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Viability of Stored Maize Seed Exposed to Different Periods of High Temperature During the Artificial Drying

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ABSTRACT
A plan for drying seed artificially is necessary, during the inadequate field drying conditions to avoid the lost of large volumes of high quality maize seed. This work aimed to examine effects of the exposure to high drying temperature at different periods on maize seed quality soon after drying, after 3 and 6 months from storage. The obtained ears of hybrid single cross 10 (Sc.10) was grown at the Agricultural Research Station Farm in Gemmiza, Garbia Governorate, Agricultural Research Center, Egypt, during 2013 season. Cobs were harvested to obtain seed with moisture percentage ranges from 30-33% and exposure to different high drying temperature periods and then completed drying at 38°C until reach to 12% seed moisture content (50°C for 28 h, 50°C for 24 h+38°C for 5.50 h, 50°C for 20 h+38°C for 12.00 h, 50°C for 16 h+38°C for 17.30 h, 50°C for 12 h+38°C for 22.50 h, 50°C for 8 h+38°C for 29.00 h, 50°C for 4 h+38°C for 34.45 h and 38°C for 40.00 h). Dried seed was stored during 2013 and 2014 seasons at the laboratory natural conditions of Seed Technology Research Unit in Mansoura, Dakahlia Governorate, Field Crops Research Institute, Agricultural Research Center, Egypt. Laboratory seed quality tests (fast green test, standard germination, abnormal seedlings, speed of germination, cold test, electrical conductivity, shoot length, root length and seedling dry weight) were conducted soon after drying, after 3 and 6 months from storage. The drying temperature can be raised to 50°C for seed harvested at a moisture range (30-33%) with maintaining adequate levels of seed and seedling vigor. The best combination treatment maintains standard germination above 90% soon after drying was drying at 50°C for 20 h before completed drying at 38°C until obtain 12% seed moisture content. But after 6 months storage, the best one was 50°C for 16 h before completed drying at 38°C which maintains standard germination above 88%. These combinations can be saving about 21 and 16.25% drying time, respectively with maintaining adequate levels of seed and seedling vigor.

Key words: Maize, seed quality, high temperature periods, artificial drying, storage periods

INTRODUCTION
The purpose of seed drying is to reduce respiration by removal of excess moisture and to prevent the qualitative deterioration of seeds in storage, which arising from microorganism growth and the activities of insects and mites (McLean, 1989). Such that, could extend their storage life. Field drying of crop seed depends on the climate at harvest. In Egypt, 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 into early or late than optimum date. This creates a significant barrier to use artificial drying of ear-maize after harvest, particularly of the late one, whereas the decline of air temperature and solar radiation at the early winter months. In addition, maize seed is usually harvested in the ear to minimize mechanical damage that allows product

removal at high moisture contents. Therefore, ear maize seed drying will be extremely slow and seed moisture content will reach about 20% based on the equilibrium moisture content for average monthly air temperature and relative humidity conditions. Since the seed moisture content is the main factor which decides whether or not seed can be stored safely, until sowing date without loss of seed quality. Seed moisture content 14% or less is considered safe for different crops species for short term storage (Kelly, 1988). In which case, the immediate artificial drying to 12-13% moisture content could be the only resolve to avoid the lost of large volumes of high quality maize genotype seed, because of excess of moisture content.

It is probable that most seeds commonly used in agriculture are injured to a greater or lesser extent by the application of high temperatures (Weaver and Clements, 1938). Hence, in order to be on the safe side, most seed producers use low temperature for their drying operations. The effect of drying of ear maize at 40-70°C on seed viability was investigated by Harrison and Wright (1929), they found that ear maize dried to less than 10% moisture content at temperatures 40-45°C was not injured either in viability, seedling growth or field performance. However, maize dried at 50°C was damaged and at 60°C had 0% viability. Contrary, Thuy *et al.* (1999) reported that maize seeds could be intermittently dried at 60°C for 10 min without quality deterioration. Drying studies conducted by other investigators reported that tolerance to a higher temperature up to 50°C dependent upon seed moisture content. Jittanit (2007) found that dryer type, drying temperature, initial moisture content of seeds and drying time had significant effects on the seed germination. Kiesselbach (1939) found that no differences in maize seed germination when seed harvested between 16 and 30% moisture content and drying at a temperature range of 42-45°C but germination was gradually reduced for seed moisture between 50 and 57%. Reiss (1944) noticed reduction in viability and seedling vigor when seed dried at 43.3 or 48.9°C as compared with those dried at 37.8°C. Wileman and Ullstrup (1945) found insignificant reduction in germination by a high drying temperature of 48.9°C when the initial seed moisture content was 25%. While, Navratil and Burris (1984) showed that drying maize by high temperatures of 45 and 50°C adversely affect germination and seedling vigor. However, McRostie (1949) found decrease in maize seed viability when dried ear with initial moisture content over 50% at temperature over 41°C. If air temperature is increased, seed germination subsequently declines (Navratil and Burris, 1982, 1984; Wellington and Bradnock, 1964) and electrical conductivity of leachate increased (Seyedin *et al.*, 1984). Harrison and Wright (1929) studied the effects of dried ear maize at high temperatures. They reported that the lower seed moisture content was the greater in damage during the early period of drying, because of the quicker penetration of heat in low-moisture maize. Wileman and Ullstrup (1945) found that maize seed with an initial moisture content of less than 25% may be dried at temperatures of 49°C without danger of impairing the germination of the seed.

More studies have concentrated on effects of drying temperatures periods on maize seed viability. De Ong (1919) obtained normal germination after exposing 5 maize varieties for 8 h at 49°C, while Burgess (1919) found that maize which germinated 94% suffered reduction in viability to 68 and 32%, respectively when heated at 80°C for periods of 1 and 3 h. According to Washko (1941) drying ear samples 46% moisture content at 49°C were injured after 36 h. On the other hand, dried ear maize below 47% moisture content at 40°C for 72 h, they found that seed viability was not affected (Burris and Navratil, 1980). Thereafter, Herter and Burris (1989a) demonstrated that ear harvested at 48 and 38% seed moisture could be dried at 50°C for 4-15 h and 18-24 h, respectively, before germination started to decrease linearly with prolonged 50°C, while seedling dry weights started to decrease after dried for a few hours. Morey *et al.* (1978) and Muhlbauer *et al.* (1981) found that maize drying at high temperature for the first stage followed by low temperature drying for the next step can reduce energy consumption as compared with a high temperature drying.

The objective of this study was to examine the effects of use high drying temperature in different periods on maize seed quality during storage periods.

MATERIALS AND METHODS

A laboratory experiment was carried out under the laboratory conditions of Seed Technology Research Unit in Mansoura, Dakahlia Governorate, Seed Technology Research Department, Field Crops Research Institute, Agricultural Research Center during the winter season of 2013 and 2014. The purpose of this investigation was to examine the effects of use high drying temperature in different periods on maize seed quality during storage periods. The obtained ears of hybrid maize (*Zea mays* L.) Single Cross 10 (SC 10) that used in these experiments were produced by Maize Research Department, Field Crops Research Institute, Agricultural Research Center, Egypt. The hybrid grown at Agricultural Research Station Farm in Gemmiza, Garbia Governorate, Agricultural Research Center, Egypt, during 2013 season by using the inbred line Sids 7 (Sd. 7) as seed parent, inbred line Sids 63 (Sd. 63) as pollinator. After physiological maturity, moisture content was measured by a BURROWS DMC 500 moisture tester. Seed samples for moisture content were obtained by removing four rows of seed from the entire length of the ear in each of the 10 ears chosen for this purpose. Ears were harvested in 29 October 2013 to obtain seed with moisture content ranges: 30-33%. Samples were brought immediately to the laboratory of Seed Technology Research Unit in Mansoura. Ears were hand-husked and three replicates of 7 ears were dried by use a Universal Rapid Dryer Type TG-1. The husked ears were spread in dryer. A preliminary experiment was conducted to calculate the drying time at 50°C until reach to 12% seed moisture content, which was 28 h. Accordingly, the other drying treatments were dried at 50°C intervals of 4 h and then completed drying at 38°C until reach to 12% seed moisture content. The drying time at 38°C was also calculated for every treatment (Table 1).

Therefore, the studied drying treatments were as follow:

- Drying ears at 50°C for 28 h
- Drying ears at 50°C for 24 h+38°C for 5.50 h
- Drying ears at 50°C for 20 h+38°C for 12.00 h
- Drying ears at 50°C for 16 h+38°C for 17.30 h
- Drying ears at 50°C for 12 h+38°C for 22.50 h
- Drying ears at 50°C for 8 h+38°C for 29.00 h
- Drying ears at 50°C for 4 h+38°C for 34.45 h
- Drying ears at 38°C for 40.00 h

Table 1: Effect of drying periods at 50°C on seed moisture content and drying period at 38°C until reach to 12% seed moisture content

Drying period (h) at 50°C	Seed moisture content (%) after drying	Drying period (h) at 38°C until reach to 12% seed moisture content
28	12.0	-
24	14.7	5.50
20	17.5	12.00
16	20.0	17.30
12	22.4	22.50
8	25.1	29.00
4	27.8	34.45
0	30.0	40.00

The air flow was set at 1800 L min^{-1}. When a sample reached about 12% moisture, it was removed from the dryer, the cobs were shelled manually and seeds for each treatment were packed in cotton bags and stored under the laboratory natural conditions until seed quality evaluation.

Fast green test (pericarp damage): Three replicates of 50 seed from each treatment were submerged in 0.1% fast green solution for 15-30 sec, rinsed under running tap water and air, dried. Staining patterns were used to classify seed damage with more stain indicating more pericarp damage (Koehler, 1957). Seeds were sorted to 3 categories:

- **Good seeds:** Few coloured zones and colourings far from embryo
- **Medium seeds:** Coloured zones near the embryo
- **Bad seeds:** Deep coloured zones on the embryo

Standard germination: Three replications of 50 seed from each treatment were planted in sand soil were placed into plastic box (25×13×10 cm) at the depth of 1.5 cm. Normal seedlings were evaluated after 7 days. Germination percentage was expressed by the percentage of seed germinating normally after 7 days according to ISTA (1996).

Abnormal seedlings: Abnormal seeding was conducted during standard germination evaluation after 7 days. Abnormal seedlings were counted and expressed by the percentage of abnormal seedlings after 7 days according to ISTA (1996).

Speed of germination: Three replicates were also used to evaluate daily speed of germination (during standard germination test). Speed of germination was calculated according to the following equation given by Maguire (1962):

$$\text{Speed of germination} = n1/d1+n2/d2+n3/d3+\text{----------}$$

where, n is the number of germinated seeds, d is the number of days.

Cold test: Three replicates of 50 seed from each treatment were planted in sand soil were 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 according to AOSA (1999).

Electrical conductivity: Three replicates of 50 weighed seed from each treatment incubated for 24 h in 250 mL flask containing 200 mL of deionized water at 20°C. After that period the conductivity of the solution immediately measured with conductivity meter CMD 830 WPA and expressed as µmhos per centimeter per gram of seed (Matthews and Powell, 1981).

Shoot length: About 10 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 of shoot length evaluation test used to evaluate root length (cm).

Seedlings dry weight: After evaluating shoot and root length, 10 seedlings were dried in a forced air oven at 110°C for 17 h (Agrawal, 1986) to obtain seedlings dry weight and expressed as grams.

Statistical analysis: Data was subjected to the statistical analysis according to the technique of analysis of variance (ANOVA) for the factorial completely randomized design as published by (Gomez and Gomez, 1984). Means of studied factors were compared using Duncan's multiple range tests at 5% level of probability as described by Duncan (1955).

RESULTS AND DISCUSSION

The fast green test (pericarp damage) was originally developed to evaluate mechanical damage in maize. Greater pericarp damage increases the amount of green staining on the seed surface. That correlated with low seed germination percentage (Koehler, 1957).

In this study, the fast green test results were strongly influenced by seed drying treatments (Table 2). Drying ears at 50°C for 28 h had a highest percentage of deep coloured zones on the embryo (Bad seeds) which was 86.0, 90.3 and 94.6% after 0, 3 and 6 months, respectively. Conversely, the category (good seeds) was not founded with drying at 50°C for 28 and for 24 h but the other treatments were not founded in category (bad seeds) except the little percentages (1 and 4%) produced after 3 and 6 months from drying at 50°C for 20 h.

Standard germination percentages of the different temperature periods (seed drying treatments) directly after drying treatment (0 month), after three months and 6 months from storage are presented in Table 3. Directly after drying treatment (at the beginning of storage) standard germination percentages for all drying treatments were highest (>90%) except drying for 28 and 24 h (79 and 83.66%). This indicated that the longer exposure period of seed to 50°C reduced germination percentage as compared with other drying treatments. All drying treatments generally showed decreasing in germination percentage with increase in storage periods. However, the decrease was greater in 50°C for each 28 and 24 h (12.67 and 10%) than other treatments which retained at higher germination after 6 months storage. Although, the drying time at 50°C (24 and 20 h) produced low standard germination (73.66 and 84.66%) after 6 months of storage but these values tended to be well below at the maize acceptance level (85%) for certified maize seed. However, the germination obtained from drying with 50°C for 28 h (66.33%) was far of the recommended minimum level of acceptance. The injury from high temperature drying such as seed internal cracks, split seed coats and discolouration might be important causes of viability loss (Siddique and Wright, 2003). Escasinas (1986) declared that seed viability was not affected by the number of stress cracks but the type (single, multiple and crazed) and location of them. Cracks which extended into the embryo had the most influence on loss of seed quality. Levitt (1980) stated that there was no injury observed with seeds until the drying temperature was high enough to break the valence bonds in proteins and other protoplasmic compounds. Enzyme and protein denaturation could be one of the reasons for quality loss of seeds. Baker *et al.* (1991) stated that at least one of the enzymes, involved in the germination process was denatured after high temperature drying. Meanwhile, Abdalla and Roberts (1968), Nellist and Hughes (1973) and Siddique and Wright (2003) found that severe heat damage of seed involved inactivation of enzymes. Subsequently, cause rapid loss of viability. These findings agree with those obtained by Herter and Burris (1989a). They reported that standard germination values started to decline after

Table 2: Fast green test with bad, medium and good values of hybrid (Sc 10) seed as affected by drying treatments after 0, 3 and 6 months storage

	Fast green test (Bad)			Fast green test (Medium)			Fast green test (Good)		
Seed drying treatments	At 0 month	After 3 months	After 6 months	At 0 month	After 3 months	After 6 months	At 0 month	After 3 months	After 6 months
50°C for 28 h	86.0^{c}	90.3^{b}	94.6^{a}	14.0^{j}	32.0^{k}	5.3^{l-o}	0.0^{m}	0.0	0.0
50°C for 24 h+38°C for 5.50 h	63.6^{f}	68.0^{e}	71.6^{d}	36.3^{f}	88.3^{g}	28.3^{h}	0.0^{m}	0.0	0.0
50°C for 20 h+38°C for 12.00 h	0.0	1.0	4.00^{g}	84.0^{b}	52.0^{a}	89.0^{a}	16.0^{j}	10.6^{k}	7.0^{l}
50°C for 16 h+38°C for 17.30 h	0.0	0.0	0.00	42.0^{e}	9.3^{d}	61.3^{c}	58.0^{g}	48.0^{h}	38.6^{i}
50°C for 12 h+38°C for 22.50 h	0.0	0.0	0.00	7.6^{kl}	5.3^{k}	23.0^{i}	92.3^{c-e}	90.6^{e}	77.0^{f}
50°C for 8h +38°C for 29.00 h	0.0	0.0	0.00	3.3^{m-p}	5.6^{l-o}	8.0^{kl}	96.6^{ab}	94.6^{bc}	92.0^{de}
50°C for 4 h+38°C for 34.45 h	0.0	0.0	0.00	2.3^{op}	2.0^{l-n}	6.3^{lm}	97.6^{a}	94.3^{b-d}	93.6^{cd}
38°C for 40.00 h	0.0	0.0	0.00	1.6^{p}	32.0^{p}	2.6^{n-p}	98.3^{a}	98.0^{a}	97.3^{a}
F-test		*			*			*	

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

Table 3: Standard germination percentage, speed of germination and abnormal seedlings percentage of hybrid (Sc 10) seed as affected by drying treatments after 0, 3 and 6 months storage

	Standard germination (%)			Abnormal seedlings (%)			Speed of germination		
Seed drying treatments	At 0 month	After 3 months	After 6 months	At 0 month	After 3 months	After 6 months	At 0 month	After 3 months	After 6 months
50°C for 28 h	79.00^{k}	73.66^{l}	66.33^{m}	13.00^{b}	13.66^{b}	18.66^{a}	22.10^{l}	19.10^{n}	15.36^{o}
50°C for 24 h+38°C for 5.50 h	83.66^{j}	79.66^{k}	73.66^{l}	9.66^{c}	10.33^{c}	14.33^{b}	27.93^{j}	24.83^{k}	20.46^{m}
50°C for 20 h+38°C for 12.00 h	90.66^{f-h}	88.00^{i}	84.66^{j}	2.66^{f-j}	4.33^{d-h}	6.33^{d}	30.73^{d-f}	28.93^{hi}	27.36^{j}
50°C for 16 h+38°C for 17.30 h	94.00^{b-d}	92.33^{d-f}	88.66^{hi}	1.33^{ij}	3.00^{e-i}	5.66^{de}	31.30^{b-e}	30.23^{fg}	28.30^{ij}
50°C for 12 h+38°C for 22.50 h	94.33^{b-d}	92.66^{c-f}	89.66^{g-i}	0.33^{ij}	2.33^{g-j}	5.33^{d-f}	31.56^{b-d}	31.13^{c-f}	29.46^{gh}
50°C for 8 h+38°C for 29.00 h	95.33^{ab}	93.00^{c-e}	90.00^{g-i}	0.33^{ij}	2.00^{h-j}	5.00^{d-g}	31.63^{b-d}	31.70^{b-d}	30.33^{e-g}
50°C for 4 h+38°C for 34.45 h	96.66^{a}	94.33^{b-d}	90.66^{f-h}	0.00^{j}	1.33^{ij}	4.33^{d-h}	32.70^{a}	32.10^{a-c}	31.30^{b-e}
38°C for 40.00 h	97.00^{a}	94.66^{bc}	91.33^{e-g}	0.00^{j}	1.00^{ij}	4.66^{d-h}	32.70^{a}	32.26^{ab}	31.66^{b-d}
F-test		*			*			*	

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

18-24 h at 50°C when ear were harvested at 38% seed moisture content. Gupta *et al.* (2005) reported that seed harvested at lower moisture and dried at high temperature retained higher germination at the end of the 6 month storage.

Significant differences in physiological seed quality (indicated by abnormal seedlings) as affected by different drying temperatures periods under storage periods (Table 3). Drying seed at 50°C up to 16 h consistently remain higher seedling vigor. These trends occurred even though storage periods with gradually increase in abnormal seedlings. Whereas, the highest percentage of abnormal seedlings (lower quality) produced from drying for 28 h followed by 24 h after 6 months this was 18.66 and 14.33%, respectively. This suggests that larger number of seed were damaged during artificial drying. Thomson (1979) found that after drying, the seedlings from seeds had the testa of the pulse seeds cracked and separated from the cotyledons, had reduced vigour and poor establishment. He added that artificial drying can lower the seed germination and give rise to abnormal seedlings.

Speed of germination values as affected by different seed drying treatments immediately after drying (0 month storage) were significant (Table 3).

As drying temperature (50°C) time increased speed of germination decreased. The lowest speed of germination values were obtained when maize ears drying at 50°C for 28 h, followed by drying for 24 h (22.10, 27.93), whereas the other ears drying treatments retained faster in germination. For example, increase time of exposure to 50°C from control (0 h) passing by 4 to 8, 12, 16 and 20 h produced 32.70, 32.70, 31.63, 31.56, 31.30 and 30.73, respectively. All drying treatments decreased speed of germination with increase storage periods up to 6 months. The decrease was small up to 20 h exposure and a much larger with 24 and 28 h at 50°C. The longer exposure periods (24 and 28 h) to high drying temperature may be deteriorating the seed further multiplying during storage which delayed germination after 6 months.

Regarding the germination in cold test, the results obtained from Table 4, indicated that normal seedling percentages soon after drying varied from 74.33-94.33% for the different drying treatments. Grabe (1976) reported that 70-80% normal seedlings resulting from the cold test as being adequate levels of quality for commercial seed lots. After three months stored seed dried at 50°C for 28 h was more sensitive to storage as revealed by significant decline

Table 4: Cold test and electrical conductivity of hybrid (Sc 10) seed as affected by drying treatments after 0, 3 and 6 months storage

	Cold test (%)			Electrical conductivity (μmhos)		
Seed drying treatments	At 0 month	After 3 months	After 6 months	At 0 month	After 3 months	After 6 months
50°C for 28 h	74.33^{k}	68.66^{l}	61.33^{m}	3.52^{c}	3.84^{b}	4.14^{a}
50°C for 24 h+38°C for 5.50 h	81.00^{j}	75.00^{k}	68.66^{l}	$3.18^{e\text{-}g}$	3.30^{d}	3.45^{c}
50°C for 20 h+38°C for 12.00 h	$88.33^{f\text{-}h}$	85.66^{i}	82.33^{j}	$3.07^{g\text{-}i}$	3.20^{de}	3.29^{d}
50°C for 16 h+38°C for 17.30 h	90.66^{de}	90.33^{e}	87.33^{hi}	3.03^{hi}	$3.09^{f\text{-}h}$	3.18^{ef}
50°C for 12 h+38°C for 22.50 h	$92.33^{b\text{-}d}$	90.33^{e}	87.66^{gh}	3.01^{hi}	3.02^{hi}	$3.08^{f\text{-}i}$
50°C for 8 h+38°C for 29.00 h	93.66^{ab}	$91.00^{c\text{-}e}$	$88.00^{f\text{-}h}$	2.98^{hi}	3.00^{hi}	3.04^{hi}
50°C for 4 h+38°C for 34.45 h	94.00^{ab}	$92.33^{b\text{-}d}$	$89.33^{e\text{-}g}$	2.97^{i}	2.99^{hi}	3.03^{hi}
38°C for 40.00 h	94.33^{a}	$92.66^{a\text{-}c}$	89.66^{ef}	2.97^{i}	2.99^{hi}	3.02^{hi}
F-test		*			*	

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

(74.33-68.66%). This value did not reach to the adequate levels of quality for commercial seed lots as compared with other drying treatments. The same case was observed with seed dried at 50° for 24 h (<70%) which was 68.66% after 6 months storage. The cold test results were lower than the standard germination percentages, which was 61.33 and 66.33%, respectively after 6 months storage. This is indicating that cold test results are a more sensitive measure of artificial drying injury. Livingston (1952) showed that among various factors have been shown to influence germination in the cold tests artificial drying. These results agree with the reports of Navratil and Burris (1984) and Herter and Burris (1989a, b, c).

The much larger reduction in standard and cold germination tests with storage for seed dried at 50°C with prolonged exposure time would indicate that the accelerated drying time result in reduced in storability.

After 24 h of soaking dried seed in deionized water at 20°C, Electrical Conductivity (EC) of the soak water differed for the eight different temperature time (Table 4).

Conductivity values of the leachate were generally higher for seed dried at each of 50°C for 28 and for 24 h (3.52 and 3.18 μmhos) than other drying treatments. The EC measures the leakage occurring during the early stages of seed imbibitions due to damage to the cell membrane (AOSA, 1983). Greater pericarp damage may be occurred from high temperature drying, subsequently increased the deterioration during storage. This is may be increased the amount of seed leachates in the water and, therefore, EC increases which were 14.4 and 3.45 μ mhos after 6 months of 50°C for 28 and for 24 h, respectively.

After drying ear-maize at high temperature, there was a substantial reduction of starch grains in the embryonic axis, while the electrolyte and sugar leakage was significantly increased. It was suggested that the starch hydrolysis in the embryonic axis caused the sugar leakage upon hydration leading to germination loss. Also, the increase in leaching of electrolytes may be indicative of increased membrane permeability, which may be due to deteriorative changes in the membranes after exposure to 50°C drying temperature (Seyedin *et al*., 1984).

Shoot and root length and its dry weight were significantly affected by different seed drying treatments and storage periods (Table 5). Shoot lengths, soon after drying were lower in seedlings grown from seed dried at 50°C for 28, 24 or 20 h (13.66, 16.00, 16.66 cm) as compared with seedlings grown from other treatments. In all treatments, the results indicated that stored seed for three months is not effective as that a period of six months, while the decline in shoot length was remarkable at longer time of exposure (28 and 24 h) than other treatments.

Similar to shoot length, root length declined with the passage of time whereas, the sharp declines were at dried of each 50°C for 28 and for 24 h (9.66, 10.33 cm) after 6 months from storage than other drying treatments. Navratil and Burris (1984) found that high drying temperature affected on shoot and root values. However, the values indicated that maize root development was susceptible to injury than shoot development.

As was the case with shoot and root lengths, drying for 28 and 24 h also showed a low seedling dry weight values, while the other six drying treatments presented the best seedling dry weight. The lower seedling dry weight resulted from seed dried at 50°C was found also by Seyedin *et al.* (1984), probably due to enzymatic modifications (Anderson and Gupta, 1986) that resulted in higher membrane permeability (Herter and Burris, 1989a, b, c).

Table 5: Shoot and root length and seedlings dry weight of hybrid (Sc 10) seed as affected by drying treatments after 0, 3 and 6 months storage

	Shoot length (cm)			Root length (cm)			Seedlings dry weight (g)		
Seed drying treatments	At 0 month	After 3 months	After 6 months	At 0 month	After 3 months	After 6 months	At 0 month	After 3 months	After 6 months
50°C for 28 h	13.66^{hi}	13.00^{hi}	10.66^{j}	12.66^{hi}	11.33^{ij}	9.66^{k}	1.095^{lm}	0.969^{n}	0.870^{o}
50°C for 24 h+38°C for 5.50 h	16.00^{fg}	14.66^{gh}	12.00^{ij}	13.66^{f-h}	12.66^{hi}	10.33^{jk}	1.225^{jk}	1.165^{kl}	1.044^{mn}
50°C for 20 h+38°C for 12.00 h	16.66^{d-f}	16.33^{e-g}	15.66^{fg}	15.33^{c-e}	14.66^{e-g}	13.33^{gh}	1.393^{d-g}	1.322^{a}	1.222^{jk}
50°C for 16 h+38°C for 17.30 h	18.00^{b-e}	17.33^{c-f}	15.66^{fg}	15.66^{b-e}	15.00^{d-f}	13.33^{gh}	1.434^{b-g}	1.355^{f-i}	1.261^{i-k}
50°C for 12 h+38°C for 22.50 h	18.66^{a-c}	18.33^{b-d}	17.33^{c-f}	16.66^{a-c}	16.33^{a-d}	15.00^{d-f}	1.454^{b-f}	1.375^{e-h}	1.284^{h-j}
50°C for 8 h+38°C for 29.00 h	19.33^{ab}	18.66^{a-c}	17.33^{c-f}	17.33^{a}	17.00^{ab}	15.66^{b-e}	1.495^{b-d}	1.420^{c-g}	1.332^{g-i}
50°C for 4 h+38°C for 34.45 h	19.33^{ab}	19.33^{ab}	18.00^{b-e}	17.33^{a}	17.00^{ab}	16.33^{a-d}	1.529^{b}	1.457^{b-f}	1.357^{f-i}
38°C for 40.00h	20.33^{a}	19.66^{ab}	18.66^{a-c}	17.66^{a}	17.33^{a}	17.00^{ab}	1.526^{bc}	1.471^{b-e}	1.385^{e-h}
F-test		*			*			*	

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

CONCLUSION

Ear maize up to 30-33% seed moisture content can be successfully quicker dried at 50°C. Selecting a combination of high and low temperature degrees can reduce the drying time as compared with a low temperature drying. The best combination maintains standard germination above 90% soon after artificial drying was at 50°C for 20 h before completed drying at 38°C for 12 h. But after 6 months storage, the best one was 50°C for 16 h before completed drying at 38°C for 17.30 h which maintains standard germination above 88%. These combinations result in saving of about 21 and 16.25% drying time, respectively with maintaining adequate levels of seed and seedling vigor.

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