: of storage conditions and packaging materials on seed germination and field emergence of okra (*Abelmoschus callei*) at different seasons

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Abstract
The conservation of okra [*Abelmoschus esculentus (L.)*] seeds in genebanks is essential for success of their use in breeding programmes. This study was conducted to investigate the impact of storage conditions and packaging materials on germination and field emergence of okra seeds. One okra accession produced during the late growing season of 2015 was used for the study. The experiments were set up using 3x3 factorial in completely randomized design (CRD) and randomized complete block design (RCBD) for germination and field emergence experiments respectively with three replications. One hundred seeds per replicate were subjected to standard germination test and immediately followed by field evaluations during four growing seasons. The results of combined ANOVA revealed that storage conditions, packaging materials, year of storage and their interactive effects were highly significant on seed germination and field emergence of okra. Okra seeds stored in plastic container had highest germination value (79.67%) and field emergence value (78.67%) under short term storage conditions while seeds stored in aluminum foil had highest seed germination value (74.33%) and field emergence value (75.33%) under medium term storage conditions. The materials stored inside deep freezer using aluminum cans had highest values for seed germination (67.00%) and field emergence (77.67%) suggesting that plastic containers, aluminum foils and aluminum cans would be suitable for storing okra seeds under short term, medium term and freezer storage conditions respectively. However, comparatively lower germination counts for okra seeds stored in aluminium can under freezer conditions suggests slow release of dormancy due to low temperature.

Conclusions
The study concludes that seed germination and field emergence of was highly influenced by the interactive effect of storage environments and packaging materials. Plastic container and aluminum foil bag and aluminum can would be suitable for storing okra seeds under short term, medium term and freezer storage conditions respectively. However, relatively lower germination counts especially for seeds stored under freezer conditions irrespective of packaging materials compared to other storage environments suggesting slow release of dormancy in okra seeds due to low temperature hence in order to avoid reduce germination which may occur as a result of low temperature in storage, breaking of dormancy in okra should be taking into consideration when evaluating for germination or field emergence especially when seed lots were stored under cold environments.

Introduction
Okra *Abelmoschus callei* (L) Moench is an economically important crop belonging to the family Malvaceae. It is a nutritious vegetable grown in tropical and sub-tropical parts of the world containing 86.1% water, 2.2% protein, 0.2% fat, 9.7% carbohydrate, 1% fiber and 0.8% ash (BARI, 2010). However, in spite of its benefits okra has been considered as a minor crop and no attention has been paid to its improvement in the international research programme in the past (Sanjeet et al., 2010). In order to promote the use of this indigenous vegetable as an important crop to mitigate food insecurity and alleviate malnutrition, improving its genetic potential is very important.

Conservation of okra germplasm is mainly by seed storage in genebanks hence efficient management of seed collections, especially under tropical conditions, depends on, among other factors, conditions of the storage environments and packaging materials used in seed storage. However, most genebanks are vulnerable to financial constraints leading to downsizing, as well as chronic losses in diversity due to storage methods, catastrophic losses from equipment failures, among other things (McGuire and Qualset, 1990). It is therefore essential to conserve of okra seeds in appropriate storage conditions for success of their use in breeding programmes.

•In Nigeria, The National Centre for Genetic Resource and Biotechnology (NACGRAB), Ibadan, has the institutional mandate for conservation and maintenance of valuable genetic resources for immediate utilization and posterity. The centre's genebanks currently hold over 400 accessions of okra seeds stored in both short and medium term storage chambers. However, in order to facilitate the conservation of this germplasm, it is essential to investigate laboratory germination and field emergence performance with a view to ascertain most suitable packaging materials for respective storage environments. The objective of this study therefore was to investigate the impact of three packaging materials (aluminum foil bag, aluminum can and plastic container) under three storage environments (short term, medium term and deep freezer) on germination and field emergence of okra seeds.

Materials and Methods
Genetic material and experiment location
- Okra accession (NGB 00372) with 12% moisture content produced during the late growing season of 2015.
- Germination test at seed testing laboratory of NACGRAB.
- Field emergence trials at the experimental field of NACGRAB

Seed storage and measurement of storage conditions
500g of processed Okra seeds, divided and packed in different materials (Figure 1)

Experimental design
- 3x3 factorial completely randomized design (CRD) for germination tests
- 3x3 factorial randomized complete block design (RCBD) for field emergence experiments
- Three replications for both laboratory and field experiments

Experimental procedures
1. **Standard germination tests.**
- Initial seed quality test before storage in December 2015.
- Effect of the factors on germination was assessed in August 2016, June 2017, September 2018 and July 2019 prior field emergence trials.
- The germination test was performed using the top paper method.
- 100 seeds per replicate were randomly distributed on the wet filter paper in petri dishes 9cm in diameter and placed inside an incubator set to a constant temperature of 25° C throughout the testing period.
- Germination percentages were calculated by expressing the number of seedlings in a replicate that germinated 9 days after planting as a percentage of the number of seeds planted according to ISTA rules (ISTA, 1999).

2. **Field Emergence trials.**
- Late season of 2016, early season of 2017, late season of 2018 and early season of 2019.
- One hundred seeds were sown in three replicates on a well prepared seed bed with adequate soil moisture.
- Field emergence was determined on the 9th day after sowing

3. **Statistical analysis**
- Analysis of variance (ANOVA), using Statistical Analysis System software (SAS, 1990).
- log-transformation of germination data before subjecting them to ANOVA.
- However, since ANOVA did not detect any significant difference between transformed and untransformed values, under transformed values were hereby presented.
- Pertinent means were thereafter separated by use of the least significant difference (LSD).

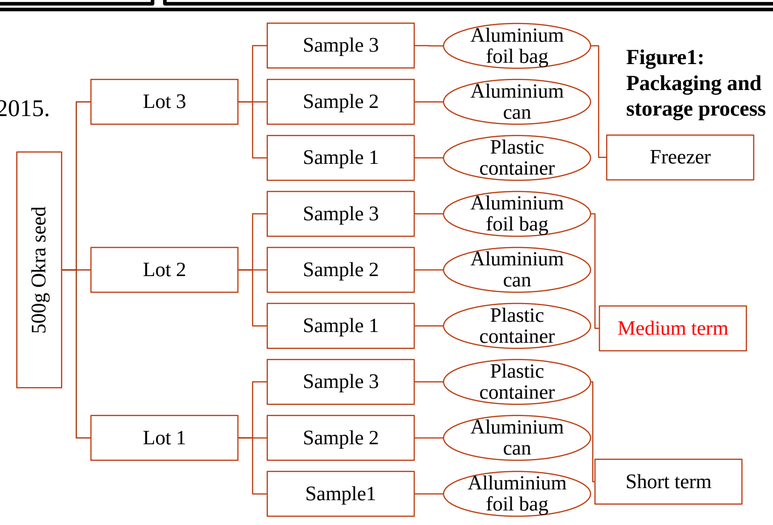

Figure1: Packaging and storage process

Results & Discussion

Conditions of the storage environments

Table 1. Atmospheric conditions of the storage environments during the study.

Storage Year	EC	Short term M1	Short term M2	Medium term M1	Medium term M2	Freezer M1	Freezer M2
2016	TM (°C)	17.0	20.2	-0.4	1.6	-4.2	4.0
	RH (%)	30.1	31.5	43.0	66.0	44.0	67.0
2017	TM (°C)	18	23.8	-0.3	2.9	0.40	3.5
	RH (%)	33.5	41.1	54.0	59.0	45.0	65.0
2018	TM (°C)	11.9	19.5	-1.6	1.2	-1.50	2.5
	RH (%)	29.0	40.1	53.0	68.1	46.0	66.0
2019	TM (°C)	18.1	23.1	-1.3	2.2	-4.20	4.0
	RH (%)	22.0	42.3	54.0	67.0	44.0	66.0

EC= Environmetal Conditions; TM = Temperature; RH= Relative Humidity; M1= Minimum; M2= Maximum

Effect of storage environments, packaging materials and storage time on germination and field emergence of okra seed

Table 3 Germination and field emergence of okra seeds as affected by storage environments, packaging materials and storage year.

Storage environment	Germination (%)	Field emergence (%)
Short term	86.53a	76.11a
Medium term	80.17b	76.78a
Freezer	72.78c	65.78b
LSD	2.3	1.98
Packaging material		
Aluminium foil bag	85.31a	78.33a
Aluminium can	83.44a	76.72a
Plastic container	70.72b	63.61b
LSD	2.3	1.98
Storage Year		
2016	75.96c	77.70a
2017	74.00c	70.15c
2018	88.15a	75.26b
2019	81.19a	68.44c
LSD	2.65	2.29

Means with the same letter are not significantly different at P= 0.05

Seed germination and field emergence performance of okra seeds stored under varied conditions.

Table 2: Means squares from the analysis of variance for germination and field emergence of okra seeds as affected by storage year (SY), storage environment (SE), packaging materials (PM) and their interaction at NAGRAB, Ibadan.

Sources of Variation	DF	Germination (%)	Field (%)
Rep	2	36.45ns	6.33ns
Storage Year (SY)	3	1079.74**	504.59**
Packaging Material (PM)	2	2267.95**	2347.44**
Storage Environment (SE)	2	1704.73**	1369.33**
PM*SE	4	928.34**	1839.78**
SY*PM	6	1813ns	121.07**
SY*SE	6	97.27*	209.93**
SY*SE*PM	12	85.44**	63.41**
Error	70	23.84	17.72
Total	107	171.57	189.78
R^2		0.91	0.94
CV		6.12	5.78
Mean		79.82	72.89

*, **, Significant at probability level of 0.05 and 0.01, respectively; ns = Not Significant
PM = Packaging material, SE = Storage environment, SY = Storage year

Interactive effect of storage environments and packaging materials on germination and field emergence of okra seed

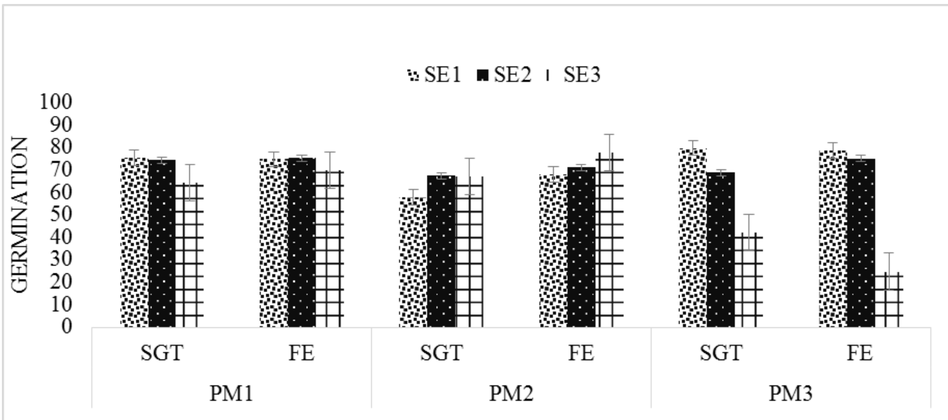

Figure 1. Germination and field emergence of okra seeds as influenced by the interaction of packaging materials (PM) and storage environments (SE)
PM 1=Aluminium foil bag; PM 2 = Aluminium can; PM 3 = Plastic container
SE 1=Short term; SE 2=Medium term; SE 3=Freezer
SGT= Standard germination; FE= Field emergence

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