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Seed longevity characteristics of tomato (*Solanum lycopersicum* L.) genotypes stored with different packaging materials under ambient tropical humid conditions

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Seed longevity characteristics of tomato (*Solanum lycopersicum* L.) genotypes stored with different packaging materials under ambient tropical humid conditions

Abstract: Tomato seeds have a high commercial value, and the loss of seed physiological quality over time is demonstrated by their low storability unless hermetic conditions are used. This study aimed to store and preserve seed quality under ambient conditions using different packaging materials such as plastic bottles, glass bottles, paper envelope, earthen pot, polyethylene bag, galvanized iron tin. Freshly harvested seeds of four tomato genotypes were packed inside different containers and then sealed and stored for eight months under ambient humid tropical conditions. Data collected were subjected to Analysis of Variance (ANOVA) and means were separated using Tukey's HSD test at 5 % probability level. The result revealed that envelope and earthen pot were not ideal for tomato seed storage for long time, because seed stored in air tight containers maintained desired seed quality than non- airtight packaging materials. Glass bottle was identified as the best packaging material in maintaining seed quality of tomato throughout the storage period. Tomato seeds could be stored up to between 120 and 180 days under ambient conditions, depending on genotype and storage medium of the seed lot.

Key words: seed deterioration; seed quality; storage life; storage container

Vzdrževanje vitalnosti semen različnih genotipov paradižnika (*Solanum lycopersicum* L.) shranjenih različno v vlažnih tropskih ambientalnih razmerah

Izvleček: Semena paradižnika imajo veliko tržno vrednost in izguba njihove fiziološke kakovosti nastopi hitro, če niso shranjena v zrakotesnih razmerah. Namen raziskave je bil shranjevati in ohranjati kakovost semen v ambientalnih razmerah z uporabo različnih materialov kot so plastične steklenice, steklenke, papirnate vrečke, glineni lonci, polietilenske vrečke in pocinane železne posode. Sveža semena štirih tipov paradižnika za bila shranjena v različne shranjevalnike, ki so jih zapečatili in hranili osem mesecev v vlažnih tropskih bivalnih razmerah. Pridobljeni podatki so bili obdelani z analizo variance (ANOVA), poprečja so bila ločenam s Tuckeyevim tesom (Tukey's HSD test) pri 5 % verjetnosti. Rezultati so pokazali, da papirnate vrečke in glinene posode niso primerne za daljše shranjevanje semen, kajti, semena ki so bila shranjena v zrakotesnih shranjevalnikih so ohranila zaželjeno kakovost v primerjavi s tistimi, ki so bila shranjena v zračnih ovojih ali posodah. Za daljše shranjevanje semen paradižnika so se izkazale najboljše steklenice. Semena paradižnika so v ambientalnih razmerah lahko shranjena od 120 do 180 dni, odvisno od genotipa in materiala, v katerem so shranjena.

Ključne besede: propadanje semen; kakovost semen; dolžina shranjevanja; shranjevalniki

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1 INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a member of the Solanaceae family which is famous for a number of medicinal and nutritional properties. Botanically, this fruit is known as berry (Salunkhe et al., 2005). Though it is a perennial crop but some of its cultivars are grown as an annual crop in various parts of the world (Nunes et al., 1996; Knapp, 2002). Tomato is one of the most important vegetables grown for edible fruits consumption in virtually every home in Nigeria. There are thousands of varieties of tomatoes in array of shapes, colours and size. The most common shapes are round (beefsteak and globe), pear shaped (roma) and the tiny cherry sized (cherry and grape) (Demir and Ellis, 1992).

Tomato seeds have a high commercial value, and the loss of seed physiological quality over time is demonstrated by their low storability unless hermetic conditions are used (Tigist et al., 2012). As a result, the development of satisfactory seed vigour test must be used and intensified. Slow, asynchronous and unreliable germination and emergence, within germinable, low vigour seeds, arise due to seed ageing (Mathew, 1980) and lead to problems for successful vegetable production.

The fact that seeds of most species can be dried and stored from year to year has been exploited since the beginning of agriculture. Indeed, the ability of many orthodox seeds (Roberts, 1973) to remain viable for tens or hundreds of years in dry storage (Walter et al., 2005) means that they also provide a convenient vehicle for the long term ex-situ conversation of plant germplasm (Probert et al., 2009).

The principal purpose of seed storage is to preserve economic crops from one season to another. Seed longevity refers to how long a seed can be stored under given set of conditions, how long a seed can remain dormant and still remain viable (Kehinde, 2018). Storage temperature and moisture content are the most important factors affecting seed longevity, with seed moisture content usually being more influential than temperature. The effect of temperature, the availability of oxygen and the greater improvement in deteriorated low vigour seeds were cited as evidence in support of metabolic repair during aerated hydration treatment (Thornton and Powell, 1992).

During storage, seed quality can remain at the initial level or decline to a level that may make the seed unacceptable for planting purpose. Several environmental factors have been reported to affect seed viability during storage (Rindels, 1995). Some of the factors that affect the longevity of seeds in storage could be genotype of seed, initial seed quality, storage conditions, and moisture content among others. Within the same plant species, different varieties may exhibit different storing abilities either from genetic variation or other external factors (Simic et al., 2007). However, irrespective of the initial seed quality, unfavorable storage conditions, particularly air temperature and relative humidity contribute to accelerating seed deterioration (Heatherly and Elmore, 2004). High relatively humidity and temperature cause high moisture content in seeds and result in low germination at the end of storage (McCormack, 2004).

In Nigeria and Ghana, most small holder farmers store their seeds in various containers including: pieces of cloth, black polyethylene bag, galvanized tin, clay pots, and plastic containers, mostly under ambient conditions (Adetumbi et al., 2009; Bortey et al., 2011; Akintobi et al., 2006). Additionally, several studies have indicated that storage containers affected the quality of seeds in terms of germination and viability over a period of time (Bortey et al., 2016). However, it has been reported that the intensity decreasing quality of stored seed under different storage techniques differ among plant species and within plant species (Al-Yahya, 2001) and as well as among varieties. Thus the type and choice of container used in storing seed is crucial in ensuring that the seed longevity characteristics of seed are maintained during storage.

Tomato is a common vegetable used frequently in the households. Thus, it is essential to have statistical estimates of seed longevity in order to decide efficient readily available storage conditions for seed storage and be able to predict how long seeds will store under ambient conditions.

Moreover, since the effect of these storage materials on the quality of seeds of different crops may vary, it is important to investigate and establish the most suitable storage material and condition for various food crop seeds. This would provide seed producers, breeders and farmers information on how to maintain the integrity of the seed during storage. The objectives of this study were therefore to: to evaluate the potential of packaging materials (storage containers) for preservation of tomato seed for seed physiological quality and to estimate potential seed longevity of some tomato genotypes stored under ambient conditions using probit modelling.

2 MATERIALS AND METHODS

2.1 SEED MATERIALS AND SOURCE

Four genotypes of tomato seeds ('Tropimech', 'Alausa', 'Cobra F1' hybrid and 'Roma VF') used in the study were sourced from National Institute of Horticulture (NIHORT), Ibadan, Nigeria.

2.2 STORAGE MATERIALS

Six storage materials were selected for the study, namely: plastic bottles, glass bottles, earthen pot, polyethylene bag, galvanized iron tin and paper envelope (control). The storage containers were selected on the following bases: polyethylene is being recommended as most cost-effective material. It is durable and reusable. In rural area, our fathers put their seeds in the earthen pot. Plastic and glass bottle are always available at ceremonies and common household and can be used as storage materials for some of the vegetables at no cost. Galvanized iron tin has a sealing which are always effective, readily available and easy to get. Most seeds are packaged in small envelope paper bags.

2.3 EXPERIMENTAL DESIGN

The trial was factorially arranged and laid out in completely randomized design with three replicates. There were three factors thus: cultivar at four levels; packaging materials at six levels; storage periods at five levels i.e. 0, 60,120,180 and 240 days. The treatments combination was 5 x 6 x 5 = 150 treatments and was replicated thrice.

2.4 STORAGE ENVIRONMENT

Storage and every other test were done in the processing and storage unit and in the laboratory of Plant Breeding and Seed Technology Department respectively, College Plant Science and Crop Production (COLPLANT), Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria under ambient conditions. The temperature and relative humidity of the storage environment were monitored daily throughout the storage period with a thermo hygrometer.

2.5 SEED DATA COLLECTION AND PARAMETERS ANALYSED

Data were collected on the following seed quality characters at 60 days interval for 240 days.

2.5.1 Seed viability test

This test was carried out in the laboratory. Hundred seeds in three replications were placed inside Petri dish in an incubator maintained at 7 ml of distilled water and germination count was taken at 7 days and germinated seeds defined as those with a radicle of at least 2 mm long (ISTA, 1995).

Seed viability was then determined as:

(Viability count at 7 days / Number of seeds sown) x 100

2.5.2 Rate of germination

This was determined from viability test at 3 days after germination as:

(Normal germination at 3 days / Number of seeds sown) x 100

2.5.3 Seedling Length

Shoot length of 10 randomly selected seedlings were measured using a ruler in centimetre (cm).

2.5.4 Seedling vigour index

Seedling vigour index was computed as follows:

(Normal germination at 3 days / Number of seeds sown) x 100

2.6 DATA ANALYSIS

Data collected were subjected to analysis of variance (ANOVA). Significant means were compared using Tukey HSD test at 5 % probability level. Probit analysis of mean percentage seed viability data was also done using the PROC statements of SAS. Seed longevity parameters were values of *Ki* (an estimate of the probit value of initial seed viability at the time of storage), slope ($1/\sigma$), an estimate of rate of seed physiological deterioration, sigma (σ), the standard deviation of seed survival curve and an estimate of time taken to lose 1 probit seed viability, and P_{50}, a measure of time taken for a seed lot to lose 50 % viability and estimate of absolute seed longevity (Ellis and Roberts, 1980; Daniel, 1997; Adebisi et al., 2008; Kehinde, 2018).

3 RESULTS

Table 1 presents the influence of genotype on the four quality parameters of tomato seeds. For the varietal effect on rate of germination, 'Tropimech' hybrid had higher value of 72 %, 'Roma VF' and 'Alausa' were statistically similar but had higher seed viability than 'Cobra F1' hybrid with 51.2 %. 'Roma VF', 'Cobra F1' hybrid and 'Alausa' had statistically similar and higher viability percentage than 'Tropimech' (72.0) which was not significantly different from 'Alausa'. For seedling length, 'Roma VF', 'Tropimech' and 'Alausa' had statistically similar values but higher value than 'Cobra F1' hybrid. For seedling vigour, 'Roma VF' and 'Alausa' were statistically similar but higher than 'Cobra F1' hybrid (7.3) which was also not significantly different from 'Tropimech' vigour 7.6 %.

The effect of packaging material (Table 1) shows that with rate of germination, galvanized iron tin had the highest percentage of 67.4 but was not significantly different from 65.3 and 65.3 % values recorded by polyethylene bag and glass bottle, respectively, and these latter was also not significantly different from that of earthen pot. But 59.8 and 60.6 % of plastic bottle and paper envelope had the lowest rate of germination respectively. For seed viability, glass bottle had the highest value of 81.8 % which was not significantly different from paper envelope (80.0 %) and earthen pot had the lowest value of 70.2 %. The result was similar to that of seedling length except that glass bottle (10.2 cm) was not significantly different from paper envelope (8.1 cm). With seedling vigour, glass bottle had the highest value of 8.4 % which was not significantly different from paper envelope (8.1 %) and galvanized iron tin (7.9 %) followed by polyethylene bag(7.6 %) which was not also significantly different from galvanized iron tin (7.9 %) and earthen pot which had the lowest value of (7.1 %) which was not significantly different from plastic bottle (7.3 %).

Influence of storage time on quality parameters of tomato seeds (Table 1) shows that the storage time of 180 days had the highest percentage the rate of germination was not statistically different from 120 days, followed by the 60 days, then 0 days and 240 days which was the lowest. With seed viability, 120 days was the highest but not statistically different from 0 and 60 days while the lowest viability was recorded at 240 days of storage. For seedling length, 120 and 180 days had similar and the highest value followed by 0 days, 240 days, the 60 days. For seedling vigour, 120 days had the highest value of 10.8 % which was not significantly different from 180 days followed by 0 days, while other storage time had statistically lower but similar values.

Table 1: Influence of treatment (genotype, storage time, package material) on quality parameters on tomato seeds under ambient conditions

Treatment	Rate of germination at 3 days (%)	Seed viability (%)	Seedling length (cm)	Seedling vigour (%)
Genotypes				
Roma VF	65.8b	78.8a	9.9a	7.9ab
Cobra F1 hybrid	51.2c	78.1a	9.1b	7.3c
Tropimech	72.0a	75.7b	9.9a	7.6bc
Alausa	65.6b	77.3ab	10.2a	8.2a
Standard error	1.3	1.3	0.2	0.2
Packaging Material				
Polyethylene Bag	65.3ab	77.9cd	9.4a	7.6abc
Plastic bottle	59.8c	75.4d	9.5b	7.3c
Glass bottle	65.3ab	81.8a	10.2a	8.4a
Paper envelope	60.6c	80.0ab	9.9ab	8.1a
Earthen pot	63.5b	70.2e	9.8b	7.1c
Galvanized Iron Tin	67.4b	79.6c	9.7b	7.9ab
Standard Error	1.6	1.6	0.2	0.2
Storage Time				
0 days	53.7c	79.8b	9.5b	7.6b
60 days	66.4b	77.8b	6.7d	5.3c
120 days	82.2a	88.8a	12.3a	10.9a
180 days	83.1a	83.4ab	12.3a	10.4a
240 days	32.9d	57.6c	7.9c	4.6c
Standard Error	1.5	1.5	0.2	0.2

Means followed by the same alphabet along the column are not different from each other at 5 % probability level according to Tukey's HSD test

Rate of germination as affected by genotype, packaging material and storage time are presented in Table 2. The result reviewed that 'Alausa' stored in galvanized iron tin had the highest viability of 85 % at zero day storage, but was not significantly different from 'Tropimech' stored in polyethylene bag, plastic bottle, glass bottle, and in galvanized iron tin and also 'Roma VF' stored in glass bottle. Whereas 'Cobra F1' stored in glass bottle and paper envelope had similar but the lowest viability rate of 13.3 at zero day of storage. At 60 days of storage, 'Alausa' stored in paper envelope had the highest viability rate of 90 % which was significantly different from the one stored in galvanized iron tin, 'Tropimech' stored in polyethylene bag, glass bottle, earthen pot. Whereas 'Cobra F1' hybrid stored in earthen pot and galvanized iron tin had the lowest viability rate of 33 %. At 120 days of storage, 'Alausa' seeds stored in glass bottle had the highest viability of 95 % which was not significantly different from the one stored in earthen pot and galvanized iron tin, also from 'Roma VF' stored in earthen pot and galvanized iron tin, 'Cobra F1' hybrid seeds stored in earthen pot and galvanized iron tin, 'Tropimech' seeds stored in polyethylene bag. At 180 days of storage, 'Alausa' seeds stored in glass bottle had the highest viability rate of 93 % while 'Tropimech' seeds stored in glass bottle had the lowest rate of 70 % which was not significantly different from the one stored in polyethylene bag, plastic bottle and 'Roma VF' seeds stored in plastic bottle. After 240 days, the viability rate decreased across all genotypes and package materials which 'Roma VF' had the highest rate of 58 %.

Table 2: Influence of storage time and packaging material on rate of germination of four tomato genotypes

Genotypes	Packaging material	Storage time (days)				
		0	60	120	180	240
Roma VF	Polyethylene Bag	58.3efgh	53.3ef	80.0bcd	91.6ab	28.3e
	Plastic Bottle	48.3hi	50.0ef	73.3d	80.0b-g	26.6e
	Glass Bottle	78.3abc	58.3e	80.0bc	90.0ab	50.0ab
	Paper Envelope	40.0ijk	78.3bcd	73.0d	88.3abc	30.0de
	Earthen Pot	63.0def	76.0bcd	86.0abc	76.0d	36.0c
	Galvanized Iron Tin	68.3cde	73.0cd	86.0abc	90.0ab	58.0a
Cobra F_1 Hybrid	Polyethylene Bag	35.0jk	46.6fg	86.6ab	86.6abcd	21.6efg
	Plastic Bottle	30.0kl	43.3fgh	76.0cd	86.6abcd	18.3fg
	Glass Bottle	13.3m	58.3e	78.3bcd	78.3c	11.6g
	Paper Envelope	13.3m	36.6gh	83.0bcd	85.0abcd	21.0efg
	Earthen Pot	48.0hi	33.0h	85.0abcd	86.0abcd	25.0e
	Galvanized Iron Tin	23.0l	33.0h	86.0abc	83.0abcde	20.0efg
Tropimech	Polyethylene Bag	83.3a	81.6abcd	86.6abc	81.6b-g	58.3a
	Plastic Bottle	81.7a	70.0d	80.0bcd	80.0b-g	48.3ab
	Glass Bottle	83.3a	83.3abcd	78.3bcd	70.0g	53.3a
	Paper Envelope	73.3bcd	75.0bcd	81.0bcd	76.6d	40.0bcd
	Earthen Pot	53.0fg	85.0ab	80.0bcd	71.0f	40.0bcd
	Galvanized Iron Tin	83.0a	76.0bcd	76.0bcd	73.0e	53.0a
Alausa	Polyethylene Bag	46.7ij	76.6bcd	80.0bcd	81.6bcde	40.0cd
	Plastic Bottle	40.0ijk	76.6bcd	83.3bcd	90.0ab	13.3fg
	Glass Bottle	48.3hi	75.0bcd	95.0a	93.0a	28.3e
	Paper Envelope	40.0ijk	90.0a	78.0bcd	83.3a-e	23.0efg
	Earthen Pot	50.0ghi	78.0bcd	88.0ab	83.3a-e	21.0efg
	Galvanized Iron Tin	85.0a	83.0abc	86.0abc	86.0abcd	20.0efg

Means followed by same alphabet along column are not different from each other at 5 % probability level according to Tukey's HSD test at 5 % probability level

Seedling length as affected by genotype, packaging material and storage time is revealed in Table 3. 'Alausa' seeds stored in galvanized iron tin had the highest value of 13.2 cm which was not significantly different from the one stored in paper envelope while 'Tropimech' seeds stored in plastic bottle had the lowest value of 7.4 cm. At 60 days of storage, 'Alausa' seeds stored in polyethylene bag had the highest value of 9.9 cm, which was statistically similar to 'Tropimech' seeds stored in glass bottle while 'Cobra F1' hybrid seeds had the lowest value of 4.3 cm which was not significantly different from the one stored in galvanized iron tin. At 120 days of storage, seeds of 'Alausa' stored in polyethylene bag had the highest value while at 180 days 'Alausa' seeds stored in earthen and galvanized iron tin had similar and the highest seedling length for the storage time. After 240 days, 'Tropimech' seeds stored in plastic bottle had the highest value 11.6 cm which was not significantly different from 'Roma VF' seeds stored in earthen pot.

Table 4 shows data on seed viability as affected by genotype, package material and storage time. Seed of 'Alausa' genotype stored in paper envelope had the highest value of 95 % which was statistically similar to 'Roma VF' stored in polyethylene bag, plastic bottle, galvanized iron tin, 'Cobra F1' hybrid stored in polyethylene bag, plastic bottle, glass bottle, 'Tropimech' stored in polyethylene bag and galvanized iron tin and 'Alausa' seeds stored in galvanized iron tin. For 60 days of storage 'Alausa' stored in polyethylene bag had the highest value of 93 % which was statistically similar to the one stored in paper envelope and plastic bottle. 'Tropimech' stored in galvanized iron tin, glass bottle, paper envelope, 'Co-

Table 3: Influence of storage time and packaging material on seedling length (cm) of four tomato genotypes

Genotypes	Packaging material	Storage time (days)				
		0	60	120	180	240
Roma VF	Polyethylene Bag	7.5ef	7.3bcd	12.9bcde	11.4gh	7.2hijk
	Plastic Bottle	8.9cde	5.4fgh	12.9bcde	13.3-e	6.9ijk
	Glass Bottle	9.6cd	7.7bc	12.6bcde	13.0a-f	9.6bcd
	Paper Envelope	9.2cd	6.2defg	13.4ab	13.7abc	9.3cde
	Earthen Pot	9.2cd	5.8efg	12.7bcde	11.3gh	10.9ab
	Galvanized Iron Tin	8.5def	7.2cde	9.6h	12.7a-g	9.7bcd
Cobra F_1 Hybrid	Polyethylene Bag	8.6def	7.4bcd	12.6bcde	9.5i	4.9mn
	Plastic Bottle	9.4cd	5.3fgh	11.5cdefg	11.7f	5.6lmn
	Glass Bottle	8.5def	7.7bc	11.7cdefg	12.2defg	7.8f-j
	Paper Envelope	9.2cd	6.2defg	10.4gh	11.8fg	6.6jkl
	Earthen Pot	9.7cd	4.3h	13.1abc	12.1defg	9.1cdef
	Galvanized Iron Tin	10.1c	4.8gh	11.6defg	11.9efg	6.1jklm
Tropimech	Polyethylene Bag	9.2cd	6.7cdef	13.0bcd	10.2hi	8.3d-i
	Plastic Bottle	7.4f	6.6cdef	10.9f	12.5c-g	11.6a
	Glass Bottle	9.4cd	8.7ab	12.5bcde	12.6b-g	9.2cdef
	Paper Envelope	8.9cde	7.7bc	11.9cdef	13.1a-f	8.4defgh
	Earthen Pot	8.6def	6.6cdef	11.9cdef	12.2defg	10.1bc
	Galvanized Iron Tin	10.1c	6.4cdef	11.7c-g	12.2defg	8.8cdefg
Alausa	Polyethylene Bag	9.0cd	9.9a	14.5a	13.5abcd	4.3n
	Plastic Bottle	11.6b	6.7cdef	12.7bcde	11.3gh	7.4g-k
	Glass Bottle	9.7cd	6.9cde	12.8bcde	11.8fg	8.8defg
	Paper Envelope	12.9ab	6.5cdef	12.3b-f	14.0ab	8.1e-i
	Earthen Pot	8.8cdef	6.0defg	13.5ab	14.1a	5.5lmn
	Galvanized Iron Tin	13.2a	6.4cdef	12.8bcde	14.1a	6.0klm

Means followed by same alphabet along column are not different from each other at 5 % probability level according to Tukey's HSD test at 5 % probability level

bra F1" hybrid seeds in glass bottle, 'Roma VF" stored in galvanized iron tin and glass bottle while 'Cobra F1' hybrid stored in earthen pot had the lowest viability of 60 %. At 120 days of storage, seeds of 'Alausa' stored in glass bottle had the highest viability rate from 120 days of storage to 240 days of storage with the value of 100, 98, 75 % respectively.

Table 5 presents seedling vigour as affected by packaging material, genotype and storage time. At zero time of storage, 'Alausa' stored in paper envelope and galvanized iron tin had the highest value of 12.2 and 12.3 respectively, while the lowest value was recorded by the same genotype stored in earthen pot. At 60 days of storage, 'Tropimech' seeds stored in glass bottle had the highest seedling vigour, while at 120 days, 'Alausa' seeds stored in polyethylene bag had the highest value. 'Cobra F1' hybrid stored in earthen pot and 'Tropimech' seeds stored in plastic bottle had the lowest value for 60 and 120 days of storage, respectively. For storage at 180 days, seeds of 'Alausa' stored in galvanized iron tin had the highest value of 12.2 while the one stored in glass bottle for 240 days of storage also had the highest value for that storage time. 'Alausa' stored in earthen pot and galvanized iron tin had similar but the lowest value for 240 days of storage.

Table 6 presents the results of probit analysis of seed viability data in four tomato genotypes and six package materials over 240 days of storage. It is evident by the positive values of the intercept of all the treatments that the seeds maintained its viability, irrespective of the package materials, over 240 days of storage. 'Roma VF' seeds stored in glass bottle had the lowest rate of deterioration (-0.609), followed by 'Tropimech' seeds stored

Table 4: Influence of storage time and packaging material on seed viability of four tomato genotypes

Genotypes	Packaging material	Storage time (days)				
		0	60	120	180	240
Roma VF	Polyethylene Bag	93.0ab	71.0fg	88.0bcde	91.0abc	41.0g
	Plastic Bottle	88.0abcd	63.0h	73.0h	81.0b-f	53.0g
	Glass Bottle	88.0abcd	86.0abc	93.0abcde	92.0abc	63.0b-f
	Paper Envelope	73.0ef	78.0b-g	93.0bcde	86.0bcde	60.0cdef
	Earthen Pot	73.oef	72.0fg	88.0bcde	86.0bcde	55.0ef
	Galvanized Iron Tin	90abc	88.0ab	90.0a-f	92.0abc	67.0abcd
Cobra F_1 Hybrid	Polyethylene Bag	85.0b	78.0bc	90.0a-f	91.0abc	53.0f
	Plastic Bottle	86.0ab	61.0h	86.0c-g	85.0bcde	63.0b-f
	Glass Bottle	85.0ab	86.0abc	85.0defg	83.0b-f	73.0ab
	Paper Envelope	78.0de	73.0ef	96.0abc	81.0b-f	71.0abc
	Earthen Pot	73.0e	60.0h	90.0a-f	90.0abc	60.0cdef
	Galvanized Iron Tin	85.0ab	60.0gh	95.0abcd	70.0g	55ef
Tropimech	Polyethylene Bag	90.0abc	75.0de	83.0efgh	85.0b-f	66.0a-e
	Plastic Bottle	83.0bcde	71.0f	80.0fgh	75.0efg	68.0abcd
	Glass Bottle	83.0bcde	85.0abcd	85.0defg	72.0fg	60.0cdef
	Paper Envelope	80.0cde	83.0abcde	91.0a-f	80.0c-g	58.0def
	Earthen Pot	65.0fg	77.0cd	83.0efg	70.0g	27.0h
	Galvanized Iron Tin	90.0abc	83.0abcde	78.0gh	88.0a-e	53.0f
Alausa	Polyethylene Bag	58.0g	76.0c-g	93.0a-e	78.0def	66.0a-e
	Plastic Bottle	61.0g	83.0a-e	83.0efg	83.0b-f	70.0abc
	Glass Bottle	58.0g	81.0b-f	100.0a	98.0a	75.0a
	Paper Envelope	95.0a	83.0a-e	90.0a-f	78.0def	62.0b-f
	Earthen Pot	56.0g	82.0b-f	90.0a-e	75.0ef	30.0gh
	Galvanized Iron Tin	93.0ab	93.0a	98.0ab	87.0bcd	28.0h

Means followed by same alphabet along column are not different from each other at 5 % probability level according to Tukey's HSD test at 5 % probability level

in glass bottle (-0.1826). 'Cobra F1' hybrid seeds stored in glass bottle recorded highest value in days to seed half-life (528.23) followed by 'Roma VF' stored in polyethylene bag with 410.7 days. On the other hand, 'Cobra F1' hybrid stored in paper envelope recorded the lowest half-life. Seeds of 'Tropimech' stored in plastic bottle had the highest time taken (793.4 days) to lose one probit viability followed by 'Cobra Fi' hybrid seeds stored in paper envelope (691.3 days). However, 'Alausa" seeds stored in galvanized iron tin had the lowest time taken (51.53) to lose one probit viability.

Moreover, the highest seed storage life of 35.21 months was obtained by 'Cobra F1' hybrid seeds stored in glass bottle followed by 'Tropimech' stored in plastic bottle while 'Cobra F1' hybrid stored in paper envelope had the lowest storage life.

Table 5: Influence of storage time and packaging material on seedling vigour of four tomato genotypes

Genotypes	Packaging material	Storage time (days)				
		0	60	120	180	240
Roma VF	Polyethylene Bag	7.9bcd	5.2cdefg	11.5b-f	10.5bc	2.8fg
	Plastic Bottle	8.1bcd	3.3hi	9.3hij	10.9abc	3.8df
	Glass Bottle	8.5bc	6.7abc	11.7bcdef	11.9ab	6.1abc
	Paper Envelope	6.7defg	4.9defg	12.5abcd	11.8ab	5.7abc
	Earthen Pot	6.7defg	4.2ghi	11.2c-h	9.7cdef	5.1abc
	Galvanized Iron Tin	7.7bcde	6.3abcd	8.6j	11.7ab	6.4abc
Cobra F_1 Hybrid	Polyethylene Bag	7.4cde	5.8bcdef	10.5e-i	8.7ef	2.8fg
	Plastic Bottle	8.2bc	3.3hi	10.0f-j	9.8cdef	3.5ef
	Glass Bottle	7.3cde	6.7abc	10.0f-j	10.0cde	5.7abc
	Paper Envelope	7.2cdef	4.5fgh	10.0f-j	9.6cdef	4.5cde
	Earthen Pot	7.1cdef	2.7i	11.7b-f	10.8abc	5.7abc
	Galvanized Iron Tin	8.6bc	3.2hi	11.0defg	8.3f	3.5ef
Tropimech	Polyethylene Bag	8.3bc	5.2cdefg	10.8efgh	10.0cd	5.6abc
	Plastic Bottle	6.2efgh	4.7efgh	8.8j	9.8cdef	6.5ab
	Glass Bottle	8.4bc	7.4a	10.4-i	8.9def	5.6abc
	Paper Envelope	7.2cdef	4.5fgh	10.0f-j	9.6cdef	4.5cde
	Earthen Pot	5.5gh	5.0defg	9.9g-j	8.5ef	2.8fg
	Galvanized Iron Tin	9.1b	5.4cdefg	9.2ij	10.8abc	4.8cde
Alausa	Polyethylene Bag	5.3gh	7.2ab	13.5a	10.8abc	2.9fg
	Plastic Bottle	7.1cdef	5.6c-g	11.2c-f	9.4cdef	5.3a-d
	Glass Bottle	5.7fgh	5.7b-g	12.8ab	11.6ab	6.7a
	Paper Envelope	12.2a	5.7b-g	11.1cdef	11.9ab	4.9cde
	Earthen Pot	4.9h	4.9defg	12.0abcde	10.6bc	1.7g
	Galvanized Iron Tin	12.3a	5.9a-f	12.6abc	12.2a	1.7g

Means followed by same alphabet along column are not different from each other at 5 % probability level according to Tukey's HSD test at 5 % probability level

4 DISCUSSION

Significant differences observed between the four genotypes of tomato for all the quality parameters suggest that there is an opportunity to select between the four genotypes for better performance. Similarly, significant difference observed among the six packaging materials for rate of germination, seed viability, seedling length and seedling vigour revealed that there is possibility for selecting among the six packaging materials that will give the best performance for the seed quality attributes evaluated. Differences in all the seed quality parameters during the storage period indicated that these seed quality parameters significantly varied with storage time.

Table 6: Probit analysis of the seed viability data in four tomato genotypes stored under six package materials over 240 days storage time

Genotypes	Packaging materials	*Intercept	**Slope	***Sigma	*%P_{50}	*#Seed storage life
Roma VF	Polyethylene bag	1.130	-0.006	322.00	410.70	27.40
	Plastic bottle	0.944	-0.004	153.80	217.20	14.50
	Glass bottle	1.615	-0.609	82.40	148.30	9.90
	Paper envelope	0.986	-0.005	294.9	234.80	15.70
	Earthen pot	0.881	-0.002	205.07	125.80	8.40
	Galvanized iron tin	1.606	-0.005	189.33	298.80	19.90
Cobra F1 Hybrid	Polyethylene bag	1.428	-0.006	616.67	326.93	21.80
	Plastic bottle	0.960	-0.002	303.19	209.63	13.90
	Glass bottle	1.316	-0.003	498.53	528.23	35.21
	Paper envelope	0.906	-0.000	691.30	467.63	31.21
	Earthen pot	0.633	0.000	280.80	45.97	3.10
	Galvanized iron tin	1.230	-0.005	257.37	256.00	17.10
Tropimech	Polyethylene bag	1.255	-0.004	240.07	303.93	20.30
	Plastic bottle	1.026	-0.003	793.40	455.37	30.40
	Glass bottle	1.467	-0.007	351.57	384.63	25.60
	Paper envelope	1.319	-0.186	83.73	131.27	8.80
	Earthen pot	1.062	-0.007	151.03	143.80	9.60
	Galvanized iron tin	1.602	-0.007	335.53	385.85	25.70
Alausa	Polyethylene bag	0.534	-0.001	571.60	344.47	22.90
	Plastic bottle	0.594	-0.002	498.67	117.36	7.80
	Glass bottle	0.750	-0.003	171.83	75.58	5.00
	Paper envelope	2.030	-0.010	97.23	189.97	12.70
	Earthen pot	0.928	-0.000	220.20	204.77	13.70
	Galvanized iron tin	3.026	-0.020	51.53	147.18	9.80

*Intercept is PROBIT estimate of initial seed viability
**slope is the rate of seed deterioration
***Sigma is time taken for seed lot to lose 1 probit viability
*% P_{50} is seed half- life in days
*# Seed storage life estimated as P_{50} value multiplied by 2 then divided by the 30 days of a month

The significant effect of packaging materials and storage time for all the seed quality parameters except rate of germination implies that the differences recorded for these two parameters were influenced by storage time. The significant genotype and packaging material effect indicated that rate of germination of the genotypes was influenced by packaging material investigated. This support earlier findings by Alegiledoye et al. (2018) and Kehinde et al. (2020) who reported influence of packaging material on seed quality of African yam beans and water melon respectively.

Likewise, significant effect of genotype and storage time on all the seed quality parameters revealed that differences in these characters among the four genotypes were modulated by storage time examined. The significant effect of genotype, storage time and packaging material on rate of germination, seed viability, seedling length and seedling vigour revealed that the variation in these characters between the four genotypes was influenced by both the storage time and packaging material.

Among the packaging materials, glass bottle gave the best performance in terms of all the seed quality parameters compared with the other five packaging materials and was also significant across the storage time. Kehinde et al. (2020) also identified glass bottle as the best storage container in maintaining seed quality of water melon out of three storage containers used in the study. The result also showed significant differences among the five storage times for rate of germination, seed viability, seedling length and seedling vigour. The seed quality sharply declined after 120 days of storage. It can be concluded that tomato seeds can be stored under ambient conditions for at least 120 days (4 months) before sowing and still retain good emergence and seedling vigour characters. The result, however, revealed that seeds stored and sown at 240 days had significantly lower rate of germination and seed viability (32.8 and 57.5 %, respectively) and seedling vigour of value (4.6). This indicates the superiority of seeds stored at other earlier storage time.

Aliyu and Akintaro (2007) reported that water imbibition in seeds stored for a longer time is associated with leakage of hydrolytes like sugars and amino acids, which often leads to disintegration of cell membrane and thus reduces the quantity of amino acids and peptides that are translocated to embryo axis and this in turns affect the rate of germination.

In this study, it was observed that glass bottle gave significantly the highest values of viability compared to other packaging materials. It also had significantly higher seedling vigour for the storage periods compared to other packaging materials. 'Tropimech' genotype had significantly higher seed viability across the six packaging materials compared to all other genotypes. Also, a sharp decline was observed in values recorded by the all the genotypes for all the seed quality parameters between 180 and 240 days of storage periods which suggests that storage can further be encouraged up till 180 days of storage with a reasonable and moderate seedling performance compared to seeds stored for 240 days before sowing.

The packaging materials used in this study had significant effect on the quality of the seeds of tomato genotypes used. Glass bottle was the best packaging material used in this study. This finding conforms with expectation as seeds stored in air tight containers maintain seed qualities longer than non-air tight packaging materials like envelopes which absorb moisture from the surrounding atmosphere. This finding agrees with the report of Kumar and Singh (1983) that the seeds of sesame stored in glass bottles maintained satisfactory germination throughout storage period while seeds stored in gunny bags lost viability after six months of storage. Majhi and Bandopadhyay (1993) also reported that freshly harvested groundnut seeds dried to moisture content of nine percent stored in glass bottles for one to nine (9) months had the highest seed viability, root and shoot length and seedling dry mass when compared to seed stored in paper and cloth bag.

Earlier reports by Daniel (1997), Adebisi et al. (2004, 2008), Esuruoso (2010), Adebisi (2012), Oni (2012) and Adebisi et al. (2019) have utilized probit modelling to predict storage life of yam, soybean, kenaf, okra, sesame and pigeon pea, respectively under ambient storage conditions. In this study, the result of probit modelling showed that tomato seeds deteriorated at different rate, irrespective of the package material in which it is been stored for a period of 240 days. 'Roma VF' stored in glass bottle had the lowest rate of deterioration (-0.609) and the highest rate (3.1826) was recorded by 'Tropimech' stored in glass bottle. The highest estimate of tomato seed shelf-life was obtained with 'Cobra F1' hybrid stored in glass bottle with 35.2 months followed by 'Tropimech' stored in plastic bottle with 30.4 months while 'Cobra F1' hybrid stored in paper envelope gave the least storage life. However, the Probit modelling predicted that tomato seeds of 'Cobra F1' hybrid stored in glass bottle can be stored for an average of 35 months and still retain high viability characteristics under good storage conditions.

5 CONCLUSIONS

Significant differences were observed in rate of germination, seed viability, seedling length and seedling vigour of the four genotypes of tomato examined in this study. Genotype, storage time and packaging material influenced all the seed quality parameters examined.

Envelope and earthen pot are not ideal for tomato seed storage for long time, because seeds stored in air tight containers maintained desired seed quality than non- airtight packaging materials. Glass bottle was identified as the best packaging material in maintaining seed quality of tomato throughout the storage period due to the fact that it withstood all environmental conditions compared to other packaging materials.

The probit modelling result revealed that 'Cobra F1' hybrid tomato genotype stored in glass bottle had the highest seed storage life of 35.21 months.

6 RECOMMENDATIONS

Tomato genotype, packaging material and storage period should be considered in maintenance of viability and seedling vigour in tomato preservation. Tomato seeds should be properly stored in the right packaging material for preservation of the seed vigour and for rapid growth characters. Glass bottles are locally available at very low cost and peasant farmers can easily handle them, therefore these storage materials should be used for storing tomato seeds and can be adopted for other crop seeds. Tomato seeds could be stored up to between 120(4 months) and 180 days (6 months) under ambient conditions, depending on genotype, and storage medium of the seed lot.

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