a	2.2a	2.2b
S. siamea wood ash	7.2b	2.5a	2.9c	3.3ab	2.2b	2.5a	2.2a	2.9ab
Control	9.0a	2.7a	4.5a	4.0a	3.3a	2.7a	2.5a	3.5a
$LSD_{(0.05)}$	0.3	0.4	0.5	0.6	0.3	0.5	0.3	0.5
CV (%)	5.1	18.1	18.2	22.5	13.1	23.7	16.0	20.3

Conclusion and Recommendation

The quality analysis of seeds revealed that Asante Aba variety was purer than Asontem and therefore had high germination, normal roots of seedlings, field emergence and establishment than Asontem. Shrivelled seeds were observed to be the highest component of impurity in both Asante Aba and Asontem varieties of okra. Eight important okra seed-borne fungi species were identified in the study and they were *Fusarium* sp., *Colletotrichum* sp., *Aspergillus flavus*, *Aspergillus niger*, *Rhizopus* sp*., Mucor, Penicillium* and *Curvularia* sp. Asontem variety recorded the highest total percentage of seed-borne fungi infection even though it had a lower moisture content.

It therefore appears that Asontem okra variety is comparatively more susceptible than Asante Aba to seed-borne fungal infection. The use of plastic containers for okra seed storage proved more effective over the treated net as indicated by all quality tests. The only exception to this was the level of fungal infection. Dresscare (insecticide-fungicide) treatment was the most effective, recording the highest germination, normal roots of seedlings, field emergence and establishment, reduction of moisture content and lowest fungi prevalence.

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