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Longevity and vigour of pigeon pea (*Cajanus cajan* (L.) Millsp.) seed stored under humid tropical ambient conditions

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Abstract: Seeds of 20 pigeon pea (*Cajanus cajan* (L.) Millsp.) genotypes were evaluated for seed longevity and vigour under humid ambient conditions. Cleaned seeds of each genotype were packed into a polyethylene bag, the packaged lot was electrically sealed and thereafter placed in a seed store under ambient conditions (30 °C, RH 75 %). Seed samples were withdrawn at 0, 60, 120, 180 and 240 days after storage for seed quality parameters evaluation. The experiment consisted of two factors which were genotype and storage duration and was a laid out in a completely randomized design with three replications. Data were collected on rate of seed germination, seed viability, seedling length, seedlings fresh mass, seedlings dry mass and seedling vigour index. Data collected were subjected to analysis of variance and significant treatment means were separated using Tukey's HSD test at 5 % probability level. PROBIT modelling was also used to predict the seed longevity of stored pigeon pea. Significant differences were observed in all seed quality attributes evaluated among the 20 pigeon pea genotypes and storage time except seedling fresh mass. Seed quality attributes decreased significantly with increasing storage periods. Genotypes NSWCC-18A, NSWCC-24, NSWC-34 and NSWCC-29A were identified to be superior for most of the seed quality attributes evaluated. PROBIT modelling result revealed that genotype NSWCC-29b had the highest storage life (16.28 months) and the highest storage potentials in terms of seed viability and other seed quality attributes of all seed lots.

Key words: PROBIT analysis; seed deterioration; seed storage; seed viability; storage period

Dolgoživost in vitalnost semen kajana (*Cajanus cajan* (L.) Millsp.) shranjenih v vlažnih tropskih razmerah

Izvleček: Dolgoživost in vitalnost semen 20 genotipov kajana (*Cajanus cajan* (L.) Millsp.) sta bili ovrednoteni v vlažnih tropskih razmerah. Očiščena semena vsakega od genotipov so bila shranjena v zaprte polietilenske vrečke, ki so bile nameščene v hrambo semen pod okoljskimi razmerami (30 °C, RH 75 %). Vzorci semen so bili odvzeti po 0, 60, 120, 180 in 240 dnevih za ovrednotenje parametrov kakovosti. Poskus je bil dvofaktorski, kjer je bil prvi dejavnik genotip, drugi pa trajanje hrambe in je bil izveden kot popolni naključni poskus s tremi ponovitvami. Zbrani so bili podatki o kalivosti semen, njihovi viabilnosti, dolžini sejank, sveži in suhi masi sejank in njihovem vitalnostnem indeksu. Podatki so bili ovrednoteni z analizo variance, poprečja značilnih obravnavanj so bila ločena s Tukeyevim HSD testom pri verjetnosti 5 %. Za predvidevanje dolgoživosti shranjenih semen kajana je bil uporaben PROBIT model. Ugotovljene so bile značilne razlike v vseh ovrednotenih kakovostnih parametrih semen med vsemi 20 genotipi kajana in med časi hrambe, z izjemo sveže mase sejank. Kakovostni parametri semen so se s časom shranjevanja značilno zmanjševali. Genotipi NSWCC-18A, NSWCC-24, NSWC-34 in NSWCC-29A so bili prepoznani kot najboljši v vseh ovrednotenih parametrih kakovosti. Na osnovi PROBIT modela je bilo odkrito, da je imel genotip NSWCC-29b med vsemi semenskimi vzorci najdaljši čas preživetja (16,28 mesecev) in največji potencial za shranjevanje glede na viabilnost semen in druge parametre kakovosti.

Ključne besede: PROBIT analiza; shranjevanje semen; propad semen; viabilnost semen; čas shranjevanja

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1 INTRODUCTION

Pigeon pea (*Cajanus cajan* (L.) Millsp.) is one of the most common tropical and subtropical legumes cultivated for its edible seeds. Pigeon pea is fast growing, hardy, widely adaptable, and drought resistant (Bekele-Tessema, 2007). Because of its drought resistance, it can be considered of utmost importance for food security in areas where rainfall is not reliable and droughts are likely to occur (Crop Trust, 2014). At the end of the dry season, pigeon pea provides green forage of outstanding value when other forages are not available (Sloan et al., 2009).

Though mainly cultivated for its edible seeds, pigeon pea can be considered a multipurpose species. Pigeon pea stems and branches are a good fuel source and basketry. Among other uses of pigeon pea, trials have shown a potential use as a raw material for paper pulp and also contribute to the environment through its use in alley cropping and as a windbreak, cover crop, shade plant and green manure (Cook et al., 2005). Despite all these numerous benefits of the crop, it is still categorized as under-utilized crop in Nigeria and little information is available on seed quality potential after harvest and during storage.

Seed is fundamental to production of crops. After maturation and harvest, seeds have to be stored until required for planting and need to maintain nearly 100 % germinations (Duffus and Slaughter, 1980). Deterioration and reduced longevity in seed is affected by enzymes activity, integrity of cell membrane, and stability of nucleic acid (Roberts, 1983). Seed quality can be influenced by environmental factors during seed production, harvesting, processing, storage and seed treatments (TeKrony et al., 1980; Copeland and McDonald, 2002; Adebisi and Ojo, 2001; Adebisi, 2004). Adetiloye (2005), Adebisi and Oyekale (2005) also reported that seed viability and seedling vigour are affected by the seed moisture level, drying temperature, seed mass, genetics constitution and length of storage. High temperature, high humidity and seed moisture content are main factors influencing seed storage behaviour (Abdul-Baki, 1980).

The longevity of seeds in storage is a good indicator of seed quantity and vigour in many crops (Ellis and Roberts, 1980; Robert, 1983; Adebisi et al., 2003, Kehinde, 2018). Ellis and Robert (1980) have developed PROBIT analysis method to quantify the initial quality of seed lot and its rate of deterioration using controlled deterioration tests. It's already well known that seed longevity is a function of storage temperature and seed moisture content (Harrington, 1972; Roberts, 1973), stresses before seed storage and initial seed quality (Ellis and Roberts, 1980), genetic make-up (Adebisi et al., 2008a; Kehinde, 2018) and pest and pathogen damages in storage (Kulik, 1995; Abdul–Rafiu, 2007). Seed deterioration in storage follows a negative cumulative normal distribution pattern (Ellis and Roberts, 1980) which make estimation of seed longevity from seed germination data using PROBIT analysis possible (Finney, 1971) and assessment of seed viability under specified conditions (Daniel, 1997; Kehinde, 2016).

Longevity of a seed is the period from seed maturation until seed death (Ellis and Roberts, 1981). Hong and Ellis (1996) reported that seed longevity varies greatly among species. This may also vary among accessions within a species. Kashyap et al. (1994) found significant differences among different cultivars and period of storage of wheat seed for all parameters of viability and vigour. There were significant differences in viability and vigour of soybean, rice, sesame and kenaf during storage (Thseng et al., 1996; Nkang and Umah 1996; Kamaswara and Jackson, 1996; Adebisi and Ajala, 2000; Adebisi et al., 2013a). Harrington (1972) reported that germination and vigour in crop decreased as storage time and relative humidity increased.

Storage of tropical seeds of different crop species is a problem under humid tropical condition due to high temperature and relative humidity. In Nigeria, pigeon pea farmers are facing problem of preservation of farm save seeds of this crop after harvest due to precarious environmental conditions of temperature and relative humidity. The seed of this crop is not commercially available in seed marketing outlets thereby reducing farmers' access to high quality seed and enabling them to contend with available stock of poor viability with poor seedling establishment and consequently reducing grain yield. However, there has been dearth of information on storage potentials of the selected 20 pigeon pea genotypes under ambient humid tropical conditions but a little information on them was their outstanding grain yield performance. Hence, there is a need to provide information to fill the knowledge gap in the focus of the research. The objectives of the study were to investigate the effect of storage duration on seed physiological quality attributes of pigeon pea genotypes stored under ambient humid tropical storage conditions, and estimate the storage life of 20 pigeon pea genotypes using PROBIT modelling techniques.

2 MATERIALS AND METHODS

2.1 SEED MATERIAL AND SOURCE

Seeds of twenty (20) genotypes of pigeon pea used were obtained from Institute of Agriculture Research and Training (IAR&T) Ibadan, Oyo State Nigeria, and International Institute of Tropical Agriculture (I.I.T.A) Ibadan, Oyo State Nigeria. The seeds were freshly harvest in the dry season of 2017.

2.2 TREATMENT, EXPERIMENT DESIGN AND LOCATION

Two factors were investigated in the study (pigeon pea genotypes in 20 levels and storage periods in five levels). The experiment was laid out in a completely randomized design with three replications. The experiment was conducted at the seed processing and storage unit and Laboratory of Plant Breeding and Seed Technology Department, Federal University of Agriculture Abeokuta (FUNAAB), Ogun State, Nigeria.

2.3 SEED STORAGE

Cleaned seeds (300 g) of each genotype were packed into thick polyethylene bags (size 15 × 15m) and each of the packaged lot was electrically sealed and thereafter placed under ambient conditions of seed store in seed processing and storage house, FUNAAB. The average temperature and relative humidity was monitored using hygrometer for the period of storage. The packaged seeds were stored for 240 days (8 months) and samples were taken at 0, 60, 120, 180 and 240 days after storage for seed quality assessment.

2.4 SEED QUALITY EVALUATION

Standard germination tests were carried out in the laboratory of Department of Plant Breeding and Seed Technology, FUNAAB with the use of Petri dishes. Fifty seeds of each of these genotypes were placed in Petri dishes with 20 ml distilled water and then put in the incubator for maintained at 20 °C for 8 days.

From the seed germination tests above, data were collected on the following seed quality parameters:

Rate of germination: Germination counts of normal seedlings were taken on 4th day and recorded in percentage of 50 seeds sown to determine the germination rate/speed (Adebisi, 2004).

Seed germination: Germination counts of normal seedlings were taken on 8thday and expressed in percentage of 50 seeds sown according to ISTA (1995).

Seedling length (cm): Shoot lengths of 10 randomly picked seedlings per replicate were measured in centimeter.

Seedling vigour index: This was determined using the formula of Kim et al. (2002), modified by Adebisi (2004):

SVI = Germination (%) x Seedling Lenght (cm)/100

Seedling fresh mass (g): Mass of 10 randomly picked fresh seedlings per replicate from the germinated seeds under the germination test were measured using a sensitive scale. (Adebisi, 2004).

Seedling dry mass (g): Mass of 10 randomly picked seedlings per replicate were measured after oven dried for 1 hour at 130 °C temperature (ISTA, 1995).

2.5 DATA ANALYSIS

Data collected on six seed physiological quality attributes were subjected to two-way Analysis of Variance (ANOVA) with storage period and pigeon pea genotypes as the treatments. Means of significant treatments were compared using Tukey's Honest Significance Difference (HSD) test at 5 % probability level and PROBIT modelling as proposed by Ellis and Robert (1980) and reported by Adebisi et al. (2008a) was also carried on seed longevity data.

3 RESULTS

Table 1 shows the mean performance of 20 pigeon pea genotypes for seed quality parameters. In rate of germination, NSWCC-24 had the highest performance of 78 % followed by NSWC-34 while the lowest performance was recorded in TCC-6 with value of 16 %. Also, for seed viability, the highest performance was found in NSWCC-24 (77 %) but not significantly different from NSWCC-18b, NSWCC-18A, NSWCC-7D, NSWCC-34A, NSWCC-29B, NSWCC-15, NSWCC-29A (69-73 %) followed by NSWCC-18A (74 %) while the lowest performance were found in TCC-6, TCC-1, TCC-8, CITA-1, CITA-2 with range of 16 % - 24 %. NSWC-34 recorded the highest seedlings length (19.25 cm) and seedling vigour index (14. 38 %) compared to other genotypes. Seedling dry mass and fresh mass were also with highest values in NSWDD-34(1.01) and CITA-2 (6.21) respectively.

From the result in Figure 1, the highest rate of germination was attained at 0 month of storage (67 %) but statistically similar values were obtained at 2-3 months of storage with 62 and 61 %, respectively while seeds stored for 8 months recorded the lowest germination rate (39 %). For seed viability, seed stored at 2 months

Table 1: Mean performance of 20 pigeon pea genotypes for seed quality parameters over storage periods under humid tropical ambient conditions (30 °C, RH 75 %)

Genotype	Rate of Germination (%)	Seed viability (%)	Seedling length (cm)	Seedling fresh mass (g)	Seedling dry mass (g)	Seedling Vigour Index
NSWDD-34	64.00cde	66.00bc	15.35cde	3.05ab	1.01a	10.22bcd
NSWCC-18b	70.00abc	72.00ab	14.37de	2.79ab	0.87ab	10.35bcd
NSWCC-18A	69.00abc	74.00ab	18.82ab	2.82ab	0.93ab	14.44a
NSWCC-24	78.00a	77.00a	16.61a-d	2.67ab	0.82b	13.02ab
NSWCC-35A	59.00de	65.00bc	16.00a-e	3.22ab	0.84ab	10.62bc
NSWCC-29b	66.00b-e	66.00bc	16.24a-d	2.94ab	0.86ab	10.98bc
NSWCC-7D	68.00a-d	71.00ab	17.92a-d	3.07ab	0.89ab	12.88ab
NSWCC-34A	71.00abc	72.00ab	16.18a-d	2.97ab	0.79b	11.86abc
NSWCC-32	61.00cde	67.00bc	13.84de	2.87ab	0.79b	9.24cd
NSWCC-34	56.00e	58.00bc	12.57e	2.16ab	0.75b	7.30d
NSWCC-29d	69.00abc	69.00ab	14.56cde	3.18ab	0.85ab	10.39bcd
NSWCC-15	65.00b-e	68.00ab	13.27de	3.04ab	0.77b	9.38cd
NSWCC-29A	69.00abc	72.00ab	16.40a-d	3.02ab	0.89ab	12.38abc
NSWC-34	74.00ab	73.00ab	19.25a	3.17ab	0.85ab	14.38a
NSWCC-3D	64.00cde	65.00bc	15.69b-e	2.82ab	0.78b	10.40bcd
TCC-1	20.00fg	16.00d	3.57h	0.49b	0.33c	1.25e
TCC-6	16.00g	16.00d	9.03f	0.59b	0.29c	1.93e
TCC-8111	21.00fg	21.00d	5.24gh	0.46b	0.27c	1.95e
CITA-1	29.00f	24.00d	7.81fg	0.72b	0.32c	2.73e
CITA-2	27.00f	19.00d	2.66h	6.21a	0.73b	2.00e

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.

showed highest performance of 68 % above value obtained at 0 month (66 %) while the lowest value was obtained after 8 months (37 %). For seedling length, 0 month stored time had highest value (16.02 cm) followed by 2 months and 4 months with 14.89 and 14.99 cm, respectively. But seedlings fresh mass value was statistically similar during the 8 months of storage while seedling dry mass had its best performance at 0 month (0.93 g) followed by values at 2 months and 4 months while it was least at 8 months. Seeds stored for 2 months had the highest seedlings vigour index (11.59 %) above seeds stored for 0 month storage time (11.29 %) followed by 6 months of storage while least seedling vigour index was in seeds stored for 8 months (4.29 %).

Bars followed by the same alphabet along the column are not different from each other

Table 2 shows the effect of storage time on rate of seed germination in the 20 pigeon pea genotype. From the Table 2, at 0 month of storage, NSWCC-24 (93 %), NSWC-34 (92 %) and NSWCC-29A (90 %) had the highest germination rate while TCC-6 (18 %) and TCC-1 (20 %) had the least germination rate. At 2 month of storage, the highest performance was also observed in NSWCC-24 (87 %) closely followed by NSWC-34 (85 %) and NSWCC-29A (80 %) while the least performance was recorded in TCC-6 (27 %), TCC-1(25 %) and CITA-2 (23 %). Also at 4 months of storage, NSWCC-24 (83 %), NSWC-34 (80 %) were with the highest values and least performance was in TCC-6 (23 %) and TCC-1 (18 %). With increase in the storage time to 6 months, NSWCC-24 (78 %) showed the highest germination rate which was followed by NSWCC-34A (70 %). However, for seed stored for 8 months, NSWCC-18b and NSWCC-7D (57 %) had the highest germination rate and closely followed by NSWCC-34A, NSWCC-15, NSWCC-3D and NSWDD-34 with (52-53 %). The least germination rate was also recorded in TCC-8111, TCC-1 and TCC-6, with values of 8 %, 10 % and 13 %, respectively.

Effect of storage time on seed viability of 20 pigeon pea genotypes (Table 3) shows that at 0 month

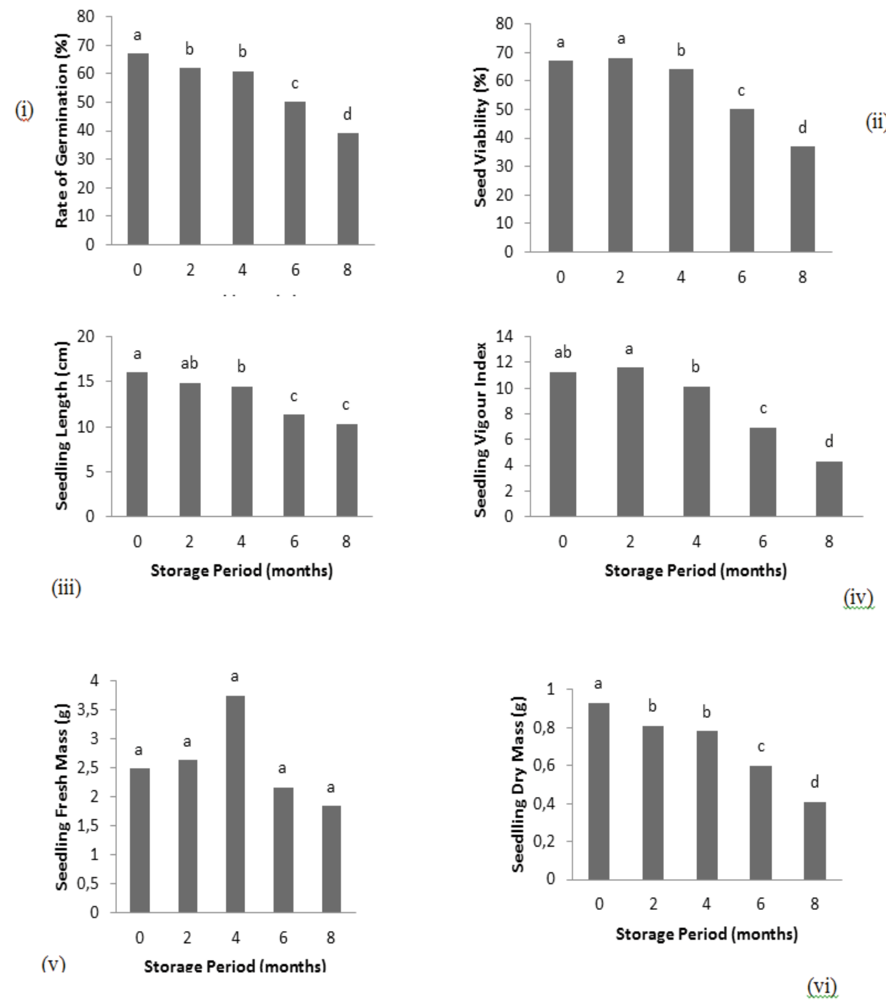

Figure 1: Changes in seed quality parameters during storage period under humid tropical ambient conditions (30 °C, RH 75 %)

of seed storage, NSWCC-24 (93 %) had the highest viability closely followed by NSWCC-18A and NSWCC-18b with values of 88 % and 87 %, respectively while TCC-6 (18 %) and TCC-1 (20 %) had the least value. At 2 months of storage, NSWCC-18A, NSWCC-24, NSWCC-29A and NSWC-34 were with highest seed viability values which ranges from 85 % - 90 % while the highest values at 4 months were obtained in NSWCC-18b (82 %), NSWCC-18A (82 %) and NSWCC-29A (82 %). Also, for seed stored for 6 months, NSWCC-24 (72 %) had the highest viability which was closely followed by NSWCC-7D and NSWCC-34 (68 %). Intrinsically, TCC-6, TCC-1, TCC-8111, CITA-2 exhibited the lowest viability of 2 - 17 % across the storage periods evaluated.

The effect of storage time on seedling length of 20 pigeon pea genotype is presented in Table 4. At 0 month of storage, NSWC-34, NSWCC-18A and NSWCC-7D were with the highest seedling lengths of 20.86 cm, 20.81 cm and 20.23 cm, respectively while least values were obtained in TCC-6 (8.96) and TCC-8111 (9.76). Similarly, NSWCC-18A (21.48) and NSWC-34 (20.79) had the highest seedling lengths for seed stored for 2 months, 4 months, 6 months and 8 months respectively. Conversely, TCC-6, TCC-1, TCC-8111, CITA-1 and CITA-2 had the lowest seedling lengths throughout the storage periods used for the research.

In Table 5, at 0 month storage period, NSWCC-29A had the highest seedling dry mass of 1.22 g followed by NSWCC-34A (1.20 g) while the lowest dry mass were found in CITA-1, TCC-8111 and TCC-1 with values of 0.48 g, 0.46 g, and 0.43 g, respectively. After 2 months storage period, NSWDD-34 (1.18 g) had the highest seedling dry mass, keenly followed by NSWCC-35A (1.09 g), NSWCC-29b (1.06 g) and NSWCC-7D (1.04 g) while the lowest dry mass was also recorded in TCC-811, CITA-1 and CITA-2, with values of (0.04 - 0.37). Similarly, the highest dry mass value was

Table 2: Effect of storage time on rate of seed germination in 20 pigeon pea stored under humid tropical ambient conditions (30 ºC, RH 75 %)

Genotype	Storage Period (Months)				
	0	2	4	6	8
NSWDD-34	75cd	68c	70b	55c	52a
NSWCC-18b	87ab	67c	78a	62c	57a
NSWCC-18A	88ab	73b	70b	67b	48b
NSWCC-24	93a	87a	83a	78a	47b
NSWCC-35A	65e	60d	58d	62c	48b
NSWCC-29b	72d	75b	73b	65b	47b
NSWCC-7D	80c	75b	67c	63b	57a
NSWCC-34A	80c	73b	80a	70b	53a
NSWCC-32	75cd	70b	63c	58c	40c
NSWCC-34	63e	66c	57d	67b	37c
NSWCC-29d	83bc	77b	70b	67b	48b
NSWCC-15	67e	68c	67c	68b	53a
NSWCC-29A	90a	80a	75b	60c	40c
NSWC-34	92a	85a	80a	63b	52a
NSWCC-3D	75cd	67c	70b	57c	52a
TCC-1	18g	27f	23f	20d	13d
TCC-6	20g	25f	18f	7e	10e
TCC-8111	28f	45e	37e	4f	8e
CITA-1	31f	42e	40e	13e	13d
CITA-2	31f	23f	42e	23d	20d

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

recorded for NSWDD-7D (1.09 g) after 4 months storage period, which was closely followed by NSWCC-29A (1.00 g). After 6 months storage period, NSWDD-7D (0.96 g) was the best performing genotype in terms of seed dry mass and this was followed by NSWCC-7D (0.89 g). Also, for seeds stored for 8 months, NSWDD-7D (0.83 g) was the best and it was followed by NSWCC-18b (0.66 g). Meanwhile, TCC-6, TCC-6, TCC-8111, CITA-1 and CITA-2 were the least performing genotypes throughout the storage periods used.

The effect of storage time on seedling vigour index on seeds of 20 pigeon pea genotypes is presented in Table 6. At 0 month of storage, NSWCC-18A had the highest seedling vigour index of 18.74 and was followed by NSWC-34 and NSWCC-24 with values of 17.75 and 17.03 respectively while the lowest value was in TCC-6 (1.73). After 2 months of storage, the highest seedling vigour index was also found in NSWCC-18A while NSWCC-18A showed the highest value after 4 and 8 months while NSWC-34 (11.51) was found to have the highest seedling vigour index. Conversely, the lowest values throughout the storage periods were found in TCC-6, TCC-1, TCC-8111, CITA-1 and CITA-2.

The results of PROBIT analysis of seed viability data in 20 pigeon pea genotypes over 240 days of storage (Table 7) reveal that the values in all studied varieties of genotypes of pigeon pea indicate that the seeds maintained its viability irrespective of the storage time. All genotypes recorded relatively low rate of deterioration ranging from 0.0142 in TCC-8111 to 0.0016 in TCC-1. Relatively, NSWCC-29b showed the highest time taken (493.08 days) to lose 1 PROBIT viability followed by NSWCC-35A (350.45) while TCC-811 with the value (70.56 days) recorded the lowest time taken to lose 1 PROBIT viability. NSWCC-29b recorded the highest value in days to seed half-life (244.1 days) while CITA-1 (18.6 days) which had lowest value of seed half-life. However, the longest seed storage life of (16.28 months) was obtained in NSWCC-29b followed by NSWCC-35A, NSWCC-7D, NSWCC-15 and TCC-1 with storage life of above 12 months but others exhibited storage life between 8 and 11 months except

Table 3: Effect of storage time on seed viability of 20 pigeon genotypes stored under humid tropical ambient conditions (30 °C, RH 75 %)

Genotype	Storage Period (Months)				
	0	2	4	6	8
NSWDD-34	75c	78b	70b	58b	47bc
NSWCC-18b	87a	78b	73b	65a	55a
NSWCC-18A	88a	90a	82a	62b	50a
NSWCC-24	93a	88a	82a	72a	50a
NSWCC-35A	65d	78b	73b	67a	43bc
NSWCC-29b	72c	73bc	72b	63b	52a
NSWCC-7D	80b	80ab	75a	68a	52a
NSWCC-34A	83b	82b	78a	68a	50a
NSWCC-32	82b	83a	77a	60b	33c
NSWCC-34	65d	67c	65c	58b	33c
NSWCC-29d	70c	85a	77a	60b	55a
NSWCC-15	62d	82ab	77a	67a	53a
NSWCC-29A	85b	88a	82a	63b	43bc
NSWC-34	85b	85a	80a	67a	50a
NSWCC-3D	72c	77b	73b	58b	46bc
TCC-1	18f	12f	23e	17c	10d
TCC-6	20f	23e	25e	7d	7d
TCC-8111	28e	43d	33d	2d	5e
CITA-1	32e	43d	33d	13c	1e
CITA-2	31e	18e	30d	17c	13d

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

NSWCC-29d (6.18 months), TCC-8111 (1.99 months), CITA-1 (1.24 months) and CITA-2 (2.72 months).

4 DISCUSSION

Storage period is an important stage in the seed production process, the preservation of seed during this process, that is, from harvest time to the time of its use is an essential aspect to be regarded in the production process, because the effort spent in the production phase may not be effective if the seed quality is not maintained (Oliviera et al., 1999). Also, the utilization of high quality seed lot constitutes one of the major factors responsible for successful crop production.

The analysis of variance shows that replicate effect was not significant and this could be attributed to the homogenous environment in which the research was carried out. The variations observed in all seed quality parameters among genotypes revealed that the studied 20 genotypes significantly differed in their genetic make-up, which led to a variation in their responses to different storage periods.

The study revealed that there were significant differences among the seed quality attributes in response to increased storage periods. Rate of germination, seed viability and seedling vigour index attributes decreased as storage period increased. Similarly, Khalequzzaman et al. (2012) reported that seed quality parameters were significantly influenced by the increase in storage period of French bean (*Phaseolus vulgaris* L.). Similarly, the report of the findings of Adebisi et al. (2008a) in sesame, Daniel et al., (2012) in maize and Adebisi et al., (2012 and 2013b) in water melon and kenaf respectively all corroborated the findings of this study that differences in genetic makeup of genotypes could influence storage performance in different crop species under the ambient tropical conditions.

On the storability performance, among the 20 genotypes, NSWCC-18A, NSWCC-24, NSWC-34 and NSWCC-29A were identified to have superior performance regarding most of the seed quality attributes studied, which could be due to superiority in the ge-

Table 4: Effect of storage time on seedling length of 20 pigeon genotype stored under humid tropical ambient conditions (30 ºC, RH 75 %)

Genotype	Storage Period (Months)				
	0	2	4	6	8
NSWDD-34	15.77c-f	16.45d-g	15.74def	15.40abc	13.36b-e
NSWCC-18b	14.68def	14.99f-i	14.68fg	14.07bcd	13.45b-e
NSWCC-18A	20.81a	21.48a	20.17a	16.04ab	15.60ab
NSWCC-24	18.11ba	17.77cde	17.40bcd	15.36abc	14.41a-d
NSWCC-35A	16.12cde	16.72d-g	16.10c-f	15.57abc	15.46ab
NSWCC-29b	17.44bc	17.40c-f	17.18b-e	14.70abc	14.48abc
NSWCC-7D	20.23a	19.41abc	18.77ab	15.50abc	15.71ab
NSWCC-34A	17.12bcd	17.18c-f	17.17b-f	14.93abc	14.50abc
NSWCC-32	14.60de	14.57ghi	14.81efg	13.27cde	11.97def
NSWCC-34	13.04f	13.20hi	12.93gh	12.03de	11.66ef
NSWCC-29d	16.24cde	15.28e-h	15.04d-g	13.40cd	12.85cde
NSWCC-15	14.25ef	15.74efg	15.30d-g	10.90e	10.15f
NSWCC-29A	18.77ab	18.64bcd	18.50abc	14.41bcd	11.67ef
NSWC-34	20.86a	20.79ab	20.67a	17.16a	16.74a
NSWCC-3D	17.14bcd	17.01c-g	16.69b-f	13.90bcd	13.74b-e
TCC-1	8.96g	2.66k	3.20j	3.05f	9.94f
TCC-6	17.17bcd	13.11hi	12.87gh	2.00f	6.83g
TCC-8111	9.76g	9.24j	8.09i	1.17f	5.05g
CITA-1	13.28f	12.62i	11.10h	2.03f	1.37h
CITA-2	5.48g	3.47kl	3.30e	2.89f	1.00h

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

netic make-up of the genotypes combined with other physical characteristics of their seeds. These genotypes, TCC-6, TCC-1, TCC-8111, CITA-1 and CITA-2 were the least storable in all the seed quality attributes which could be due to their genetic weakness and weak physical characteristics of their seeds.

The highest seed viability percentages were recorded at 0 and 2 months of storage while there was a great fall in seed viability at 6 months of storage and seeds stored at 8 months of storage had the lowest seed viability. However, seed stored at 0 month had the highest seedling vigour index while seeds store at the end of 8 months had the lowest seedling vigour. This decline in seed quality could be due to deteriorative process which occurs in all biological organisms. Ageing gradually sets in and advanced with length of storage and was further aggravated by the high temperature (30) and high relative humidity (75 %) of the ambient humid conditions which enhanced higher respiration and led to higher degradation of assimilates leading to the death of many of the stored seeds.

Seed deterioration is associated with various cellular, metabolic and chemical alterations including chromosome aberrations and damage to the DNA, impairment of RNA and protein synthesis, changes in the enzymes and food reserves and loss of membrane integrity (Kibinza et al., 2006). According to Kapoor et al. (2011), seed deterioration is the loss of seed quality (viability and vigour) due to the adverse effect of environmental factors and is a natural process which involves cytological, physiological and biochemical changes. The rate of deterioration fluctuates critically from one species to another and also among varieties of the same species (Jatoi et al., 2001; Jyoti and Malik, 2013). The deterioration is evident in the reduction in percentage germination, production of weak seedlings, loss of vigour, seed become less viable and ultimately seed death (Murthy et al., 2000; Tilebeni and Golpayegani, 2011).

Furthermore, the study observed that storage period under ambient should be given due consideration when storing seeds, irrespective of genotypes available for storage. The environmental conditions in storage are very difficult to maintain and highly influenced the period of seed survival (Jyoti and Malik, 2013). Lower

Table 5: Effect of storage time on seedling dry mass of 20 pigeon pea genotypes stored under humid tropical ambient conditions (30 ºC, RH 75 %)

Genotype	Storage Period (Months)				
	0	2	4	6	8
NSWDD-34	0.97de	1.18a	1.09a	0.96a	0.83a
NSWCC-18b	0.98de	0.97b-f	0.88b-f	0.86abc	0.66b
NSWCC-18A	1.18ab	1.07abc	0.97abc	0.83abc	0.61bc
NSWCC-24	0.94de	0.92def	0.87b-f	0.77bc	0.60bc
NSWCC-35A	0.92de	1.09ab	0.91b-e	0.82bc	0.46d-g
NSWCC-29b	0.88e	1.06abc	0.91b-e	0.86abc	0.58bcd
NSWCC-7D	1.02cd	1.04bcd	0.93bcd	0.89ab	0.56b-e
NSWCC-34A	1.20a	0.78g	0.77f	0.74cd	0.48cde
NSWCC-32	0.97de	0.97b-f	0.85c-f	0.76bc	0.43efg
NSWCC-34	0.96de	0.84f	0.83def	0.79bc	0.33g
NSWCC-29d	0.98de	0.95c-f	0.95def	0.74cd	0.61bc
NSWCC-15	0.94de	0.86efg	0.83bcd	0.75cd	0.48c-f
NSWCC-29A	1.22a	0.99b	1.00ab	0.81bc	0.41fg
NSWC-34	1.02cd	0.92def	0.91b-e	0.78bc	0.60bc
NSWCC-3D	1.05bcd	0.87efg	0.80ef	0.62d	0.56b-e
TCC-1	1.15abc	0.32j	0.18h	2.03^{-16}e	9.20^{-16} e
TCC-6	0.73f	0.48hi	0.54g	8.92^{-17}e	8.80^{-16} e
TCC-8111	0.46f	0.37ij	0.51g	1.33^{-16}e	1.18^{-15} f
CITA-1	0.48f	0.61h	0.49g	9.00^{-17}e	3.30^{-15} f
CITA-2	0.30f	0.04k	0.26h	2.04^{-15}e	3.08^{-14} f

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

temperature and relative humidity delayed seed deterioration process thereby leads to prolong viability period (Mohammadi et al., 2011).

Earlier reports by Adebisi et al. (2003, 2008b), Esuruoso (2010), Adebisi and Oyekale (2005) and Oni (2012) have utilized probit modelling to predict storage life of soybean, rice, kenaf, okra, and sesame, respectively under ambient humid storage conditions. In this study, the result of PROBIT modelling showed that the seeds maintained its viability, irrespective of the storage time of a period of 240 days. The pigeon pea seeds had very low rate of deterioration, in all the (20) genotypes used in this study implying that seed longevity was prolonged. NSWCC-29b had the highest value in days to seed half-life indicating high storability potential of such seeds, while CITA-1 had the lowest value in days to seed half-life indicating that this genotype was least storable under ambient humid conditions. Both genotypes also exhibited same rate for storage life. Nevertheless, the PROBIT modelling predicted that NSWCC-29b can be stored for an average of 16.28 months before it starts deteriorating, if the seeds are put under good storage conditions.

5 CONCLUSIONS

There were highly significant differences in all included seed quality parameters among 20 studied pigeon pea genotypes. These seed quality parameters were greatly influenced by storage period and all seed quality parameters declined with increase in storage duration due to the intrinsic factors in the seeds, irrespective of genotype as well as other factors such as endosperm size, seed coat, hormonal profile of the seed, the type of assimilate that is predominant in the seed among others. Storage period of pigeon pea under ambient conditions should be between 1-6 months in order to maintain high seed quality parameters. NSWCC-18A, NSWCC-24, NSWC-34 and NSWCC-29A were the best genotypes across the seed quality attributes across the 240 days of storage and should be considered in selection for high quality seeds. The highest estimated seed

Table 6: Effect of storage time on seedling vigour index on 20 pigeon pea genotypes stored under humid tropical ambient conditions (30 °C, RH 75 %)

Genotype	Storage Period (Months)				
	0	2	4	6	8
NSWDD-34	11.89e	12.99de	11.02f	9.07b-f	6.14abc
NSWCC-18b	12.70de	11.68e	10.84f	9.13b-e	7.04ab
NSWCC-18A	18.74a	19.31a	16.38a	9.25abc	7.80a
NSWCC-24	17.03ab	15.71bc	14.20abc	11.01ab	7.15ab
NSWCC-35A	10.80ef	13.18de	11.88c-f	10.52ab	6.70ab
NSWCC-29b	12.92de	12.83d	13.31c-f	9.33a-d	7.49ab
NSWCC-7D	16.11bc	15.47bc	14.10bbc	10.63ab	8.09a
NSWCC-34A	14.26cd	14.09cd	13.43b-e	10.20abc	7.30ab
NSWCC-32	11.95de	12.12d	11.36e	6.80f	3.98c
NSWCC-34	8.53d	8.75f	8.39g	6.97ef	3.88c
NSWCC-29d	12.06de	13.18de	11.59def	8.04c-f	7.08ab
NSWCC-15	9.29f	13.06de	11.83def	7.24def	5.45bc
NSWCC-29A	15.95bc	16.51b	15.13ab	9.16b-e	5.17bc
NSWC-34	17.75ab	17.17ab	16.54a	11.51a	8.37a
NSWCC-3D	12.40de	12.97e	1316c-f	8.10c-f	6.36ab
TCC-1	1.73h	3.30h	0.73i	0.49g	0.00d
TCC-6	3.47gh	3.03h	3.15h	1.76-15h	0.00d
TCC-8111	2.82gh	4.17gh	2.75hi	1.76-15h	0.00d
CITA-1	4.16g	5.43g	3.62h	0.41g	0.00d
CITA-2	4.08g	6.29g	1.00i	0.51g	0.20d

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

storage life of 16.28 months was derived for genotype NSWCC-29b. Storage of pigeon pea seeds under favourable ambient environments offer good potential for short term pigeon pea seed quality maintenance.

6 RECOMMENDATIONS

Seed quality of pigeon pea deteriorates as storage time increases therefore, storage period should not exceed 6 months NSWCC-18A, NSWCC-24, NSWC-34 and NSWCC-29A were recommended for breeding process with utmost aim of high seed quality.

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Table 7: PROBIT parameters of the seed viability data in 20 Pigeon pea genotypes stored under humid tropical ambient conditions (30 °C, RH 75 %) over 240 days storage time

Genotype	*Intercept	**Slope	***Sigma	*%P_{50} (Days)	*#Seed storage life (Months)
NSWDD-34	1.06	-0.0071	141.66	149.41	9.96
NSWCC-18b	1.32	-0.0079	131.29	169.43	11.30
NSWCC-18A	1.85	--0.0122	86.75	152.94	10.20
NSWCC-24	2.02	-0.0130	86.`13	163.17	10.88
NSWCC-35A	0.87	-0.0034	350.45	207.00	13.80
NSWCC-29b	0.87	-0.0049	493.08	244.16	16.28
NSWCC-7D	1.36	-0.0081	196.25	189.00	12.60
NSWCC-34A	1.37	-0.0082	128.53	172.27	11.48
NSWCC-32	1.59	-0.0120	84.77	130.69	8.71
NSWCC-34	0.76	-0.0062	173.94	128.68	8.58
NSWCC-29d	1.34	-0.0233	190.47	92.71	6.18
NSWCC-15	0.77	-0.0032	256.42	199.35	13.29
NSWCC-29A	1.69	-0.0114	89.15	147.41	9.83
NSWC-34	1.53	-0.0096	108.86	162.48	10.83
NSWCC-3D	0.97	-0.0062	160.88	155.45	10.36
TCC-1	0.61	-0.0016	274.32	197.20	13.15
TCC-6	0.41	-0.0073	248.03	137.87	9.19
TCC-8111	0.16	-0.0142	70.56	29.60	1.98
CITA-1	0.25	-0.0115	77.87	18.63	1.24
CITA-2	0.34	-0.0048	161.90	40.80	2.72

*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
*% P50 is seed half- life in days
*# Seed storage life estimated as P50 value multiplied by 2 then divided by the 30 days of a month

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