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GENETIC VARIABILITY IN SEED PHYSIOLOGICAL QUALITY AND STORAGE LIFE OF GROUNDNUT (*Arachis hypogaea* L.) GENOTYPES STORED UNDER AMBIENT CONDITIONS

Adebisi, M. A., Arogundade, L. A., Kehinde, T. O., Onikola, A. A., Adebisi, Q. A. and Olufelo, J.

Department of Plant Breeding and Seed Technology,
Federal University of Agriculture Abeokuta, P.M.B 2240, Abeokuta, Ogun State, Nigeria
Corresponding Authors' email: kehindeto@funaab.edu.ng

Abstract

This study, conducted at the laboratory of Plant Breeding and Seed Technology Department, Federal University of Agriculture, Abeokuta, Nigeria, was carried out to determine genetic variability in seed physiological quality and storage life of groundnut genotypes stored under ambient conditions. Seeds of 14 groundnut genotypes were used in the study. Clean seeds of each genotype were packed in a polyethylene bag and the packaged lots were electrically sealed and placed in a laboratory cabinet under ambient conditions. The packed seed lots were stored for 150 days (5 months). Seed samples were taken at 0, 30, 60, 90, 120 and 150 days after storage for seed quality evaluation. The experiment was a 6 x 14 factorial in a completely randomized design with three replications. Data were collected on rate of germination, seed viability, seedling length, seedling vigour index, seedling fresh weight and seedling dry weight. Significant differences were observed in all seed attributes evaluated among the 14 groundnut genotypes. Seed storage period significantly influenced each of the six seed quality attributes of the 14 genotypes. Storage period of groundnut should not exceed 3 months (90 days) under ambient conditions in all the genotypes except Samnut 25 and Samnut 26. Seed quality attributes decreased with increase in storage periods. Samnut 26 and Samnut 25 were identified to be superior for most of the seed quality attributes evaluated, while Kwandala local, Kampala spp and Maizabuwa local had the least performance. Storage time had negative and strong association with all the six quality attributes. Probit modeling result showed that Samnut 26 had the highest estimated storage life. All the genotypes had a relatively low rate of deterioration except Kwandala with a slope of 0.4383.

Keywords: Seed quality, groundnut, storage, probit modelling, and seed deterioration

Introduction

Groundnut (*Arachis hypogea* L.) is one of the world's major food legume crops. It originated in South America, where the genus *Arachis* is widely distributed. It is an important cash crop for the tropical farmers. It is of agronomic and economic importance as oilseed crop grown extensively throughout the semi-arid tropics of Asia, Africa and Latin America (FAO, 2003). Grown on 26.4 million ha worldwide with a total production of 37.1 million metric tonnes and an average productivity of 1.4 metric t/ha (FAO, 2011). Over 100 countries worldwide grow groundnut and developing countries constitute 97% of the global area and 94% of the global production of this crop (FAO, 2011). Nigeria is the largest groundnut producing country in West Africa, accounting for 51% of production in the region. The country contributes 10% of total global production and 39% that of Africa (Ajeigbe *et al.,* 2014).

With the costs of animal protein becoming increasingly prohibitive, groundnut is becoming an even more important source of protein. Groundnut seeds are also a nutritional source of vitamin E, niacin, calcium, phosphorus, magnesium, zinc, iron, riboflavin, thiamine and potassium (Savage and Keenan, 1994). Groundnut plays an important role in the diets of rural populations, particularly children, because of its high contents of protein and carbohydrate. Groundnut meal, a by-product of oil extraction, is an important ingredient in livestock feed. Groundnut haulms are nutritious and widely used for feeding livestock especially during the dry season when fresh green grasses are not available. This serves as an additional source of income for farmers in the dry season when the fodder is in high demand (Ajeigbe *et al.,* 2015). The groundnut oil is composed of mixed glycerides, and contain a high proportion of unsaturated fatty acids, in particular Oleic (50-56 %) and Linoleic (18-30 %) (Young, 1996).

Seed is the basic input in agriculture. The quality of seed used by farmers, to a great extent, determines productivity. Seed quality mainly depends on appropriate field seed production, seed processing and appropriate storage conditions. Seed processing facilitates the selection of the best seeds, while storage conditions ensure the preservation of high seed quality. However, seed quality can be influenced by environmental factors during seed production, genetic constitution, harvesting, processing, storage and seed treatments (Adebisi, 2004; Adebisi *et al.,* 2019). Research has shown that the length of time that a seed lot remains viable in storage (seed longevity) is influenced by the initial quality of the seed lot, its moisture content, temperature, relative humidity and gaseous exchange in the storage environment (Vertucci and Roos, 1990). Because accumulation of seed storage substances is genetically predetermined, seed longevity in storage is a genetically regulated process (Delouche, 1968). Maximum seed quality, as defined by seed germination and vigour, is reached at physiological maturity (Bewley and Black, 1994). Beyond this stage, the seed deteriorates. Seed deterioration is defined as an inexorable process that cannot be reversed. Only its rate can be slowed by controlling the conditions of the storage environment (Delouche, 1968).

Seed deterioration is loss of seed quality, viability and vigour due to effect of adverse environmental factors (Kapoor *et al*., 2011). Deteriorative changes enhance when seed exposure to external challenges increases, and it decreases the ability of the seed to survive. It is an undesirable attribute of agriculture. Annual losses due to deterioration can be as much as 25% of the harvested crop. It is one of the basic reasons for low productivity. The process has been described as cumulative, irreversible, degenerative and inexorable process (Kapoor *et al*., 2011). As seed deterioration increases, seed performance progressively decreases. However, storage of tropical seeds of different crop species is a challenge under humid tropical condition due to high temperature and relative humidity (Adebisi *et al.,* 2019). In Nigeria, groundnut farmers usually are constrained with preservation of farm save-seeds of this crop after harvest due to precarious environmental conditions of temperature and relative humidity. Also, groundnut being an oily seed tends to loose viability easily. Important as these genotypes are to the Nigerian groundnut value chain, there is little or no information on storage potentials of the groundnut genotypes under ambient humid tropics which characterizes their area of importance, hence this study.

Materials and Methods

Sources of seeds and materials

Fresh seeds of 14 genotypes of groundnut seeds were used and they were obtained from the Institute of Agricultural Research, Zaria, Kaduna State, Nigeria; Benin Republic and Ibadan open market, Oyo State, South West Nigeria.

Experimental design and location

The experiment was a 6x14 laid out in a completely randomized design with three replications. The experiment was conducted at the laboratory of the Department of Plant Breeding and Seed Technology (PBST), Federal University of Agriculture, Abeokuta, Ogun State, Nigeria under ambient conditions.

Storage duration

Seeds of each of the genotypes were sorted and graded. Seeds within the range of 0.41 -0.51g were selected and used for the experiment. Fourteen genotypes of groundnut seeds were stored for five months under ambient conditions. The experiment began in July, 2018 and ended in December, 2018.

Experimental factors

There were two main factors for investigation: groundnut genotypes (14 levels); storage period at six levels (0, 30, 60, 90, 120, and 150 days). The treatment combinations were 84 treatments.

***Assessment of the quality of seed for the experiment*:**

Standard germination tests were carried out in the laboratory with the use of paper towels and 10 seeds of each genotype were tested in three replications. Normal seedlings were evaluated after 7days. Germination percentage was expressed by the percentage of seed germination after 8 days according to ISTA (1999). Seedling vigour characteristics were evaluated according to Adebisi (2004).

Storage procedure and conditions

Clean seeds of each genotype were packed into a polyethylene bag of 11 mm density. The packaged lot measuring 25 by 25 cm was electrically sealed and thereafter placed in a laboratory cabinet under ambient conditions (30^{o}C, RH 75 %) for 5 months (150 days).

Data collection

Data were collected on the following characters:

i. Seed germination rate (%): germination counts were taken at the 3rd day and were recorded in percentage (Adebisi, 2004).
ii. Seed viability (%): germination counts were taken at the 8th day and recorded in percentage according to ISTA (1999).
iii. Seedling length (cm): lengths of five randomly picked seedlings were measured.
iv. Seedling vigour index: this was determined using the formula of Kim *et al.* (1994) as:
SVI= Seed viability (%) x Seedling length (cm)
v. Seedling fresh weight (g): weights of five randomly selected fresh seedlings were measured using sensitive scale.
vi. Seedling dry weight (g): weights of five randomly selected seedlings were measured after oven drying for 1hour at 130^{o}C according to Adebisi (2004).

Data Analysis

Data collected were subjected to two-factor analysis of variance (ANOVA) in completely randomized design with genotype and storage period as factors according to Gomez and Gomez (1984). Means of genotypes and storage periods were compared using Tukey's HSD test at 5% probability level. All analyses were conducted using SPSS statistical software (12.0 version). In order to predict the storage life of the seed after treatments, Probit analysis was carried out on seed longevity data obtained in the study according to the procedures of Roberts (1973). The Probit analysis of seed longevity data was done with SAS™ PROC PROBIT statements that first sorted the data by genotype and seed treatments. Estimates of intercept (time = 0) of the seed survival line, slope i.e. rate of seed determination (*l/s*) and time taken for seed ageing to decline to 50 % longevity (P_{50}) were estimated for each treatment combination. Seed storage life was estimated as half-life (P_{50}) value multiplied by 2, then divided by the 30 days (month).

Results and Discussion

Table 1 presents summary of ANOVA showing the mean square values for the two factors and their interaction for all the seed quality parameters. Results show that genotype, storage period and their interaction effects were highly significant ($p \leq 0.01$) for all the seed quality traits. The variations observed in each of the seed quality parameters among genotypes revealed that the 14 genotypes were significantly different in their genetic constituents which led to variation in their responses to different storage periods. Significant differences in seed quality traits during storage had been reported by several authors in different crop genotypes (Adebisi *et al.,* 2008) in sesame, Adebisi *et al.* (2012) in watermelon, Adebisi (2012) in okra, Kehinde *et al.* (2018) in kenaf and Adebisi *et al.* (2019) in pigeon pea).

Table 2 presents the effect of storage period, genotypes and their interaction on seed viability of groundnut genotypes stored under ambient conditions. At 0 month of storage, Cotonou 1 had the highest seed viability of 96.67% which was not significantly different from Samnut25, Samnut26 and Cotonou2 at 93.33% each, followed by Samnut22 and Alausa Red at 83.33% each, while Kwandala had the lowest value of 13.33%. With increase in storage period to 1 month, the result shows that Samnut26 had the highest seed viability of 96.67% which was not significantly different from Samnut25 and Alausa Red at 93.33% and 86.67%, respectively. The lowest was recorded in Kwandala with 0.09%.

At 2 months of storage, Samnut25 recorded the highest seed viability of 100.00%, which was not significantly different from Samnut26 at 93.33%, followed by Alausa red with seed viability of 76.67%, which was significantly similar to Cotonou2 and Cotonou1 at 76.67 % and 73.37%, respectively, while Kwandala recorded the lowest value of 0.07%. At 3 months of storage, Samnut26 had the highest value of 93.33%, which was significantly similar to Samnut25 at 83.33%, Kwandala and Samnut23 had the lowest values of 0.05 and 0.10, respectively. Samnut26 and Samnut25 had the highest viability at 4 months with values of 86.67 and 76.67% respectively. Also, Samnut23, Samnut24, Kwandala, Kampala and Maizabuwa had the least viability performance (0.06, 3.33, 0.03, 3.33 and 3.33 % respectively). However, at 5 months of storage, Samnut26 had highest viability (83.33%), followed by Samnut25 (66.67%) which was not significantly different from Samnut22 (56.67%), while other genotypes had lowest or zero viability values.

The effect of storage time and genotype on seedling length of 14 groundnut genotypes stored under ambient conditions is shown in Table 3. At 0 month of storage, Cotonou1 had the longest seedling (30.19cm), and was not significantly different from Samnut25 (27.62cm), followed by Samnut22 and Samnut26 (25.34 and 24.11cm, respectively). The shortest seedling was Kwandala (1.53cm). After a period of 1 month, Samnut26 recorded the highest value of 23.87cm followed closely by Samnut 22 and Cotonou 2 (19.85 and 19.87cm, respectively). Kwandala also had the shortest seedling with value of 0.08cm. At 2 months of storage, Samnut25 and Samnut26 recorded the highest values of 19.01 and 18.82cm respectively, followed by Samnut22 and Cotonou1 (15.05 and 15.01cm respectively). Samnut23, Kwandala and Kampala were the shortest with values of 1.02cm, 0.02cm and 1.01cm, respectively. After 3 months of storage, Samnut25 recorded the highest (17.03cm) and was not significantly different from Samnut26 (14.83cm); however Samnut23, Kwandala and Kampala also had the least values. At 4 months of storage, Samnut22 recorded the highest value (3.58cm), which was not significantly different form Samnut26 (10.93cm), followed closely by Samnut25 (8.74cm). Shortest seedlings were Kwandala, Kampala, Samnut23 and Samnut24, while at 5 months of storage, Samnut26 recorded the highest value (9.82cm) and was not significantly different from Samnut22 (8.86cm) and Samnut25 (7.42cm).

The effect of storage time, genotype and their interaction on seedling vigour index of groundnut genotypes stored under ambient conditions is presented in Table 4. Cotonou1 had the highest value of 2909.53, followed by Samnut25 (2589.47). The least value was recorded in Kampala and Kwandala with values of 174.00 and 23.33, respectively. At 1 month of storage, Samnut26 had the highest seedling vigour index value (2019.20), which was not significantly different from Cotonou2 (1808.870), followed by Samnut25 (1702.67). Samnut23, Kwandala, Kampala and Maizabuwa recorded the lowest with values less than 300. After a period of 2 months, Samnut26 and Samnut25 recorded the highest values of 1611.73 and 1593.33 respectively. Lowest seedling vigour index values of less than 200 were recorded in Samnut23, Kwandala, Kampala and Maizabuwa each. Samnut26 also recorded the highest at 3 months with value of 1374.27, which was significantly similar to Samnut25 (1206.60), followed by Cotonou1 and Alausa Red with values less than 1000. Samnut23, Samnut24, Kwankwaso, Kwandala, Kampala, and Maizabuwa recorded least values. Samnut26 had the highest vmalue at 4 months of storage with value of 1053.53 and was not significantly different from Sanut22 (812.53), followed by Samnut25 (812.53) and Alausa Red (433.13), while Samnut26, Samnut25 and Samnut22 had the highest value at 5 months of storage with values of 884.93, 677.07 and 623.33 respectively.

Table 5 presents the effect of storage time, genotype and their interaction on rate of germination of groundnut genotypes under ambient conditions. From the data, Samnut26 recorded the highest value at 0 month with rate of germination of 93.33%, followed by Samnut25, with value of 76.67%. The lowest values were recorded in Maizabuwa, Kampala and Kwandala with values of 20.00, 13.33 and 10.00%, respectively. After a period of 1 month; Samnut26, Samnut25, Cotonou2 and Cotonou1 had statistically similar highest values of 70.00, 70.00, 66.67 and 66.63% respectively. These values were significantly similar to 60.00% obtained in Samnut22 and Alausa Red, however Kwandala recorded the least value of 0.05%. Samnut26 and Samnut25 had the highest value of 63.33% each at 2 months, followed by Alausa Red, Bororo, Cotonou1 and Samnut22 with values of 50.00% each and also Cotonou 2 (46.67 %), Kwandala recorded the lowest value of 0.05%. Values recorded at 3 months of storage showed that Samnut26 was the highest with value of 60.00% which was significantly similar to 50.00% obtained in Samnut22, Alausa Red and Bororo. Samnut 25 followed closely with a value of 46.67%, while Samnut23 and Kwandala recorded the least values of 0.03 and 0.01 respectively. At 4 months, Samnut26 and Alausa Red recorded the highest values of 56.67 and 50.00% respectively, followed by Samnut25 and Samnut22 with values of 33.33% each. Samnut23, Kampala and Kwandala recorded the least values of 0%, while at 5 months of storage, Samnut26 recorded the highest value of 56.67%, followed by Alausa Red with value of 43.33% and Samnut25 (30.00 %).

The effect of storage, genotype and their interaction on seedling fresh weight of groundnut genotypes stored under ambient conditions is presented in Table 6. From the results, Alausa Red and Samnut25 recorded the highest value of 19.23 and 18.95g respectively, which was significantly similar to Kwankwaso with value of 18.60g, while Kwandala had the lowest fresh weight of 2.04g. At 1 month of storage, Samnut25 had the highest seedling fresh weight which was significantly similar to values obtained in Samnut26 and Alausa Red with weight values of 13.64 and 13.45g respectively, while Kwandala also had the lowest value of 0.01g. Data collected at 2 months of storage showed that Samnut25 had the highest value of 13.29g which was statistically similar to Alausa Red (11.48g), followed by Samnut26, Bororo, Cotonou1, Cotonou2, Samnut21 and Samnut22 with weight values of less than 11g. Kwandala had the lowest weight value of 0.01g. As storage period progresses to 3 months, Alausa Red had the highest weight of 11.42g though statistically similar to value obtained in Samnut25 (10.42g) and Samnut26 (10.16 g), while Kwandala recorded zero weight value. At 4 months, Samnut26 recorded the highest value (7.54g) though statistically similar to values obtained in Alausa Red, Samnut22, and Samnut25 (7.22, 6.95, 6.59g respectively). Kwandala also recorded zero weight value. Samnut25, Samnut22, Samnut26 and Alausa Red had statistically similar higher values of 6.75, 6.32, 6.07 and 5.00g respectively at 5 months of storage, while other genotypes recorded statistically lower values.

Table 7 shows the effect of storage time on seedling dry weight of 14 groundnut genotypes stored under ambient conditions. From the table, Kwankwaso, Alausa Red and Samnut25 had the highest dry weight value at 0 month of storage (2.41, 2.22 and 2.18g respectively) which was not significantly different from Samnut23 (2.06g). Kwandala had the lowest value of 0.50g. After 1 month, Alausa Red, Kwankwaso and Samnut25 recorded the highest values of 2.08g, 2.06g, and 1.99g respectively, which was not significantly different from value of 1.80g recorded in Samnut22.

The lowest value was also recorded in Kwandala (0.06g). At 2 months, Alausa Red and Samnut26 had the highest values of 1.96 and 1.90g respectively, followed by Kwankwaso, Bororo and Samnut22 at 1.54, 1.42 and 1.39g. Kwandala recorded the least value of 0.06g. The highest value of 1.88g was recorded for Alausa Red at 3 months which was statistically similar to Samnut25, followed by Samnut26, Samnut22, and Cotonou1 with values less than 1.3g. Least value of 0.02g was also recorded in Kwandala. Alausa Red also performed best at 5 months of storage with a value of 1.96g followed by Samnut 25 and Samnut 26 (1.09 and 1.07g respectively).

The study revealed that there were significant differences among all the seed quality attributes in response to increase in storage period. Seed quality parameters decreased as storage period increased. Adebisi *et al.* (2008) and Kehinde *et al*. (2019) reported similar findings in which seed quality parameters were significantly influenced by increase in storage period of sesame and pigeon pea seeds respectively. Among the 14 genotypes, Samnut26 and Samnut25 were identified to be superior for most of the seed quality attributes under study, while Kwandala had the least performance in this study. The highest seed viability and seedling vigour index were observed at 0 month, followed by 1 month, then 2 months of storage. Seeds stored up till 5 months had the lowest viability values and seedling vigour indices. Furthermore, the study observed that storage period under ambient condition should be given due consideration when storing seeds irrespective of genotypes available for storage.

Table 8 presents relationship among seed quality parameters across storage time among groundnut seeds under ambient conditions. From the result, storage time had negative and significant correlation with seed viability, seedling length, seedling vigour index, rate of germination, seedling fresh weight and seedling dry weight with values of r= -0.25** to -0.65**. Also, seed viability recorded significant and positive correlation with seedling length, seedling vigour index, rate of germination, seedling fresh weight and seedling dry weight (with values of r= 0.78** to 0.89**), seedling length also had a positive and significant correlation with seedling vigour index, rate of germination, seedling fresh weight and seedling dry weight (with values of r= 0.66** to 0.96**). Seedling vigour index had a significant and positive correlation with rate of germination, seedling fresh weight and seedling dry weight (with value with values of r= 0.59** to 0.89**). Rate of germination had a positive and significant correlation with seedling fresh weight and seedling dry weight (0.67** to 0.68**), while seedling fresh weight had a positive and significant correlation with seedling dry weight (0.77**).

The result from Probit analysis of seed viability data is shown in Table 9 for 14 groundnut genotypes over 150 days of storage (5 months) time under ambient conditions. Samnut26 gave the highest value for seed half-life (P_{50}) of 391.00 days, followed by Samnut25 with 210.00 days. Meanwhile, Kwandala, Kampala and Maizabuwa recorded the lowest values of 0 days each. Storage life estimated in months showed that Samnut26 had the highest seed storage life of 26 months followed by Samnut25 with 14 months. Kwandala, Kampala and Maizabuwa had the lowest seed storage life of 0 month each. The result also showed that all genotypes recorded relatively low rate of deterioration ranging from 0.0048-0.0261, except Kwandala which had a high rate of deterioration of 0.4383. The use of Probit modeling to predict storage life in different crop species has been reported by several authors [Daniel, 1997 (yam); Adebisi *et al.* 2003 (soybean); Adebisi *et al.* 2008 (sesame), Adebisi, 2012 (okra); Adebisi *et al.* 2013 (kenaf), Kehinde *et al*. 2019 (pigeon pea)]. The result of the Probit modeling in this study shows that the seeds of the groundnut genotypes had low rate of deterioration except Kwandala. Samnut26 had the highest value in days to seed half-life and storage life (months), while Kwandala, Kampala and Maizabuwa had the lowest values. Nevertheless, the Probit modeling predicted that Samnut26 can be stored for an average of 26 months before it starts deteriorating if put under a more favourable storage condition.

Conclusion

The study showed high significant differences in all seed quality parameters evaluated among the 14 groundnut genotypes. These seed quality parameters were highly influenced by the storage period and low rate of deterioration was observed in all the genotypes except Kwandala. All seed quality parameters significantly declined with increase in storage period due to the intrinsic factors in the seeds, irrespective of genotype. Genotypes Samnut26 and Samnut25 showed superior seed quality during storage time, therefore, storage period of these two genotypes could still be achieved after 5 months. An estimated seed storage life of 26 months was predicted by Probit modeling in Samnut26, if stored in a more favourable condition. Seed quality of groundnut deteriorates as storage time increases, therefore, the duration should be considered during storage under ambient conditions. Genotypes-Samnut26 and Samnut 25 were superior genotypes in terms of storage, and are recommended for seed improvement programmes with utmost aim of high seed quality. Further studies are therefore recommended on storage of groundnut with increase in storage length and with use of seed treatment to extend their storage life**.**

Table 1: Mean square values for the effect of length of storage on seed quality of groundnut genotypes

Sources of variation	Degree of freedom	Seed viability	Seedling length	Seedling vigour index	Rate of germination	Seedling fresh weight	Seedling dry weight
Replicates	2	258.33^{ns}	29.14^{ns}	327431.94*	86.11^{ns}	7.37^{ns}	0.08^{ns}
Genotype (G)	13	13241.39**	554.84**	4492120.42**	7437.36**	216.11**	4.10**
Storage time(S)	5	11278.10**	1459.91**	8726814.11**	3664.44**	765.71**	6.04**
G x S	65	875.53**	41.29**	408508.49**	713.33**	17.34**	0.49**
Error	166	131.43	10.60	106400.17	111.41	5.04	0.13

***Significant at 5% probability level; **Significant at 1% probabi lity level; ns: Non significant**

Table 2: Effect of storage time, genotype and their interaction on seed viability of groundnut stored under ambient conditions

Genotypes	Storage Period (Days)						
	0	**30**	**60**	**90**	**120**	**150**	***Mean**
Samnut 21	66.67^{c}	46.67^{d}	40.00^{d}	40.00^{d}	26.67^{c}	13.33^{d}	38.89
Samnut 22	83.33^{b}	76.67^{bc}	60.00^{c}	60.00^{c}	60.00^{b}	56.67^{b}	66.11
Samnut 23	60.00^{c}	36.67^{de}	20.00^{e}	0.10^{f}	0.06^{e}	0.04^{e}	19.48
Samnut 24	73.33^{bc}	70.00^{c}	36.67^{d}	13.33^{e}	3.33^{e}	0.03^{e}	32.78
Samnut 25	93.33^{ab}	93.33^{ab}	100.00^{a}	83.33^{ab}	76.67^{a}	66.67^{b}	85.56
Samnut 26	93.33^{ab}	96.67^{a}	93.33^{a}	93.33^{a}	86.67^{a}	83.33^{a}	91.11
Kwankwaso	63.33^{c}	66.67^{c}	56.67^{c}	20.00^{e}	10.00^{de}	0.08^{e}	36.13
Kwandala	13.33^{e}	0.09^{f}	0.07^{f}	0.05^{f}	0.03^{e}	0.01^{e}	2.26
Kampala	26.67^{d}	23.33^{e}	23.33^{e}	13.33^{e}	3.33^{e}	0.04^{e}	15.01
Maizabuwa	30.00^{d}	33.33^{e}	30.00^{de}	10.00^{e}	3.33^{e}	0.03^{e}	17.78
Alausa red	83.33^{b}	86.67^{ab}	76.67^{b}	76.67^{b}	60.00^{b}	43.33^{c}	71.11
Bororo	86.67^{ab}	80.00^{bc}	66.67^{bc}	50.00^{cd}	23.33^{cd}	20.00^{d}	54.45
Cotonou 1	96.67^{a}	80.00^{bc}	73.33^{b}	66.67^{bc}	20.00^{cd}	0.01^{e}	56.11
Cotonou 2	93.33^{ab}	83.33^{b}	76.67^{b}	53.33^{c}	13.33^{d}	0.01^{e}	53.33
**Mean	68.81	62.39	53.82	41.44	27.63	20.26	

Mean values followed by the same alphabet along column are not different from another at 5% probability level according to Tukey's HSD test. *Mean of genotypes across storage periods. **Mean of storage periods across genotypes

Table 3: Effect of storage time, genotype and their interaction on seedling length of groundnut genotypes stored under ambient conditions

Genotypes	Storage Period (Days)						
	0	**1**	**2**	**3**	**4**	**5**	***Mean**
Samnut 21	22.05^{c}	17.69^{bc}	11.42^{c}	11.22^{b}	3.42^{c}	2.25^{c}	11.34
Samnut 22	25.34^{b}	19.85^{b}	15.05^{b}	12.43^{b}	13.58^{a}	8.86^{ab}	15.85
Samnut 23	12.32^{e}	6.37^{e}	1.02^{e}	0.01^{e}	0.07^{d}	0.00^{c}	3.30
Samnut 24	21.69^{c}	16.24^{c}	5.46^{d}	2.47^{d}	0.28^{d}	0.04^{c}	7.70
Samnut 25	27.62^{ab}	18.07^{bc}	19.01^{a}	17.03^{a}	8.74^{b}	7.48^{ab}	16.33
Samnut 26	24.11^{b}	23.87^{a}	18.82^{a}	14.83^{ab}	10.93^{ab}	9.82^{a}	17.06
Kwankwaso	21.21^{c}	14.01^{cd}	8.96^{c}	4.11^{d}	1.28^{cd}	0.00^{c}	8.26
Kwandala	1.53^{g}	0.08^{f}	0.02^{e}	0.07^{e}	0.04^{d}	0.00^{c}	0.29
Kampala	5.67^{f}	4.39^{e}	1.01^{e}	1.68^{e}	0.27^{d}	0.03^{c}	2.18
Maizabuwa	6.22^{f}	4.2^{2e}	3.88^{d}	1.11^{c}	0.43^{cd}	0.03^{c}	2.65
Alausa red	23.33^{bc}	15.13^{cd}	12.99^{b}	10.41^{b}	7.56^{b}	6.04^{b}	12.58
Bororo	16.59^{d}	13.58^{d}	11.87^{c}	9.23^{c}	2.81^{cd}	1.05^{c}	9.19
Cotonou 1	30.19^{a}	18.45^{bc}	15.01^{b}	11.70^{b}	1.14^{cd}	0.02^{c}	12.75
Cotonou 2	22.64^{bc}	19.87^{b}	14.45^{bc}	11.86^{b}	1.06^{cd}	0.02^{c}	11.65
**Mean	18.61	13.70	9.93	7.73	3.69	2.55	

Mean values followed by the same alphabet along column are not different from another at 5% probability level according to Tukey's HSD test. *Mean of genotypes across storage periods. **Mean of storage periods across genotypes

Table 4: Effect of storage time, genotype and their interaction on seedling vigour index of groundnut genotypes under ambient conditions

Genotypes	Storage Period (Months)						
	0	1	2	3	4	5	*Mean
Samnut 21	1150.33^{e}	1068.13^{d}	455.83^{c}	334.80^{cd}	160.00^{bc}	29.97^{b}	533.18
Samnut 22	2116.33^{cd}	1219.87^{cd}	1217.87^{b}	819.49^{bc}	812.53^{ab}	632.33^{a}	1136.40
Samnut 23	774.53^{f}	250.73^{e}	23.47^{d}	0.05^{d}	0.05^{c}	0.00^{b}	174.81
Samnut 24	1605.47^{de}	1150.53^{cd}	215.00^{cd}	30.17^{d}	2.80^{c}	0.05^{b}	500.67
Samnut 25	2589.47^{b}	1702.67^{b}	1593.33^{a}	1206.60^{ab}	678.13^{b}	677.07^{a}	1407.88
Samnut 26	2261.60^{c}	2019.20^{a}	1611.73^{a}	1374.27^{a}	1053.53^{a}	884.93^{a}	1534.21
Kwankwaso	1394.60^{e}	970.53^{d}	518.60^{c}	121.22^{d}	12.80^{c}	0.07^{b}	502.97
Kwandala	23.33^{g}	0.06^{e}	0.03^{d}	0.02^{d}	0.05^{c}	0.07^{b}	3.93
Kampala	174.00^{g}	123.3^{3e}	40.27^{d}	40.07^{d}	2.67^{c}	0.01^{b}	63.39
Maizabuwa	186.60^{g}	141.07^{e}	126.53^{d}	33.20^{d}	4.33^{c}	0.01^{b}	81.96
Alausa red	1863.60^{d}	1193.33^{cd}	1018.53^{b}	913.00^{b}	433.13^{b}	267.93^{b}	948.25
Bororo	1444.40^{e}	1086.60^{d}	801.20^{bc}	577.87^{c}	54.93^{c}	28.87^{b}	665.65
Cotonou 1	2909.53^{a}	1402.27^{c}	1017.87^{b}	947.13^{b}	22.30^{c}	0.02^{b}	1049.85
Cotonou 2	1869.60^{d}	1808.87^{ab}	1099.60^{b}	791.80^{bc}	15.47^{c}	0.01^{b}	930.89
**Mean	1454.53	1009.80	695.70	513.55	232.34	180.10	

Mean values followed by the same alphabet along column are not different from another at 5% probability level according to Tukey's HSD test. *Mean of genotypes across storage periods. **Mean of storage periods across genotypes

Table 5: Effect of storage time, genotype and their interaction on rate of germination of groundnut genotypes under ambient conditions

Genotypes	Storage Period (Days)						
	0	1	2	3	4	5	*Mean
Samnut 21	43.33^{d}	4.00^{b}	20.00^{cd}	13.33^{d}	13.33^{c}	10.00^{d}	17.33
Samnut 22	66.67^{bc}	60.00^{ab}	50.00^{b}	50.00^{ab}	33.33^{b}	20.00^{cd}	46.67
Samnut 23	33.33^{d}	13.33^{d}	10.00^{d}	0.03^{e}	0.02^{d}	0.00^{d}	9.45
Samnut 24	56.67^{cd}	26.67^{c}	20.00^{cd}	13.33^{d}	3.33^{c}	0.06^{d}	20.01
Samnut 25	76.67^{b}	70.00^{a}	63.33^{a}	46.67^{b}	33.33^{b}	30.00^{c}	53.33
Samnut 26	93.33^{a}	70.00^{a}	63.33^{a}	60.00^{a}	56.67^{a}	56.67^{a}	66.67
Kwankwaso	50.00^{d}	43.33^{b}	23.33^{cd}	13.33^{d}	10.00^{c}	0.01^{d}	23.33
Kwandala	10.00^{e}	0.05^{e}	0.05^{e}	0.01^{e}	0.00^{d}	0.00^{d}	1.69
Kampala	13.33^{e}	13.33^{d}	10.00^{d}	3.33^{d}	0.01^{d}	0.00^{d}	6.67
Maizabuwa	20.00^{e}	13.33^{d}	13.33^{d}	3.33^{d}	3.33^{c}	0.05^{d}	8.90
Alausa red	63.33^{c}	60.00^{ab}	50.00^{b}	50.00^{ab}	50.00^{a}	43.33^{b}	52.78
Bororo	66.67^{bc}	50.00^{b}	50.00^{b}	50.00^{ab}	23.33^{bc}	20.00^{cd}	43.33
Cotonou 1	73.33^{bc}	63.33^{a}	50.00^{b}	23.33^{cd}	13.33^{c}	0.01^{d}	37.22
Cotonou 2	73.33^{bc}	66.67^{a}	46.67^{b}	30.00^{c}	10.00^{c}	0.09^{d}	37.79
**Mean	52.86	39.57	33.57	25.48	17.86	12.87	

Mean values followed by the same alphabet along column are not different from another at 5% probability level according to Tukey's HSD test. *Mean of genotypes across storage periods. **Mean of storage periods across genotypes

Table 6: Effect of storage time, genotype and their interaction on seedling fresh weight of groundnut genotype stored under ambient condition

Genotypes	Storage Period (Days)						
	0	**1**	**2**	**3**	**4**	**5**	***Mean**
Samnut 21	14.56^{c}	12.61^{b}	8.52^{b}	6.78^{bc}	3.08^{b}	1.20^{b}	7.79
Samnut 22	16.91^{b}	12.86^{b}	8.38^{b}	7.82^{bc}	6.95^{a}	6.32^{a}	9.87
Samnut 23	10.97^{d}	6.43^{c}	1.64^{e}	0.06^{e}	0.02^{c}	0.00^{b}	3.19
Samnut 24	15.95^{bc}	12.31^{b}	3.61^{d}	2.01^{de}	0.28^{c}	0.05^{b}	5.70
Samnut 25	18.95^{ab}	14.87^{a}	13.29^{a}	10.42^{ab}	6.59^{a}	6.75^{a}	11.81
Samnut 26	15.48^{bc}	13.64^{ab}	10.72^{b}	10.16^{ab}	7.54^{a}	6.07^{a}	10.60
Kwankwaso	18.60^{ab}	10.94^{b}	6.27^{c}	3.06^{d}	1.21^{b}	0.07^{b}	6.69
Kwandala	2.04^{f}	0.01^{d}	0.01^{f}	0.00^{e}	0.00^{c}	0.03^{b}	0.35
Kampala	6.66^{e}	5.81^{c}	2.10^{de}	3.04^{d}	0.43^{c}	0.05^{b}	3.02
Maizabuwa	7.17^{e}	5.82^{c}	3.94^{d}	1.41^{e}	0.82^{c}	0.01^{b}	3.20
Alausa red	19.23^{a}	13.45^{ab}	11.48^{ab}	11.42^{a}	7.22^{a}	5.00^{a}	11.30
Bororo	11.39^{d}	10.57^{b}	9.60^{b}	6.66^{c}	2.16^{bc}	1.43^{b}	6.97
Cotonou 1	17.00^{b}	12.51^{b}	9.20^{b}	3.07^{d}	1.72^{bc}	0.04^{b}	7.26
Cotonou 2	13.65^{c}	12.17^{b}	9.18^{b}	8.86^{b}	1.16^{bc}	0.01^{b}	7.51
**Mean	13.47	10.29	7.00	5.34	2.80	1.93	

Mean values followed by the same alphabet along column are not different from another at 5% probability level according to Tukey's HSD test. *Mean of genotypes across storage periods. **Mean of storage periods across genotypes

Table 7: Effect of storage time, genotype and their interaction on seedling dry weight of groundnut genotypes stored under ambient conditions

Genotypes	Storage Period (Days)						
	0	**1**	**2**	**3**	**4**	**5**	***Mean**
Samnut 21	1.39^{c}	1.00^{c}	0.90^{c}	0.81^{bc}	0.76^{c}	0.61^{c}	0.91
Samnut 22	1.90^{b}	1.80^{ab}	1.39^{b}	1.24^{b}	0.97^{bc}	0.94^{bc}	1.37
Samnut 23	2.06^{ab}	1.39^{b}	0.70^{cd}	0.09^{e}	0.07^{d}	0.04^{d}	0.73
Samnut 24	1.53^{c}	1.34^{bc}	0.83^{c}	0.20^{de}	0.10^{d}	0.01^{d}	0.67
Samnut 25	2.18^{a}	1.99^{a}	1.90^{a}	1.63^{ab}	1.62^{a}	1.09^{b}	1.74
Samnut 26	1.73^{bc}	1.43^{b}	1.30^{bc}	1.27^{b}	1.25^{b}	1.07^{b}	1.34
Kwankwaso	2.41^{a}	2.06^{a}	1.54^{b}	0.56^{cd}	0.37^{d}	0.03^{d}	1.16
Kwandala	0.50^{d}	0.06^{d}	0.06^{d}	0.02^{e}	0.02^{e}	0.00^{d}	0.11
Kampala	1.36^{c}	1.25^{bc}	0.81^{c}	0.38^{d}	0.17^{d}	0.01^{d}	0.66
Maizabuwa	1.65^{bc}	1.14^{bc}	0.84^{c}	0.34^{d}	0.19^{d}	0.09^{d}	0.71
Alausa red	2.22^{a}	2.08^{a}	1.96^{a}	1.88^{a}	1.72^{a}	1.58^{a}	1.91
Bororo	1.49^{bc}	1.45^{b}	1.42^{b}	0.73^{c}	0.57^{cd}	0.56^{c}	1.04
Cotonou 1	1.42^{bc}	1.42^{b}	1.26^{bc}	1.14^{b}	0.48^{cd}	0.01^{d}	0.96
Cotonou 2	1.17^{cd}	1.16^{bc}	1.06^{c}	0.78^{c}	0.52^{cd}	0.00^{d}	0.78
**Mean	1.64	1.40	1.14	0.79	0.63	0.43	

Mean values followed by the same alphabet along column are not different from another at 5% probability level according to Tukey's HSD test. *Mean of genotypes across storage periods. **Mean of storage periods across genotypes

Table 8: Relationship among seed quality parameters across storage time of groundnut seeds under ambient conditions

	Storage time	**Seed viability**	**Seedling length**	**SVI**	**Rate of seed germination**	**Seedling fresh weight**	**Seedling dry weight**
Storage time	1	-0.41**	-0.60**	-0.53**	-0.25**	-0.65**	-0.45**
Seed viability		1	0.82**	0.85**	0.89**	0.82**	0.78**
Seedling length			1	0.96**	0.69**	0.95**	0.66**
SVI				1	0.72**	0.89**	0.59**
RSG					1	0.68**	0.67**
SFW						1	0.77**

***correlation coefficient significant at 5% probability level;**correlation coefficient significant at 1% probability level; SVI- Seedling vigour index; RSG- Rate of Seed Germination; SFW- Seedling Fresh Weight**

Table 9: Result from probit analysis of the seed viability data in 14 groundnut genotypes stored under ambient condition over 150 days storage time

Genotype	Intercept	*Slope	#Sigma	**P_{50} (days)	***Seed storage life (months)
Samnut 21	0.35	-0.008	125.05	34.44	2.30
Samnut 22	0.81	-0.005	227.58	176.83	11.79
Samnut 23	0.38	-0.025	40.78	13.85	0.92
Samnut 24	0.92	-0.022	45.28	41.86	2.79
Samnut 25	2.35	-0.012	122.63	209.80	13.99
Samnut 26	1.76	-0.005	223.09	390.78	26.05
Kwankwaso	0.82	-0.018	60.79	41.32	2.75
Kwandala	-1.14	-0.438	5.05	0	0
Kampala	-0.66	-0.020	114.95	0	0
Maizabuwa	-0.22	-0.012	85.90	0	0
Alausa red	1.23	-0.008	130.11	155.16	10.34
Bororo	1.34	-0.017	65.32	83.97	5.60
Cotonou 1	1.93	-0.023	44.87	85.14	5.68
Cotonou 2	2.15	-0.026	40.63	79.73	5.32

* slope is the rate of deterioration; #Sigma is time taken to lose 1 probit viability; **P50 (days) is the seed half life ;
*** seed storage life was estimated as half- life (P50) value multiplied by 2 then divided by the 30 days of a month

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