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Use of some Seed Laboratory Tests During Storage to Predict Field Emergence of Maize

¹M.I. El-Abady, ²S.E. Seadh and ¹A.A.M. El-Emam

¹Department of Seed Technology Research, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt

²Department of Agronomy, Faculty of Agriculture, Mansoura University, Mansoura, Egypt

Corresponding Author: M.I. El-Abady, Department of Seed Technology Research, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt

ABSTRACT

Seed laboratory tests conducted on seed lots during storage are useful in predicting the commercial attributes of their performance in the field. The objective of the present study was to examine the relationship between various laboratory seed tests and field emergence of some maize hybrids lots. Laboratory and field emergence experiments were conducted on samples of 30 maize hybrids lots. Seeds of lots were placed in storage for 18 months from October 2011 to March 2013 under laboratory natural conditions of Seed Technology Research Unit in Mansoura, Dakahlia Governorate, Field Crops Research Institute, Agricultural Research Center, Egypt. Every 6 months, samples of each lot were evaluated in the laboratory for standard germination, shoot and root lengths and seedlings dry weight (seedlings measurements), cold and accelerated aging tests (vigor tests). Field emergence experiments were carried out on seeds lots after 6 and 18 months in storage at Tag AL-Ezz, Agricultural Research Station Farm, Dakahlia Governorate, Agricultural Research Center, Egypt, in March 2012 and 2013 years. The standard germination, seedling measurements and seed vigor tests were significantly different in the studied maize hybrids lots after 0, 6, 12 and 18 months storage. Standard germination, cold test and accelerated aging test of 30 maize hybrids lots were significantly declined with prolong storage period up to 18 months as well as field emergence from 6 to 18 months. The highest correlations were detected between field emergence after 6 months storage and standard germination after 6 and 0 month followed by cold test after 6 months and accelerated aging test after 0 month. The best model for prediction of field emergence after 6 months storage was; field emergence = $11.33 + 0.82$ (standard germination); $r^2 = 0.725$. After 18 months of storage, the highest correlations value (0.741) was recorded between field emergence percentage after 18 months of storage and field emergence percentage after 6 months of storage. It was followed by germination percentage after 6 and 18 months, accelerated aging test after 0 month, germination percentage after 12 or 0 month and accelerated aging test after 6 months of storage. In order to predict field emergence after 18 months of storage, we can use the following model $5.36 - 0.86$ (standard germination percentage after 6 month); $r^2 = 0.438$, followed by $17.94 + 0.66$ (standard germination after 18 months); $r^2 = 0.351$.

Key words: Maize, hybrids lots, field emergence prediction, seed laboratory tests, storage periods

INTRODUCTION

Every year breeders and breeding companies produce several new and better maize hybrids. Because of the high cost of hybrid seed, these companies are often compelled to store the unsold

seed to the next year or even longer. Thus, it is of key importance to derive some good relationships between seed quality tests and field emergence to predict the commercial value of those seeds after a particular storage period. Field emergence capability is the foremost characteristic of seed quality. Maize, as a species from warm climate regions, can be planted under stressful field conditions. In conditions of early spring, planted seeds are often exposed to low temperature causing poor field emergence. Also, temporal separation is often used to genetic isolation by maize seed producers to reduce isolation distance requirements. This is usually done by displacing planting date, which occurs in the adverse conditions. Standard germination test refer to the maximum potential of a particular seed lot under optimum conditions (ISTA, 1985). Therefore, it does not necessarily result in rapid and uniform emergence or vigorous crop stand under field planting conditions (Delouche and Baskin, 1973). While, the standard germination test was not a good indicator for actual field emergence percentage (Aliloo and Shokati, 2011), good correlation was found between standard germination and field emergence (Navratil and Burris, 1980; Sulewska *et al.*, 2009).

Seedling measurements are also considered to be very important parameter for assessment maize seedling vigor (Woodstock and Feeley, 1965). Many investigators have found good relationship between seedling length and its dry weight with field emergence in some crops (Ching *et al.*, 1977; Nayeem and Mahajan, 1991; Kim *et al.*, 1994; Divsalar *et al.*, 2013). Meanwhile, Van de Venter and Lock (1991) observed this relation in maize under adverse conditions. Maize genotypes having longer shoot length, faster seedling growth and more seedling dry weight have a better field emergence under low temperature conditions (Nagar and Dadlani, 2004).

Seed vigor testing assesses seed ability to germinate under a wide range of environmental conditions (Woodstock, 1969). Vigor tests have an important role in seed production (Copeland and Mc-Donald, 1995) and would provide a better prediction of seed performance in the field than standard germination test (Perry, 1981).

Among seed vigor tests, cold test is widely used to determine seed vigor and simulates cold and wet soil which associated with poor field performance in many crops, particularly maize (Tekrony, 1983; Ferguson, 1990; Hampton, 1999). The maize cold test can explain slow germination and emergence (Navratil and Burris, 1980; Tekrony *et al.*, 1989) of low field emergence lots. Martin *et al.* (1988) and Woltz *et al.* (1998) stated that cold test is a good predictor of field emergence of maize during low temperature. Also, the maize seed deterioration could be evaluated effectively with that test (Gill and Delouche, 1973).

Accelerated aging test is one of the most often used tests for vigor testing today. It is well correlated with field emergence (Lovato *et al.*, 2001) and is equal with cold test as a reliable vigor test for maize (Lovato *et al.*, 2005). It was initially developed as a test to estimate the longevity of seed in commercial storage (Delouche and Baskin, 1973) and has successfully related to field emergence and stand establishment (Tekrony, 1994).

The present study was undertaken to use some seed laboratory tests during storage to predict field emergence of some maize hybrids lots.

MATERIAL AND METHODS

The different laboratory experiments were conducted during 2011 to 2013 years at the laboratory natural conditions of Seed Technology Research Unit in Mansoura, Dakahlia Governorate, Field Crops Research Institute, Agricultural Research Center, Egypt, for assessing standard germination percentage, seedling measurements and seed vigor of some maize hybrid lots.

Table 1: Randomly hybrid 30 maize lots

Lot No.	Hybrid name	Lot No.	Hybrid name	Lot No.	Hybrid name
1	T.W.C. 352	11	T.W.C. 321	21	T.W.C. 310
2	T.W.C. 321	12	T.W.C. 311	22	T.W.C. 352
3	T.W.C. 323	13	T.W.C. 321	23	T.W.C. 352
4	S.C. 103	14	T.W.C. 352	24	T.W.C. 323
5	S.C. 128	15	T.W.C. 352	25	T.W.C. 323
6	T.W.C. 323	16	T.W.C. 352	26	T.W.C. 310
7	S.C. 128	17	T.W.C. 324	27	S.C. 167
8	T.W.C. 352	18	T.W.C. 323	28	T.W.C. 352
9	T.W.C. 310	19	T.W.C. 321	29	S.C. 167
10	T.W.C. 352	20	T.W.C. 352	30	T.W.C. 310

T.W.C: Three Way Cross, S.C: Single Cross

Four seed samples (0.5 kg) of 30 lots of maize hybrids were obtained from seed testing station in Mansoura, Dakahlia Governorate, Central administration for seed certification, Giza, Egypt. The description of 30 maize hybrids lots which numbered randomly was as in (Table 1).

All seed lots that used in this study exhibited high levels of germination (>96%). The four seed samples of each hybrid lot were placed into cotton bags and were then placed in storage under the laboratory natural conditions. After 0, 6, 12, 18 months, a sample of each hybrid was removed from storage and laboratory evaluation of standard germination, seedlings measurements and seed vigor were conducted as.

Standard germination was carried out in sand soil which placed into plastic box (25×13×10 cm) at 25°C with seeds sown at depth of 1.5 cm. Normal seedlings evaluated after 7 days. Germination percentage was expressed by the percentage of seed germinating normally after 7 days according to ISTA (1996).

Seedling measurements

- **Shoot length:** Ten normal seedlings were taken at random from each replicate at the end of standard germination test to evaluate shoot length (cm)
- **Root length:** The same 10 normal seedlings selected for shoot length evaluation test used to evaluate root length (cm)
- **Seedling dry weight:** After evaluating seedling length, seedlings dried in a forced air oven at 105°C for 24 h to obtain seedlings dry weight and expressed as grams

Cold test: Three replications of 50 seeds from each treatment were planted in sand soil placed into plastic box (25×13×10 cm) at the depth of 1.5 cm. Cold water (10°C) was added to adjust the moisture content (70%) saturation. The boxes were then covered and incubated at 10°C for 7 days and followed by 25°C for 6 days and standard germination evaluation was conducted (AOSA, 1999).

Accelerated aging test: One hundred seeds from each seed lots samples were placed on a wire mesh tray in a plastic container containing 40 mL of distilled water. The seeds were aged by closing the containers and placing them in water of accelerated aging chamber at 42°C for 96 h upon completion of the aging period, the seeds were removed from the containers and standard germination evaluation was conducted (according to AOSA, 1983).

Field emergence: The 30 hybrids lots were sown at the farms of Tag AL-Ezz, Agricultural Research Station Farm, Dakahlia Governorate, Agricultural Research Center, Egypt, in March 2012 and March 2013 in 3 replications in randomized complete block design. The plot size was four rows of 5 m length of each hybrid. One hundred seeds per plot were sown (25 seeds per row). The spacing between the rows was 75 cm. Number of seedlings emerged per plot were recorded for 23 days after sowing and percent of field emergence was calculated. The mean minimum and maximum temperatures during sowing date were 11, 18, 12 and 20°C in the first and second seasons, respectively.

Data were subjected to analysis of variance according to completely randomized block design. The combined analysis was done among storage periods as published by Gomez and Gomez (1984). Means of seed lots were compared using Duncan's multiple range tests at 5% level of probability as described by Duncan (1955). Means of storage periods were compared using Least Significant of Difference (LSD) method at 5% level of probability as described by Sendecor and Cochran (1980). Correlation coefficients were calculated between laboratory test results and field emergence. Multiple regression analysis using a stepwise variable selection procedure was employed to determine the best model for prediction of field emergence using SPSS (Statistical Package for Social Science) program version 17 for windows.

RESULTS AND DISCUSSION

The standard germination percentage, seedling measurements (shoot and root length and seedlings dry weight) and seed vigor tests (cold and accelerated aging test) were significantly affected by studied maize hybrid lots after 0, 6, 12 and 18 months storage. Except, root length after 6 months storage, seedling dry weight after 12 months storage and shoot length after 18 months storage as shown from data presented in Table 2, 3, 4 and 5.

At the beginning of the experiment (0 month storage) as shown from data in Table 2, seed lot number 11 (T.W.C. 321) surpassed the other studied seed lots in germination percentage, shoot and root length, seedlings dry weight and accelerated aging percentage. However, seed lots number 17 (T.W.C. 324) and 24 (T.W.C. 323) resulted in highest cold test percentage. In addition, seed lot number 11, 3 (T.W.C. 323) and 8 (T.W.C. 352) gave the highest accelerated aging percentage without significant differences among them.

After 6 months of storage as shown from data in Table 3, seed lot number 11 (T.W.C. 321) continue to surpass other studied seed lots in germination percentage, shoot length, seedlings dry weight, cold and accelerated aging percentages. Thus, this seed lot gave the highest percentage of field emergence. It means that maize hybrids having good laboratory seed measurements have a better field emergence under adverse conditions (Nagar and Dadlani, 2004). Seed lot number 1 (T.W.C. 352) ranked after seed lot number 11 in germination percentage, shoot length, cold and accelerated aging percentages as well as field emergence then seed lot number 3 (T.W.C. 323). Whereas, seed lot number 25 (T.W.C. 323) produced the highest values of shoot length and seedlings dry weight only.

After 12 month of storage, the highest averages of germination and accelerated aging percentages were obtained from seed lot number 1 (T.W.C. 532) as shown from data in Table 4. The longest shoots were obtained from seed lot number 10 (T.W.C. 352), followed by that from seed lot number 1 (T.W.C. 352), without significant differences between them. Regarding root length trait, seed lot number 3 (T.W.C. 323), 6 (T.W.C. 323) and 11 (T.W.C. 321) produced the longest roots,

Table 2: Standard germination, seedlings measurements and seed vigor tests as affected by maize hybrids lots at 0 month storage

No. of seed lots	Standard germination (%)	Seedlings measurements			Seed vigor tests	
		Shoot length (cm)	Root length (cm)	Seedlings dry weight (g)	Cold test (%)	Accelerated aging test (%)
1	98.33 ^{ab}	13.66 ^{abcd}	9.66 ^{ab}	1.426 ^{abcdef}	93.33 ^{ab}	95.33 ^{ab}
2	97.33 ^{abc}	12.33 ^{cd}	9.33 ^{ab}	1.235 ^{efgh}	92.66 ^{abcd}	94.66 ^{abc}
3	98.33 ^{ab}	12.66 ^{bcd}	9.66 ^{ab}	1.235 ^{efgh}	93.00 ^{abc}	95.66 ^a
4	95.33 ^d	11.66 ^d	8.66 ^{ab}	1.180 ^h	89.66 ^f	92.66 ^d
5	95.33 ^d	12.00 ^{cd}	9.00 ^{ab}	1.148 ^h	90.00 ^{fg}	92.66 ^d
6	97.66 ^{abc}	13.33 ^{abcd}	9.33 ^{ab}	1.332 ^{defgh}	93.33 ^{ab}	95.00 ^{ab}
7	96.33 ^{cd}	12.33 ^{cd}	9.00 ^{ab}	1.249 ^{efgh}	90.33 ^{efg}	92.33 ^d
8	98.66 ^a	13.33 ^{abcd}	9.33 ^{ab}	1.405 ^{bcdef}	93.33 ^{ab}	95.66 ^a
9	96.33 ^{cd}	12.66 ^{bcd}	8.66 ^{ab}	1.309 ^{defgh}	90.66 ^{defg}	92.66 ^d
10	96.33 ^{cd}	15.00 ^{ab}	9.33 ^{ab}	1.493 ^{abcd}	92.33 ^{abcde}	93.33 ^{bcd}
11	98.66 ^a	15.33 ^a	10.33 ^a	1.629 ^a	93.00 ^{abc}	95.66 ^a
12	98.33 ^{ab}	14.00 ^{abcd}	9.33 ^{ab}	1.447 ^{abcde}	93.00 ^{abc}	94.33 ^{abcd}
13	96.33 ^{cd}	12.66 ^{bcd}	9.33 ^{ab}	1.307 ^{defgh}	90.66 ^{defg}	92.66 ^d
14	97.66 ^{abc}	13.66 ^{abcd}	9.66 ^{ab}	1.413 ^{bcdef}	92.33 ^{abcde}	93.66 ^{abcd}
15	96.66 ^{bcd}	12.66 ^{bcd}	9.00 ^{ab}	1.303 ^{defgh}	91.33 ^{bcddefg}	92.66 ^d
16	97.33 ^{abc}	13.33 ^{abcd}	9.00 ^{ab}	1.405 ^{bcdef}	93.00 ^{abc}	94.00 ^{abcd}
17	96.66 ^{bcd}	13.66 ^{abcd}	9.33 ^{ab}	1.491 ^{abcd}	93.66 ^a	93.33 ^{bcd}
18	96.33 ^{cd}	12.33 ^{cd}	8.33 ^b	1.249 ^{efgh}	90.66 ^{defg}	92.66 ^d
19	96.66 ^{bcd}	13.33 ^{abcd}	9.33 ^{ab}	1.397 ^{bcddefg}	91.00 ^{cdefg}	94.00 ^{abcd}
20	97.66 ^{abc}	13.33 ^{abcd}	9.66 ^{ab}	1.429 ^{abcdef}	92.00 ^{abcdef}	93.66 ^{abcd}
21	98.00 ^{abc}	13.33 ^{abcd}	9.33 ^{ab}	1.423 ^{abcdef}	93.33 ^{ab}	94.33 ^{abcd}
22	97.00 ^{abcd}	12.33 ^{cd}	8.66 ^{ab}	1.246 ^{efgh}	92.33 ^{abcde}	93.33 ^{bcd}
23	97.66 ^{abc}	13.33 ^{abcd}	9.00 ^{ab}	1.415 ^{bcdef}	92.66 ^{abcd}	93.66 ^{abcd}
24	97.00 ^{abcd}	14.00 ^{abcd}	8.66 ^{ab}	1.550 ^{abc}	93.66 ^a	94.33 ^{abcd}
25	97.33 ^{abc}	14.33 ^{abc}	9.33 ^{ab}	1.611 ^{ab}	93.00 ^{abc}	93.66 ^{abcd}
26	97.00 ^{abcd}	12.33 ^{cd}	8.66 ^{ab}	1.219 ^{efgh}	92.66 ^{abcd}	93.66 ^{abcd}
27	96.33 ^{cd}	11.66 ^d	9.00 ^{ab}	1.165 ^h	91.66 ^{abcdefg}	93.33 ^{bcd}
28	97.33 ^{abc}	13.00 ^{abcd}	9.33 ^{ab}	1.384 ^{cdefg}	92.66 ^{abcd}	94.00 ^{abcd}
29	96.33 ^{cd}	12.33 ^{cd}	8.33 ^b	1.247 ^{efgh}	91.66 ^{abcdefg}	92.66 ^d
30	96.33 ^{cd}	13.33 ^{abcd}	9.00 ^{ab}	1.294 ^{defgh}	91.00 ^{cdefg}	93.33 ^{bcd}
F. test	*	*	*	*	*	*

Values with the same letter are not significantly different at $p < 0.05$

followed by seed lot number 1 (T.W.C. 352), although without significant differences among them. The highest percentages of cold test were given from seed lot number 17 (T.W.C. 324) and 24 (T.W.C. 323).

After 18 month storage as shown in Table 5, seed lot number 1 (T.W.C. 532) continue to exceed other studied seed lots in germination and accelerated aging percentages. However, seed lot number 3 (T.W.C. 323), 6 (T.W.C. 323), 7 (S.C. 128) and 11 (T.W.C. 321) resulted in the highest means of root length and field emergence without significant differences among them. While, seed lot number 1 (T.W.C. 352), 6 (T.W.C. 323) and 11 (T.W.C. 321) produced the highest averages of seedlings dry weight and field emergence, without significant differences among them. Seed lot number 12 (T.W.C. 311) and 24 (T.W.C. 323) gave the highest means of cold test and field emergence without significant differences between them. Noli *et al.* (2010) found significant differences among lots in all laboratory tests.

Table 3: Standard germination, seedlings measurements and seed vigor tests as affected by maize hybrids lots at 6 months storage

No. of seed lots	Standard germination (%)	Seedlings measurements			Seed vigor tests		
		Shoot length (cm)	Root length (cm)	Seedlings dry weight (g)	Cold test (%)	Accelerated aging test (%)	Field emergence (%)
1	98.00 ^{ab}	13.66 ^{ab}	9.33 ^a	1.397 ^{abc de}	90.00 ^a	92.66 ^a	92.00 ^{abc}
2	97.33 ^{abc}	12.33 ^{ab}	9.00 ^a	1.205 ^{efg}	90.33 ^{abc}	92.00 ^{abc}	91.33 ^{abc d}
3	98.00 ^{ab}	12.33 ^{ab}	9.66 ^a	1.214 ^{defg}	89.33 ^{ab}	92.33 ^{ab}	92.33 ^{ab}
4	95.33 ^{cd}	11.66 ^b	8.33 ^a	1.163 ^{efg}	85.66 ^{cde}	89.66 ^{cde}	89.33 ^d
5	95.00 ^d	11.66 ^b	8.66 ^a	1.131 ^g	86.33 ^{de}	89.33 ^{de}	89.33 ^d
6	97.33 ^{abc}	13.00 ^{ab}	9.00 ^a	1.243 ^{cdefg}	89.66 ^{abc d}	91.66 ^{abc d}	91.33 ^{abc d}
7	96.33 ^{abc d}	12.00 ^{ab}	9.00 ^a	1.223 ^{cdefg}	87.00 ^{de}	89.33 ^{de}	90.33 ^{bc d}
8	98.00 ^{ab}	12.66 ^{ab}	9.00 ^a	1.365 ^{abc defg}	89.66 ^{ab}	92.33 ^{ab}	92.00 ^{abc}
9	96.33 ^{abc d}	12.33 ^{ab}	8.66 ^a	1.284 ^{bc defg}	87.33 ^{de}	89.33 ^{de}	90.66 ^{abc d}
10	96.00 ^{bc d}	14.00 ^a	9.00 ^a	1.464 ^{abc}	89.66 ^{abc de}	90.33 ^{abc de}	90.66 ^{abc d}
11	98.33 ^a	14.00 ^a	9.66 ^a	1.512 ^{ab}	90.00 ^{ab}	92.33 ^{ab}	92.66 ^a
12	98.33 ^a	13.33 ^{ab}	9.33 ^a	1.401 ^{abc de}	90.33 ^{abc de}	91.00 ^{abc de}	92.33 ^{ab}
13	96.00 ^{bc d}	12.66 ^{ab}	9.33 ^a	1.303 ^{bc defg}	87.66 ^{de}	89.33 ^{de}	90.33 ^{bc d}
14	97.33 ^{abc}	13.33 ^{ab}	9.00 ^a	1.361 ^{abc defg}	89.66 ^{abc de}	91.00 ^{abc de}	92.00 ^{abc}
15	96.33 ^{abc d}	12.66 ^{ab}	9.00 ^a	1.293 ^{bc defg}	89.33 ^e	89.00 ^e	90.33 ^{bc d}
16	97.00 ^{abc d}	13.00 ^{ab}	8.66 ^a	1.382 ^{abc def}	90.33 ^{abc de}	91.33 ^{abc de}	91.33 ^{abc d}
17	96.33 ^{abc d}	13.33 ^{ab}	9.00 ^a	1.455 ^{abc d}	90.66 ^{abc de}	91.00 ^{abc de}	90.66 ^{abc d}
18	96.00 ^{bc d}	12.00 ^{ab}	8.33 ^a	1.225 ^{cdefg}	87.66 ^{cde}	89.66 ^{cde}	90.33 ^{bc d}
19	96.00 ^{bc d}	13.33 ^{ab}	9.00 ^a	1.371 ^{abc defg}	87.66 ^{abc de}	90.66 ^{abc de}	90.00 ^{cd}
20	97.33 ^{abc}	13.00 ^{ab}	9.33 ^a	1.323 ^{abc defg}	88.66 ^{abc de}	90.66 ^{abc de}	91.33 ^{abc d}
21	97.66 ^{ab}	13.33 ^{ab}	9.33 ^a	1.403 ^{abc de}	90.00 ^{abc de}	91.00 ^{abc de}	91.33 ^{abc d}
22	96.33 ^{abc d}	12.33 ^{ab}	8.33 ^a	1.217 ^{defg}	88.66 ^{abc de}	90.33 ^{abc de}	91.33 ^{abc d}
23	97.33 ^{abc}	13.00 ^{ab}	8.66 ^a	1.399 ^{abc de}	89.33 ^{abc de}	90.33 ^{abc de}	91.00 ^{abc d}
24	96.66 ^{abc d}	13.33 ^{ab}	8.66 ^a	1.507 ^{ab}	90.33 ^{abc de}	91.00 ^{abc de}	91.33 ^{abc d}
25	96.66 ^{abc d}	13.33 ^{ab}	9.00 ^a	1.555 ^a	89.33 ^{abc de}	90.66 ^{abc de}	90.66 ^{abc d}
26	96.66 ^{abc d}	12.33 ^{ab}	8.00 ^a	1.158 ^{efg}	89.66 ^{abc de}	91.00 ^{abc de}	90.66 ^{abc d}
27	96.00 ^{bc d}	11.66 ^b	8.66 ^a	1.151 ^{fg}	89.00 ^{bc de}	90.00 ^{bc de}	90.66 ^{abc d}
28	97.00 ^{abc d}	12.33 ^{ab}	8.33 ^a	1.347 ^{abc defg}	89.33 ^{abc de}	90.66 ^{abc de}	91.33 ^{abc d}
29	96.00 ^{bc d}	12.00 ^{ab}	8.00 ^a	1.219 ^{cdefg}	88.33 ^{de}	89.33 ^{de}	90.66 ^{abc d}
30	96.33 ^{abc d}	12.66 ^{ab}	8.33 ^a	1.269 ^{bc defg}	88.33 ^{abc de}	90.33 ^{abc de}	91.00 ^{abc d}
F. test	*	*	ns	*	*	*	*

Values with the same letter are not significantly different at $p < 0.05$

Generally, seed lot number 11 (T.W.C. 321) is consider the best maize hybrid lot due to highest averages of field emergence after 6 and 18 months storage as well as germination percentage, shoot and root length, seedlings dry weight and accelerated aging test (after 0 month storage), germination percentage, shoot length, seedlings dry weight, cold test and accelerated aging test (after 6 months storage), shoot and root length (after 12 months storage), germination percentage, root length and seedlings dry weight (after 18 months storage).

Standard germination, cold test, accelerated aging test and field emergence percentages of 30 maize hybrids lots were significantly differed after 0, 6, 12 and 18 months storage as shown from data graphically illustrated in Fig. 1. The standard germination test indicated insignificant decrease in germination % from 0 to 6 months storage. In contrast, a significant decrease observed from 6-12 and 12-18 months in storage, perhaps owing to the decline in seed viability after 6 months.

Table 4: Standard germination, seedlings measurements and seed vigor tests as affected by maize hybrids lots at 12 month storage

No. of seed lots	Standard germination (%)	Seedlings measurements			Seed vigor tests	
		Shoot length (cm)	Root length (cm)	Seedlings dry weight (g)	Cold test (%)	Accelerated aging test (%)
1	95.33 ^a	11.66 ^{ab}	8.33 ^{ab}	1.239 ^a	86.33 ^{abcd}	90.33 ^a
2	92.66 ^{bc}	10.66 ^{ab}	8.33 ^{ab}	1.125 ^a	85.33 ^{c d}	87.66 ^{bc de}
3	94.66 ^{ab}	10.66 ^{ab}	8.66 ^a	1.184 ^a	86.00 ^{abcd}	89.00 ^{abc}
4	92.33 ^c	10.00 ^{ab}	7.33 ^{abc de}	1.073 ^a	82.66 ^e	86.33 ^f
5	92.33 ^c	10.33 ^{ab}	7.33 ^{abc de}	1.059 ^a	82.66 ^e	85.66 ^f
6	94.00 ^{abc}	11.33 ^{ab}	8.66 ^a	0.829 ^a	86.33 ^{abcd}	88.33 ^{bc d}
7	92.66 ^{bc}	10.33 ^{ab}	8.33 ^{ab}	1.152 ^a	84.66 ^d	86.66 ^{def}
8	94.66 ^{ab}	10.66 ^{ab}	7.66 ^{abc d}	1.167 ^a	86.66 ^{abc}	89.33 ^{ab}
9	93.33 ^{abc}	10.66 ^{ab}	7.33 ^{abc de}	1.093 ^a	85.33 ^{c d}	86.33 ^{ef}
10	92.66 ^{bc}	12.00 ^a	7.66 ^{abc d}	1.221 ^a	86.66 ^{abc}	87.33 ^{def}
11	94.33 ^{abc}	11.66 ^{ab}	8.66 ^a	1.217 ^a	86.66 ^{abc}	89.00 ^{abc}
12	94.33 ^{abc}	11.33 ^{ab}	8.33 ^{ab}	1.226 ^a	87.33 ^{ab}	87.66 ^{bc de}
13	92.66 ^{bc}	10.33 ^{ab}	8.00 ^{abc}	1.134 ^a	85.66 ^{bc d}	87.00 ^{def}
14	93.66 ^{abc}	11.00 ^{ab}	8.00 ^{abc}	1.183 ^a	86.66 ^{abc}	88.33 ^{bc d}
15	93.00 ^{bc}	10.66 ^{ab}	7.33 ^{abc de}	1.153 ^a	87.00 ^{abc}	86.33 ^f
16	93.33 ^{abc}	10.33 ^{ab}	6.66 ^{bc de}	1.096 ^a	87.33 ^{ab}	88.33 ^{bc d}
17	93.00 ^{bc}	10.66 ^{ab}	7.00 ^{abc de}	1.136 ^a	87.66 ^a	88.00 ^{bc de}
18	93.00 ^{bc}	10.00 ^{ab}	6.33 ^{c de}	1.070 ^a	85.33 ^{c d}	86.66 ^{def}
19	92.33 ^c	11.33 ^{ab}	6.33 ^{c de}	1.093 ^a	85.66 ^{bc d}	87.66 ^{bc de}
20	93.33 ^{abc}	10.66 ^{ab}	7.00 ^{abc de}	1.110 ^a	86.33 ^{abcd}	87.33 ^{def}
21	93.66 ^{abc}	11.33 ^{ab}	7.33 ^{abc de}	1.146 ^a	86.66 ^{abc}	87.66 ^{bc de}
22	92.66 ^{bc}	10.33 ^{ab}	6.66 ^{bc de}	1.072 ^a	86.66 ^{abc}	87.33 ^{def}
23	92.66 ^{bc}	10.66 ^{ab}	6.66 ^{bc de}	1.102 ^a	87.33 ^{ab}	87.66 ^{bc de}
24	93.66 ^{abc}	11.66 ^{ab}	7.33 ^{abc de}	1.183 ^a	87.66 ^a	87.66 ^{bc de}
25	92.66 ^{bc}	11.33 ^{ab}	7.66 ^{abc d}	1.189 ^a	86.33 ^{abcd}	87.00 ^{def}
26	93.33 ^{abc}	10.33 ^{ab}	6.33 ^{c de}	1.075 ^a	86.66 ^{abc}	87.66 ^{bc de}
27	92.66 ^{bc}	9.66 ^b	5.66 ^e	1.020 ^a	86.33 ^{abcd}	87.66 ^{bc de}
28	93.00 ^{bc}	10.33 ^{ab}	6.33 ^{c de}	1.069 ^a	87.00 ^{abc}	87.33 ^{def}
29	92.66 ^{bc}	10.33 ^{ab}	6.00 ^{de}	1.049 ^a	85.66 ^{bc d}	87.00 ^{def}
30	93.00 ^{bc}	11.00 ^{ab}	6.66 ^{bc de}	1.117 ^a	85.33 ^{c d}	86.33 ^{ef}
F. test	*	*	*	ns	*	*

Values with the same letter are not significantly different at $p < 0.05$

There was also a significant decrease in seed vigor mentioned by cold test and accelerated aging test %, the decrease between the different periods was significant. This this means that the decline began from 0 month storage and continued to 18 month storage. Field emergence % was measured for seed stored for 6 and 18 months, which indicated a significant decline in seed stored for 18 months than seed stored for 6 months. Similar results have been reported by Shah *et al.* (2002) who found a significant decrease in field emergence and vigor tests after 12 months storage of hybrid seed lots. It is worth noting that standard germination values were relatively higher than 0, 6, and 12 cold test, accelerated aging test and field emergence because the test was conducted under optimum conditions, while the vigor tests measured under stressful conditions. These results suggest that the cold test and accelerated test are reliable as vigor tests for maize (Lovato *et al.*, 2005).

Table 5: Standard germination, seedlings measurements and seed vigor tests as affected by maize hybrids lots at 18 months storage

No. of seed lots	Standard germination (%)	Seedlings measurements			Seed vigor tests		
		Shoot length (cm)	Root length (cm)	Seedlings dry weight (g)	Cold test (%)	Accelerated aging test (%)	Field emergence (%)
1	92.66 ^a	10.66 ^a	7.33 ^{abcd}	1.127 ^{ab}	80.00 ^{abcde}	85.66 ^a	79.66 ^{ab}
2	89.33 ^{cde}	10.00 ^a	7.66 ^{abc}	1.119 ^{abc}	79.00 ^{def}	82.33 ^c	79.33 ^{ab}
3	91.66 ^{ab}	10.00 ^a	8.00 ^{ab}	1.027 ^{bcdef}	79.66 ^{bcde}	85.00 ^{abc}	80.33 ^{ab}
4	89.66 ^{bcde}	9.00 ^a	6.66 ^{abcd}	0.941 ^{efghi}	76.00 ^g	83.00 ^{abc}	76.66 ^{ab}
5	89.33 ^{cde}	9.66 ^a	6.66 ^{abcd}	1.017 ^{cdefg}	76.33 ^g	82.33 ^c	76.33 ^b
6	91.00 ^{abcd}	10.00 ^a	8.33 ^a	1.130 ^{ab}	79.66 ^{bcde}	84.33 ^{abc}	79.33 ^{ab}
7	89.33 ^{cde}	9.66 ^a	8.00 ^{ab}	1.065 ^{abcd}	77.33 ^{fg}	82.33 ^c	81.00 ^a
8	91.33 ^{abc}	9.33 ^a	7.00 ^{abcd}	1.025 ^{bcdef}	80.00 ^{abcde}	83.66 ^{abc}	79.00 ^{ab}
9	89.66 ^{bcde}	10.00 ^a	6.66 ^{abcd}	1.026 ^{bcdef}	78.66 ^{ef}	82.66 ^{bc}	79.00 ^{ab}
10	89.33 ^{cde}	10.33 ^a	7.00 ^{abcd}	1.116 ^{abc}	80.33 ^{abcde}	82.66 ^{bc}	78.33 ^{ab}
11	91.66 ^{ab}	10.66 ^a	8.00 ^{ab}	1.135 ^a	80.33 ^{abcde}	84.66 ^{abc}	80.33 ^{ab}
12	91.66 ^{ab}	9.66 ^a	7.66 ^{abc}	1.057 ^{abcd}	82.00 ^a	85.00 ^{abc}	80.33 ^{ab}
13	89.66 ^{bcde}	9.00 ^a	7.33 ^{abcd}	0.995 ^{defgh}	80.00 ^{abcde}	83.33 ^{abc}	77.33 ^{ab}
14	90.66 ^{bcde}	9.66 ^a	7.33 ^{abcd}	1.038 ^{abcde}	80.33 ^{abcde}	84.33 ^{abc}	78.66 ^{ab}
15	89.33 ^{cde}	9.00 ^a	6.66 ^{abcd}	0.942 ^{efghi}	80.00 ^{abcde}	83.00 ^{abc}	77.33 ^{ab}
16	90.66 ^{bcde}	9.00 ^a	6.33 ^{bcd}	0.930 ^{efghi}	81.33 ^{abc}	84.00 ^{abc}	78.00 ^{ab}
17	90.33 ^{bcde}	8.66 ^a	6.66 ^{abcd}	0.929 ^{efghi}	81.00 ^{abcd}	84.33 ^{abc}	77.66 ^{ab}
18	89.33 ^{cde}	9.33 ^a	6.00 ^{cd}	0.921 ^{efghi}	79.66 ^{bcde}	82.66 ^{bc}	77.33 ^{ab}
19	89.00 ^{de}	9.66 ^a	6.00 ^{cd}	0.949 ^{efghi}	79.33 ^{cdef}	82.66 ^{bc}	76.66 ^{ab}
20	89.66 ^{bcde}	8.66 ^a	6.33 ^{bcd}	0.913 ^{ghi}	80.33 ^{abcde}	83.33 ^{abc}	78.33 ^{ab}
21	90.33 ^{bcde}	9.33 ^a	7.00 ^{abcd}	0.998 ^{defgh}	80.66 ^{abcde}	83.00 ^{abc}	77.66 ^{ab}
22	89.33 ^{cde}	8.66 ^a	6.33 ^{bcd}	0.930 ^{efghi}	80.33 ^{abcde}	83.00 ^{abc}	78.00 ^{ab}
23	89.66 ^{bcde}	9.33 ^a	6.33 ^{bcd}	0.989 ^{defgh}	81.33 ^{abc}	83.33 ^{abc}	77.66 ^{ab}
24	90.66 ^{bcde}	10.00 ^a	6.66 ^{abcd}	1.015 ^{cdefg}	81.66 ^{ab}	85.33 ^{ab}	78.33 ^{ab}
25	89.00 ^{de}	9.33 ^a	7.00 ^{abcd}	0.989 ^{defgh}	79.66 ^{bcde}	82.33 ^c	77.00 ^{ab}
26	89.00 ^{de}	8.33 ^a	6.00 ^{cd}	0.876 ⁱ	80.33 ^{abcde}	83.00 ^{abc}	77.00 ^{ab}
27	88.66 ^e	8.33 ^a	5.66 ^d	0.867 ⁱ	79.66 ^{bcde}	82.66 ^{bc}	77.00 ^{ab}
28	89.33 ^{cde}	8.66 ^a	6.00 ^{cd}	0.890 ^{hi}	80.33 ^{abcde}	83.33 ^{abc}	78.66 ^{ab}
29	88.66 ^e	8.33 ^a	5.66 ^d	0.859 ⁱ	79.33 ^{cdef}	82.33 ^c	76.66 ^{ab}
30	89.33 ^{cde}	9.00 ^a	6.00 ^{cd}	0.909 ^{ghi}	79.66 ^{bcde}	82.66 ^{bc}	77.33 ^{ab}
F. test	*	ns	*	*	*	*	*

Values with the same letter are not significantly different at $p < 0.05$

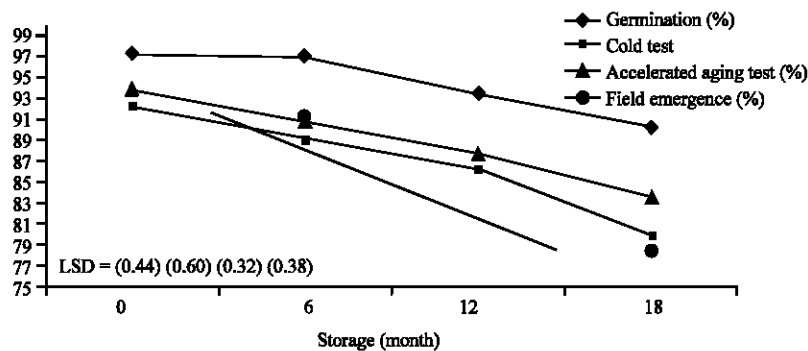


Fig. 1: Averages of germination, cold test, accelerated aging test and field emergence percentages of 30 maize hybrids lots after 0, 6, 12 and months storage

Table 6: Correlation coefficients between field emergence at 6 months storage and laboratory evaluations of 30 maize hybrids lots after 0 and 6 months (germination, shoot and root length, seedlings dry weight, cold test and accelerated aging test)

Seeds test	Correlation coefficient
Germination (%) at 0 month storage	0.761**
Shoot length (cm) at 0 month storage	0.402**
Root length (cm) at 0 month storage	0.431**
Seedlings dry weight (g) at 0 month storage	0.375**
Cold test (%) at 0 month storage	0.603**
Accelerated aging test (%) at 0 month storage	0.640**
Germination (%) at 6 months storage	0.852**
Shoot length (cm) at 6 months storage	0.374**
Root length (cm) at 6 months storage	0.238
Seedlings dry weight (g) at 6 months storage	0.327**
Cold test (%) at 6 months storage	0.646**
Accelerated aging test (%) at 6 months storage	0.593**

*: Significant at the level 0.05 level of probability, **: Significant at the level 0.01 level of probability

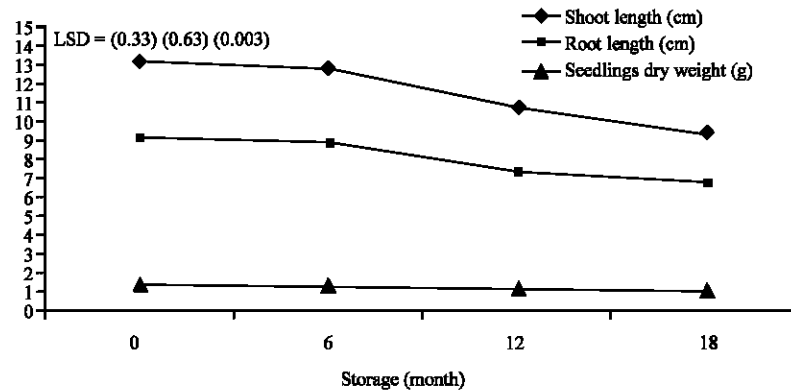


Fig. 2: Averages of shoot and root length (cm), seedlings dry weight (g) of 30 maize hybrids lots after 0, 6 and 12 months storage

Seedling measurements (shoot length, root length and seedling dry weight) were significantly differed after 0, 6, 12 and months storage as shown from data graphically demonstrated in Fig. 2. The decline in shoot length during different storage periods was significant. While, the differences in root length from 0 to 6 months as well as from 12 to 18 months were not significant. But, the decrease in root length was significant from 6 to 12 months storage. Regarding seedling dry weight, the continued decline was noted with significant differences during the different storage periods. Joao Abba and Lovato (1999) showed that storage reduced seedling growth in subsequent germination tests.

The correlations between various laboratory evaluations after 0 and 6 months storage (standard germination, shoot and root length, seedlings dry weight, cold test and accelerated aging test) and field emergence after 6 months storage were significant (Table 6). The highest correlations were detected between field emergence after 6 months storage and standard germination after 6 and 0 month. Followed by cold test after 6 months and accelerated aging test after 0 month, which were 0.852, 0.761, 0.646 and 0.640, respectively. Noli *et al.* (2010) found that all the laboratory measures were in close agreement with field performance when the latter was evaluated under less unfavorable conditions. Some studies in sesame and wheat crops had reported strong correlations

Table 7: Correlation coefficients between field emergence at 18 months storage and laboratory evaluations of 30 maize hybrids lots after 0, 6, 12 and 18 months (germination, shoot and root length, seedlings dry weight, cold test and accelerated aging test)

Seeds test	Correlation coefficient
Germination (%) at 0 month storage	0.585**
Shoot length (cm) at 0 month storage	0.368**
Root length (cm) at 0 month storage	0.293**
Seedlings dry weight (g) at 0 month storage	0.307**
Cold test (%) at 0 month storage	0.435**
Accelerated aging test (%) at 0 month storage	0.589**
Germination (%) at 6 months storage	0.662**
Shoot length (cm) at 6 month storage	0.314**
Root length (cm) at 6 months storage	0.171
Seedlings dry weight (g) at 6 months storage	0.236*
Cold test (%) at 6 months storage	0.436**
Accelerated aging test (%) at 6 months storage	0.568**
Field emergence (%) at 6 months storage	0.741**
Germination (%) at 12 months storage	0.585**
Shoot length (cm) at 12 months storage	0.281**
Root length (cm) at 12 months storage	0.310**
Seedlings dry weight (g) at 12 months storage	0.194
Cold test (%) at 12 months storage	0.336**
Accelerated aging test (%) at 12 months storage	0.520**
Germination (%) at 18 months storage	0.592**
Shoot length (cm) at 18 months storage	0.184
Root length (cm) at 18 months storage	0.279**
Seedlings dry weight (g) at 18 months storage	0.253**
Cold test (%) at 18 months storage	0.324**
Accelerated aging test (%) at 18 months storage	0.453**

*: Significant at the level 0.05 level of probability, **: Significant at the level 0.01 level of probability

between the standard germination test and field emergence (Adebisi, 2008; Khan *et al.*, 2010). While, Shah *et al.* (2002), Maree *et al.* (2007) and Aliloo and Shokati (2011) reported that because of high correlation with field emergence, among vigor tests, accelerated aging and cold tests can be utilized to predict field emergence of maize hybrids under unfavorable conditions. These results are in agreement with those stated by Woltz *et al.* (1998) and Lovato *et al.* (2005). The best model for prediction of field emergence after 6 months storage of 30 maize hybrids lots obtained from stepwise multiple regression analysis was a single-variable model utilizing standard germination at 6 months as the independent variable [field emergence = $11.33 + 0.82$ (standard germination); $r^2 = 0.725$]. Followed utilizing standard germination at 0 month as the independent variable [field emergence = $24.70 + 0.68$ (standard germination); $r^2 = 0.579$], then utilizing cold test at 6 months as the independent variable [field emergence = $52.50 + 0.43$ (cold test); $r^2 = 0.417$] and utilizing accelerated aging test after 0 month as the independent variable [field emergence = $39.44 + 0.55$ (accelerated aging test); $r^2 = 0.409$]. Navratil and Burris (1980) observed in their work to develop equations to predict field emergence that most predictive equation included both standard germination and time of 50% emergence.

After 18 months storage, the correlations between field emergence and different laboratory evaluations after 0, 6, 12 and 18 months storage (standard germination, shoot and root length, seedlings dry weight, cold test and accelerated aging test) were significant. Except, root length after 6 months storage, seedlings dry weight after 12 months storage and shoot length after 18 months storage as shown from data in Table 7. The highest correlations value (0.741) was recorded

between field emergence percentage after 18 months storage and field emergence percentage after 6 months storage. Followed by germination percentage after 6 and 18 months, accelerated aging test after 0 month, germination percentage after 12 or 0 month and accelerated aging test after 6 months storage, which were 0.662, 0.592, 0.589, 0.585 and 0.568, respectively. Sulewska *et al.* (2009) found that maize seed germination in field conditions after two years storage were more positively correlated with results of standard germination test than of the cold one. In order to predict field emergence after 18 months storage of 30 maize hybrids lots the best model was obtained from stepwise multiple regression analysis was a single-variable model utilizing field emergence percentage after 6 month as the independent variable [field emergence after 18 months = $12.78 - 0.99$ (field emergence after 6 months); $r^2 = 0.548$]. While, when using laboratory tests, the best model for prediction field emergence after 18 months storage of 30 maize hybrids lots was obtained from stepwise multiple regression analysis as a single-variable model utilizing standard germination percentage after 6 month as the independent variable [field emergence after 18 months = $5.36 - 0.86$ (standard germination percentage after 6 month); $r^2 = 0.438$], followed by utilizing standard germination after 18 months as the independent variable [field emergence after 18 months = $17.94 + 0.66$ (standard germination after 18 months); $r^2 = 0.351$]. Followed by utilizing accelerated aging test after 0 month as the independent variable [field emergence after 18 months = $14.02 + 0.68$ (accelerated aging test after 0 month); $r^2 = 0.347$]. Then utilizing standard germination after 0 month as the independent variable [field emergence after 18 months = $9.35 + 0.70$ (standard germination after 0 month); $r^2 = 0.342$], utilizing standard germination after 12 months as the independent variable [field emergence after 18 months = $3.17 + 0.80$ (standard germination after 12 months); $r^2 = 0.343$] and utilizing accelerated aging test after 6 months as the independent variable [field emergence after 18 months = $21.94 + 0.61$ (accelerated aging test after 6 months); $r^2 = 0.323$].

CONCLUSION

Summarizing the results of the laboratory seed tests showed that the standard germination percentage, seedling measurements and seed vigor tests were significantly affected by studied maize hybrids lots after 0, 6, 12 and 18 months storage, except root length, seedling dry weight and shoot length after 6, 12 and 18 months storage, respectively. Seed quality mentioned by laboratory seed tests as well as field emergence decreased as storage period increased. The highest correlations were detected between field emergence after 6 months storage and standard germination after 6 and 0 month followed by cold test after 6 months and accelerated aging test after 0 month. The best model for prediction of field emergence after 6 months storage variable was [field emergence = $11.33 + 0.82$ (standard germination); $r^2 = 0.725$]. In order to predict field emergence after 18 months storage the best model was [field emergence after 18 months = $5.36 - 0.86$ (standard germination after 6 month); $r^2 = 0.438$], followed by = $17.94 + 0.66$ (standard germination after 18 months); $r^2 = 0.351$].

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