Moor Journal of Agricultural Research 18, 27 - 34, 2017

Effects of mechanical damage at processing on seed germination, vigor and field emergence of Maize (*Zea mays* L.)

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Abstract
Shelling operation is an important aspect of seed conditioning in processing of maize seed. The objective of this study was to investigate the effect of locally fabricated maize sheller used during processing on seed quality of maize. Freshly harvested maize ears dried to about (control). A 500g of maize seeds was weighed from each part and the materials were packed separately in well-covered plastic containers and kept under short term conditions (18±3°C). Samples were drawn and subjected to seed quality tests (standard germination and accelerated ageing tests) and field emergence trials for three seasons. The results of analysis of variance (ANOVA) revealed that shelling method was highly significant ($P < 0.01$)) for accelerated ageing test and field emergence but not for standard germination test. Also, effect of season x shelling method interaction was highly significant ($P < 0.01$) for field emergence. The mean germination values under accelerated ageing test were 85.58 and 76.92% for hand-shelled and machine-shelled maize seeds respectively. Similarly, mean emergence value sunder field conditions were 88.67 and 75.17% for hand-shelled and machine-shelled maize seeds, respectively. From this study, it seemed therefore that hand-shelled maize seeds would store longer in the storage environment and ensure relatively higher number plant population on the field. In addition, significant effect of season x shelling method interaction on field emergence implies that shelling method should be given a prime consideration in evaluating for field emergence in a particular growing season in order to avoid wrong conclusion about actual performance of the seed lot on the field.

Keywords: Maize; shelling; germination; ageing; emergence

Introduction
Shelling operation is one of the steps of seed conditioning that influences maize seed quality. Wilson *et al*., (1994) reported that among steps involved in seed conditioning of maize, shelling is the only operation that consistently damages the seed and thereby reduces standard germination in shrunken-2 sweet corn. Similar results were reported for other crop species, for instance, the seed germination of narrow-leaved lupin seeds harvested with combined harvester reduced after 5 and 10 days and increased the percent of abnormally germinated and ungerminated seeds (Faligowskal *et al*., 2015). Poor quality seeds will result in low field emergence and seedlings that are less tolerant to abiotic stress, more sensitive to plant diseases and will reduce the yield of crops produced (Ahmed and Siddiqui, 1995).

The fundamental objective of seed testing is to establish the quality level of seed. The standard germination test, which describes the percentage of normal seedlings under optimum conditions, was considered as quality test of seed during conditioning. However, this test has its drawbacks as it evaluates seed quality under ideal conditions that are rarely found in farmers' fields. Differences in field emergence of seed lots with similar high germinations may occur due to vigor differences. Ahmed (1977) evaluated nine high germination percentage seed lots of sorghum [*Sorghum bicolor* (L) Moench] for field emergence and found out that seven of the seedlots were superior to the others. Seed vigor testing has, therefore, become an increasingly important component of seed testing and more accurately reflects the potential performance of a seed batch if stress would be encountered in the field at planting.

Accelerated ageing test was one of the vigor tests developed to estimate the longevity of seed in commercial storage (Delouche and Baskin, 1973) and has been used to predict the life span of a number of different species of crops (Hampton and Coolbear, 1990). This test is one of the most often used tests for vigor testing today and has been reported to positively correlated with field emergence in maize (Lovato *et al.*, 2001).

The National Center for Genetic Resources and Biotechnology (NACGRAB), located in Moor Plantation, Ibadan, Nigeria, has national mandate for conservation and utilization of genetic resources in Nigeria. In order to facilitate processing of maize seeds, a locally fabricated maize sheller was donated to the center by UNDP/FAO. However, there is little or no information on the effect of maize shelling using this machine on seed germination, vigor and field emergence of maize. The objective of this study therefore was to investigate the effect of the locally fabricated maize sheller on seed quality of maize variety.

Materials and Methods

Maize variety, DMR ESR-Y, sourced from Institute of Agricultural Research and Training (IAR&T), Ibadan was used for the study. The variety was regenerated in isolation at the experimental field of NACGRAB, Moor Plantation; Ibadan located on latitude 007^0 48' 11.3''N, longitude 003^0 50' 52.0''E and altitude of 183m above sea level. The location of the experimental field was within rainforest agro-ecological zone of Nigeria. The seed regeneration was carried out during the early growing season of 2015. At maturity, 200 well filled ears were harvested and selected for further sun-drying to reduce seed moisture content to about 12%. Dried ears were divided into two parts, one part was shelled using locally fabricated maize sheller (Figure 1) and the second part was shelled manually with hands. Further cleaning of seeds was done and 500g of maize seeds was weighed from each part. The seed samples were packed separately in well-covered plastic containers and kept in a short term storage conditions (18±3^{o}C) to minimize reduction of seed quality due to ageing prior laboratory seed quality and field emergence tests.

Figure 1. Maize sheller

Laboratory seed quality tests

The laboratory seed quality tests (standard germination and accelerated ageing) were carried out at the Seed Testing Laboratory, NACGRAB, Ibadan Nigeria. The tests were conducted at the beginning of late growing season of 2015 in August, early growing season of 2016 in March and late season of 2016 in August prior the field emergence trials. All the tests were conducted using Complete Randomisation Design (CRD), replicated four times with 100 seeds per replication.

Standard germination test was carried out on seed samples using sterilized riverbed sand as substratum. Seed germination was assayed by placing 100 seeds in sand inside plastic trays and covered with moist sand up to about 2cm level. These trays were kept at room temperature of about 25^0C for 7 days. Germination counts were carried out and percentages were calculated by expressing the number of seedlings in a replicate that emerged 7 days after planting as a percentage of the number of seeds planted according to ISTA (1993) rules.

Accelerated ageing test was conducted by placing one hundred seeds per replicate on a wire mesh suspended in a container over 40 ml of distilled water in a sealed accelerated ageing box (AOSA, 1983). Boxes were covered and placed in an accelerated ageing chamber which provided a relative humidity near 100 percent at 43^0C for 72 hours. However, during this study, minimum of twelve hours power supply was ensure in the ageing chamber. The seed samples were removed and germination test was carried out on aged seed samples. Germination percentages were also determined seven days after planting.

Field emergence trials

Field experiments were conducted during the late growing season (August) 2015, early growing season of (March) 2016 and late season of (September) 2016 at the experimental field of NACGRAB. Ibadan. Each of the trial was conducted using randomized complete block design with four replications. One hundred seeds were sown manually into 1-row plots, each row was 1.5 m long and spaced at 0.75 m apart with plants spaced at 0.25 m within rows at about 3 cm depth. Emergence counts were taken when the seedlings were visible at7 days after planting. Emergence percentage was calculated by expressing the number of seedlings in a replicate that emerged as a percentage of number of seeds planted.

Statistical Analysis

Data obtained from laboratory experiments and field emergence trials were subjected to analysis of variance (ANOVA), using Generalized Linear Model Procedure (PROC GLM) of Statistical Analysis System (SAS, 1990) package. Data on percentages do not conform to normal distribution; hence the germination data were log-transformed before subjecting them to the ANOVA. However, ANOVA was not able to detect any significant difference between transformed and untransformed values; untransformed values are presented in this study. Treatment means were thereafter separated by use of the least significant difference (LSD) at 0.05 level of probability.

Results

Effect of season was highly significant ($P< 0.01$)) for germination and vigour (accelerated ageing) tests as well as for field emergence(Table 1).Mean for standard germination conducted at the beginning of the late growing season (100%) of 2015 was significantly higher than that of early growing season (99.38%) of 2016 which was also significantly higher than that of

Table 1. Mean squares, mean, coefficient of determination (R^2) and coefficient of variation (CV) from the combined analysis of variance for laboratory seed quality and field emergencetests.

Source of variation	Degree of freedom	Standard germination(%)	Accelerated ageing (%)	Field Emergence(%)
Replication	3	0.04ns	23.28ns	61.50ns
Season (S)	2	3.13**	883.50**	3504.20**
Shelling methods (M)	1	0.38ns	450.67**	1093.50**
S x M	2	0.38ns	43.17ns	541.50**
Error	15	0.14	25.24	59.37
Total	23	0.42	119.67	446.08
Mean		99.38	81.25	81.92
R^2 (%)		0.78	0.86	0.91
CV (%)		0.38	6.18	9.41

*, **, Significant at probability level of 0.05 and 0.01, respectively; ns = not significant

Table 2. Effect of cropping seasons and shelling methods on seed germination vigour and field emergence.

Factors	Seed germination (%)	Seed vigour (%)	Field emergence (%)
Cropping season			
Late2015	100a	91.50a	94.00a
Early2016	99.38b	70.50c	57.75b
Late2016	98.75c	81.75b	94.00a
LSD	0.40	5.35	8.21
Shelling method			
Hand-shelled	99.50a	85.58a	88.67a
Machine-shelled	99.30a	76.92b	75.17b
LSD	0.33	4.37	6.70

Means with different letters within the column of the same factor are significantly different at P=0.05

late growing seasons (98.75%) of 2016 (Table 2). Similarly, mean for accelerated ageing test conducted at the beginning of the late growing season (91.50%) of 2015 was significantly higher than that of early (70.50%) and late (81.75%) growing seasons of 2016 (Table 2).Field emergence (94.00%) for the late growing season of 2015 and for the late growing season of 2016 (94.00%) were significantly higher than that of the early growing season (57.75%) of 2016 (Table 2).

Effect of maize sheller was highly significant ($P < 0.01$) for accelerated ageing test and field emergence trial but not significant for standard germination test (Table1). The mean germination for hand-shelled maize seeds (85.58%) under accelerated ageing conditions was significantly higher than that of machine-shelled maize seeds (76.92%) (Table 2). Similarly, mean emergence (88.67%) for hand-shelled maize seeds was significantly higher than that of machine-shelled maize seeds (75.17%) (Table 2) under field conditions. In addition, season x shelling method interaction was highly significant for field emergence ($P < 0.01$).The significant cropping season by shelling method interaction implies that germination of maize seeds observed at each of the seasons varied with shelling method. Although, for the first season (late 2015), the germination between the two shelling methods were not significant with respective germination values of 96% and 92% for hand and machine threshed maize seeds. Similarly, for the last season (late 2016), the germination between the two shelling methods were not significant with respective germination values of 96% and 92% for hand and machine threshed maize seeds However, the difference was pronounced at the second season with respective values of 74% and 41% for hand and machine threshed maize seeds (Table 3).

Discussion

The objective of seed storage is to maintain seed quality for the longest duration possible. The storage potential of seed is mainly under genetic control (Chauhan *et al*., 1984; Singh and Gill, 1994) but is influenced by several other factors like environment and period of storage (Reddy, 1985). This study also investigated the effect of duration in storage (cropping

Table 3. Interactive effect of cropping seasons and shelling methods on field emergence.

Cropping Seasons	Shelling method	Field Emergence (%)
1	H	96a
1	M	92a
2	H	74b
2	M	41c
3	H	96a
3	M	92a
LSD		6.7

1= Late season 2015; 2= early season 2016; 3= Late season 2016
H= Hand-shelled; M= machine shelled

season) on maize seed germination and vigor as well as emergence on the field. Standard germination test results revealed significant decrease in germination values as duration in storage increases. These results support the report of McDonald, 1999, who reported that seed gradually deteriorates during prolonged storage and loses viability even under controlled storage conditions. The standard germination test estimates germination under ideal growing conditions (Munamava *et al.,* 2004) but the principle of accelerated ageing test is based on the artificial acceleration of the deterioration rate of the seed, by exposing them to high temperature and relative humidity levels, which is considered as the most prominent environmental factors with respect to the intensity and velocity of deterioration (McDonald, 1999). This test has been used for predicting the storability of seed of different species of crops, including maize. However, significantly lower germination percentage for accelerated ageing test conducted at the beginning of the early growing season of 2016 at NACGRAB compared with that of late growing season of 2016 indicates the inability to maintain uninterrupted power supply to the ageing chamber for 72 hours during the conduct of the test nevertheless, the results of vigor and field emergence tests from this study revealed that most vigor tests do not give results that provide an absolute vigor value (Hampton and Coolbear, 1990) because soil and seed bed conditions vary from field to field.

The non-significant difference between both shelling methods for standard germination suggests that this test could mask the extent of damage caused by the machine during shelling operation. However, accelerated ageing test, which is a vigor test, revealed that the machine had caused damages which might reduce storability potential of this maize variety in storage environment. These results support the findings of Miah *et al.,* (1994) which stated that the percentage of grain damage was significantly affected by the threshing method used for rice. In addition, higher field emergence percentage for hand-shelled maize seeds showed that the effect of damage due to machine may not be noticeable under standard germination test conditions but may definitely manifest when it encountered certain unfavorable conditions on the field. Moreover, the significant season x shelling method interaction for field emergence suggests that, field emergence response to seasons depends on the type of shelling method used during seed processing. Hence, shelling method should be given a prime consideration in evaluating for field emergence in a particular growing season, in order to avoid wrong conclusion about actual performance of the seedlot on the field.

Conclusion

In conclusion, from this study, it seemed therefore that hand-shelled maize seeds would store longer in short term storage environment and ensure a relatively higher number plant population on the field compared with machine-shelled maize seeds. For maize seed conservation in the genebanks, it can be recommended that hand-shelling method should be employed in shelling of maize in order to enhance maize storability in genebanks, and ensure maximum plant population on the field although hand-shelling is labor intensive. In addition, significant season x shelling method interaction for field emergence suggests shelling method should be given a prime consideration in evaluating for field emergence in a particular growing season, in order to avoid wrong conclusion about actual performance of the seedlot on the field.

Acknowledgments
The authors greatly acknowledge the Institute of Agricultural Research and Training (IAR&T) Moor plantation Ibadan, where genetic material used for the study was sourced. We also highly acknowledge the efforts of Afolabi Oluwatobi of Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria and Adepeju Tayo of Department of Agronomy, Ladoke Akintola University of Technology, Ogbomoso, Nigeria for their unreserved support during data collection.

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