Germination and Seedling Parameters of Wheat as Affected by Storage Conditions

S E Seadh*, M A Badawi, M A Abdel-Moneamand, M M E Borham
Agronomy Department, Faculty of Agriculture, Mansoura University, Egypt.

*Corresponding author e-mail: seseadh04@mans.edu.eg

Abstract. A storage experiment was carried out from 27\textsuperscript{th} April to 27\textsuperscript{th} December, 2019 to study the effect of storage conditions \textit{i.e.} methods (open air, under sunshade and in stores), packages type (normal, gunny, polyethylene and metal containers) and periods of seeds fumigation with phosphine (15, 30 and 45 days) on germination and seedling parameters of wheat. The experiment was arranged in a factorial experiment in randomized complete block design (R.C.B.D.) with four replications. Stored wheat seeds under sunshade produced the highest values of final germination percentage, germination index, mean germination time, plumule length, radical length, seedling vigor index and seedlings dry weight, followed by stored wheat seeds in stores. The highest germination index, mean germination time, plumule and radical lengths, seedling vigor index and seedlings dry weight were recorded in the samples of wheat seeds sealed stored in metal containers, followed by normal stored in gunny packages. The highest percentage of final germination was obtained by normal stored in gunny packages, followed by sealing storage in metal containers. The highest final germination percentage, germination index, mean germination time, plumule length, radical length, seedling vigor index and seedlings dry weight and the lowest abnormal seedlings percentage, rotten and sold seeds percentages, speed germination index, co-efficient of germination and germination energy percentage were recorded when treated with phosphine at the rate of 3 tablets/m\textsuperscript{3} after 15 days from beginning the storage. This study recommended that stored wheat seeds under sunshade in metal packages and treating with phosphine at the rate of 3 tablets/m\textsuperscript{3} after 15 days from beginning the storage to enhance germination and seedlings parameter of wheat under the environmental conditions of Dakalia Governorate, Egypt.

1. Introduction
Wheat (\textit{Triticum aestivum vulgare} L.) is the most widely grown crop in the world with its unique protein characteristics and serves as an important source of food and energy [1]. But, seeds are stored to preserve it from storing to consuming without any quality loss. The choice of the most suitable and economical storage method has great importance on storage period under consideration of climate conditions. [2] showed that the germination and seedling vigor of wheat seeds stored under the hermetic system increased, due to the seed dormancy breaking, while those stored under the conventional system (open air) showed a linear decrease. The selection of a storage packages depends on the production level, cultural practices and the climatic conditions of the region [3]. [4] concluded that wheat seed stored in gunny, cloth and plastic
bags were in good terms of germination characters in comparison with those in metal and earthen bins. [5] revealed that tin container showed an increase in germination percentage, plumule and radical length, seedling vigor index, seedlings dry weight with decrease in days to germination of seeds during storage. [6] showed that the highest final germination percentage was recorded in samples of wheat sealed stored in metal packages, followed that normal stored in jute bags. [7] showed that at room temperature, seed stored in polythene bag had the highest germination %.

Fumigation is a technique employed to eliminate insect pests in stored seeds by using gas. Fumigation with phosphine (PH$_3$, hydrogen phosphide) has the potential to disinfect seed stored in silo bags. [8] found that seed of wheat can be stored in the open air, while maintaining the seed of good quality in the moisture content does not exceed 14% after fumigation with phosphine in relative humidity up to 57%. [6] revealed that the highest final germination percentage was produced from treating with phosphine at the rate of 5 tablets/m$^3$. [9] stated that the lowest abnormal seedlings, rotten seeds and sold seeds percentages and the highest final germination of wheat seeds were produced from treating with phosphine at the rate of 8 ppm.

Thus, this investigation was established to study the effect of storage methods, packages type and periods of seeds fumigation with phosphine on germination and seedling parameters of wheat under the environmental conditions of Dakahlia Governorate, Egypt.

2. Materials and methods

A storage experiment was carried out under environmental conditions of Al-Nassimia warehouse, Mansoura Branch, El-Mansoura Center, Agricultural Bank of Egypt, from 27$^{th}$ April to 27$^{th}$ December, 2019. The purpose of this storage experiment was to study the effect of storage methods, packages type and periods of seeds fumigation with phosphine on germination and seedlings parameter of wheat under the environmental conditions of Dakahlia Governorate, Egypt.

The experiment was arranged in a factorial experiment in randomized complete block design (R.C.B.D.) with four replications. The first factor contained different four storage periods of wheat seeds (2, 4, 6 and 8 months) after harvesting time directly. The second factor included three storage methods for wheat seeds as shown in Fig. 1 (stored wheat seeds in open air "as control method", stored wheat seeds under sunshade and in stores). The third factor included four packages type for wheat seeds as shown in Fig. 2 i.e. normal storage (stored wheat seeds in normal packages "twisting plastic" and gunny packages) and sealing storage (stored wheat seeds in polyethylene "nylon" packages and metal containers). The fourth factor was periods of seeds fumigation seeds with phosphine after the beginning the storage (treating wheat seeds with phosphine at the rate of 3 tablets/m$^3$ after 15, 30 and 45 days).
In all studied treatments, about 1.5 kg of wheat seeds with 12-13% moisture content in each replicate were stored in various packages and then treated with phosphineat the rate of 3 tablets/m$^3$ after formerly mentioned periods from beginning the storage. The studied wheat Misr-1 cultivar was obtained directly after harvesting from the Agricultural Research Station in Mansoura, Dakahlia Governorate, Agricultural Research Center, Egypt.

Meteorological data (temperature °C and relative humidity %) of Al-Nassimia Village, El-Mansoura Center, Dakahlia Governorate, Egypt, were taken at 1.00 am daily during performing the experiment (from 27$^{th}$ April to 27$^{th}$ December, 2019) and then calculated weekly, as shown in Table 1.

**Studied characters**

**Germination and seedling parameters**

Random sample of 100 seeds for each treatment at the end of storage period (8 months) were allowed to germinate under the environmental conditions of Agronomy Department, Faculty of Agriculture, Mansoura University, Egypt as the rules of International Seed Testing Association (ISTA, 1996) on top filter paper in sterilized Petri-dishes (14 cm diameter) and each Petri-dish contains 25 seeds.

1. Final germination percentage (%), Normal seedlings of each replicate were counted after 8 days from planting and expressed as percentage according to the following equation described by international rules of [10]:

$$FG\% = \frac{\text{Number of normal seedlings}}{\text{Number of total grains}} \times 100$$

2. Abnormal seedlings percentage (%), was counted and expressed by the percentage of abnormal seedlings after 8 days according to [10].

3. Rotten seeds percentage (%), was counted and expressed by the percentage of rotten seeds after 8 days according to [10].
4. Sold seeds percentage (%), was counted and expressed by the percentage of hard seeds after 8 days according to [10].
5. Speed germination index (SGI), was calculated by the following formula [10]:
\[
\text{SGI} = \frac{\text{No. of germinated grains}}{\text{Days to first count}} + \frac{\text{No. of germinated grains}}{\text{Days to final count}}
\]
6. Germination index (GI %), was calculated according to the following equation [11] as the following equation:
\[
\text{GI} = \frac{\text{Germination percentage in each treatment}}{\text{Germination percentage in the control}} \times 100
\]

Table 1: Average weekly temperature (°C) and relative humidity (%) at Al-Nassimia Village, El-Mansoura Center, Dakahlia Governorate, Egypt, from 27th April to 27th December, 2019.

| Day/month                  | Temperature Max./Min. (°C) | Relative humidity (%) |
|----------------------------|---------------------------|-----------------------|
| 27th April – 3rd May.      | 24/18                     | 50                    |
| 4th – 10th May.            | 25/18                     | 43                    |
| 11th – 17th May.           | 29/22                     | 43                    |
| 18th – 24th May.           | 27/21                     | 43                    |
| 25th – 31st May.           | 25/18                     | 43                    |
| 1st – 7th June.            | 2719                      | 56                    |
| 8th – 14th June.           | 28/22                     | 56                    |
| 15th – 21st June.          | 30/22                     | 56                    |
| 22nd – 28th June.          | 29/22                     | 56                    |
| 29th June – 5th July.      | 30/24                     | 59                    |
| 6th – 12th July.           | 30/24                     | 59                    |
| 13th – 19th July.          | 30/23                     | 59                    |
| 20th – 26th July.          | 31/24                     | 59                    |
| 27th July – 2nd August.    | 31/25                     | 62                    |
| 3rd – 9th August.          | 32/25                     | 62                    |
| 10th – 16th August.        | 31/25                     | 62                    |
| 17th – 23rd August.        | 31/25                     | 62                    |
| 24th – 30th August.        | 32/25                     | 62                    |
| 31st August – 6th September.| 31/26                     | 66                    |
| 7th – 13th September.      | 32/26                     | 66                    |
| 14th – 20th September.     | 31/26                     | 66                    |
| 21st – 27th September.     | 31/26                     | 66                    |
| 28th September – 4th October.| 31/25                     | 64                    |
| 5th – 11th October.        | 30/24                     | 64                    |
| 12th – 18th October.       | 28/23                     | 64                    |
| 19th – 25th October.       | 28/23                     | 64                    |
| 26th October – 1st November.| 27/23                     | 64                    |
| 2nd – 8th November.        | 25/18                     | 57                    |
| 9th – 15th November.       | 25/18                     | 57                    |
| 6th – 22nd November.       | 23/17                     | 57                    |
| 23rd – 29th November.      | 21/16                     | 57                    |
| 30th November – 6th December.| 20/14                     | 63                    |
| 7th – 13th December.       | 22/14                     | 63                    |
| 14th – 20th December.      | 21/14                     | 63                    |
| 21st – 27th December.      | 20/15                     | 63                    |
7. Co-efficient of germination (CG), was calculated using the following formula according to [12]:

\[
CG = \frac{100 \left( A_1 + A_2 + \ldots + A_n \right)}{A_1 T_1 + A_2 T_2 + \ldots + A_n T_n}
\]

Where:
- A = Number of seed germinated.
- T = Time (days) corresponding to A.
- n = No. of days to final count.

8. Mean germination time (day), was measured due to the following equation as showed by [13]:

\[
MGT = \frac{\sum D_n}{\sum n}
\]

Where (n) is the number of seeds, which were germinated on day, D is number of days counted from the beginning of germination.

9. Germination energy percentage (GE %), was determined from the percentage of germinating seeds at the first count (4 days after sowing) relative to the total number of tested seeds as described by [14].

\[
EG = \frac{\text{Number of germinated seeds after four days}}{\text{Number of seeds tested}} \times 100
\]

10. Plumule length (cm), ten of seedlings at the end of germination test from the seed to the tip of the bade were recorded in centimeters (cm).

11. Radical length (cm), ten of seedlings at the end of germination test from the seed to the tip of the radical were recorded in centimeters (cm).

12. Seedling vigor index (SVI), was calculated according to the formula of [15]:

\[
(SVI) = \frac{(\text{Shoot length} + \text{Root length}) \times \text{Germination percentage}}{100}
\]

13. Seedlings dry weight (g), the weight of ten seedling (shoots + roots) were recorded after oven drying at 70 °C to constant weight according to [10].

Data were subjected to the statistical analysis according to the technique of analysis of variance (ANOVA) for the factorial experiment in randomized completeblock design (R.C.B.D.) as published by [16] by using “MSTAT-C” computer software package. Least significant difference (L.S.D.) method was used to test the differences between treatment means at 0.05 % level of probability as described by [17].

3. Results and discussion

1- Effect of storage methods

Statistical analysis of the obtained data showed that studied storage methods for wheat seeds (stored wheat seeds in open air “as control method”, stored wheat seeds under sunshade and stored wheat seeds in stores) had a significant effect on germination and seedlings parameters (final germination percentage, abnormal seedlings percentage, rotten seeds percentage, sold seeds percentage, germination index, plumule length, radical length, seedling vigor index and seedlings dry weight) at the end of storage period of wheat. While, speed germination index, co-efficient of germination, mean germination time and germination energy percentage at the end of storage period did not showed significant effect due to studied storage methods for wheat seeds as shown from data presented in Tablets 2, 3 and 4.

From acquired results in this study, it could be perceived that stored wheat seeds under sunshade produced the highest values of final germination percentage, germination index, mean germination time, plumule length, radical length, seedling vigor index and seedlings dry weight at the end of storage period, followed by stored wheat seeds in stores and lastly stored wheat seeds in open air (control method) at the end of storage period. However, the lowest values of abnormal seedlings percentage, rotten and sold seeds percentages, speed germination index, co-efficient of germination and germination energy percentage were recorded when stored wheat seeds under sunshade, followed
by stored wheat seeds in stores as combined over storage periods. Whereas, the highest values of abnormal seedlings percentage, rotten and sold seeds percentages, speed germination index, coefficient of germination and germination energy percentage have been recorded in the samples of wheat seeds stored in open air (as control method) as combined over storage periods. These effects by cause of stored wheat seeds under sunshade or in stores conceivably outstanding to suitable conditions for storage, allow gas exchange, good aeration and inadequate conditions for the growth and spread of insects during storage periods, thus preserving the vitality of the embryos. Corresponding results were declared by [2].

Table 2: Final germination, abnormal seedlings, rotten and sold seeds percentages of wheat as affected by storage methods, packages type and periods of fumigation with phosphine as well as their interactions at the end of storage period.

| Treatments                          | Final germination (%) | Abnormal seedlings (%) | Rotten grains (%) | Sold grains (%) |
|-------------------------------------|-----------------------|------------------------|-------------------|-----------------|
| **A. Storage methods:**             |                       |                        |                   |                 |
| Open air                            | 76.87                 | 6.87                   | 7.91              | 9.06            |
| Sunshade                            | 78.45                 | 6.14                   | 6.75              | 7.85            |
| Stores                              | 78.25                 | 6.66                   | 6.83              | 8.33            |
| L.S.D. (at 0.05)                    | 0.40                  | 0.30                   | 0.39              | 0.32            |
| **B. Packages type:**               |                       |                        |                   |                 |
| Normal (twisting plastic)           | 72.47                 | 7.63                   | 7.19              | 7.30            |
| Gunny                               | 80.02                 | 4.22                   | 6.19              | 7.00            |
| Polyethylene (nylon)                | 79.05                 | 7.44                   | 9.61              | 12.69           |
| Metal                               | 79.88                 | 6.94                   | 5.66              | 6.66            |
| L.S.D. (at 0.05)                    | 0.46                  | 0.34                   | 0.44              | 0.37            |
| **C. Periods of fumigation with phosphine from beginning the storage:** |                       |                        |                   |                 |
| 15 days                             | 80.70                 | 5.66                   | 5.68              | 6.39            |
| 30 days                             | 78.33                 | 6.79                   | 6.64              | 8.22            |
| 45 days                             | 74.54                 | 7.22                   | 9.16              | 10.62           |
| L.S.D. (at 0.05)                    | 0.40                  | 0.30                   | 0.38              | 0.32            |
| **D. Interactions (F. test):**      |                       |                        |                   |                 |
| A × B                               | *                     | *                      | *                 | *               |
| A × C                               | *                     | *                      | *                 | *               |
| B × C                               | *                     | *                      | *                 | *               |
| A × B × C                           | *                     | *                      | *                 | *               |

2- Effect of packages type
Studding packages type that used in storage wheat seeds i.e. normal storage (stored wheat seeds in normal packages "twisting plastic" and stored wheat seeds in gunny packages) and sealing storage (stored wheat seeds in polyethylene "nylon" packages and stored wheat seeds in metal containers) significantly germination and seedlings parameters (final germination percentage, abnormal seedlings percentage, rotten seeds percentage, sold seeds percentage, speed germination index, germination index, co-efficient of germination, mean germination time, germination energy percentage, plumule length, radical length, seedling vigor index and seedlings dry weight) at the end of storage period of wheat as shown from data presented in Tables 2, 3 and 4.
The highest germination index, mean germination time, plumule and radical lengths of wheat seedlings, seedling vigor index and seedlings dry weight of wheat were recorded in the samples of wheat seeds sealed stored in metal containers, followed by normal stored in gunny packages without significant differences, and then sealed stored in polyethylene (nylon) packages at the end of storage period.
The highest percentage of final germination was obtained by normal stored in gunny packages, followed by sealing storage in metal containers, and then sealing storage wheat seeds in polyethylene (nylon) packages at the end of storage period. While, storage wheat seeds in normal packages (twisting plastic) produced in the lowest percentage of final germination at the end of storage period. Sealed stored wheat seeds in metal containers packages produced the lowest values of rotten and sold seeds percentage, speed germination index, co-efficient of germination and germination energy percentage at the end of storage period, followed by normal stored in gunny packages, and then stored in normal packages (twisting plastic) at the end of storage period. Whereas, sealed stored in polyethylene (nylon) resulted in the highest values of rotten and sold seeds percentage, speed germination index, co-efficient of germination and germination energy percentage at the end of storage period.

Table 3: Speed germination index (SGI), germination index (GI %), co-efficient of germination (CG), mean germination time and germination energy percentage (GE %) of wheat as affected by storage methods, packages type and periods of fumigation with phosphine as well as their interactions at the end of storage period.

| Treatments          | Characters                      | Speed germination index (SGI) | Germination index (GI %) | Co-efficient of germination (CG) | Mean germination time (day) | Germination energy percentage (GE %) |
|---------------------|--------------------------------|-------------------------------|--------------------------|----------------------------------|----------------------------|-------------------------------------|
| A. Storage methods: |                                |                               |                          |                                  |                            |                                     |
| Open air            |                                | 18.88                         | 0.940                    | 18.56                            | 5.38                       | 77.83                              |
| Sunshade            |                                | 18.83                         | 0.960                    | 18.50                            | 5.40                       | 76.50                              |
| Stores              |                                | 18.87                         | 0.957                    | 18.54                            | 5.39                       | 77.58                              |
| L.S.D. (at 0.05)    |                                | NS                            | NS                       | NS                               | NS                         | NS                                  |
| B. Packages type:   |                                |                               |                          |                                  |                            |                                     |
| Normal (twisting plastic) |                    | 18.85                         | 0.967                    | 18.52                            | 5.40                       | 76.88                              |
| Gunny               |                                | 18.81                         | 0.977                    | 18.47                            | 5.41                       | 76.22                              |
| Polyethylene (nylon) |                                | 19.02                         | 0.887                    | 18.71                            | 5.34                       | 80.33                              |
| Metal               |                                | 18.78                         | 0.979                    | 18.43                            | 5.42                       | 75.77                              |
| L.S.D. (at 0.05)    |                                | 0.07                          | 0.006                    | 0.09                             | 0.03                       | 1.38                                |
| C. Periods of fumigation with phosphine from beginning the storage: |                      |                               |                          |                                  |                            |                                     |
| 15 days             |                                | 18.78                         | 0.987                    | 18.44                            | 5.42                       | 75.50                              |
| 30 days             |                                | 18.84                         | 0.958                    | 18.50                            | 5.40                       | 76.83                              |
| 45 days             |                                | 18.97                         | 0.912                    | 18.66                            | 5.36                       | 79.58                              |
| L.S.D. (at 0.05)    |                                | 0.06                          | 0.005                    | 0.08                             | 0.02                       | 1.19                                |
| D. Interactions (F. test): |                      |                               |                          |                                  |                            |                                     |
| A × B               |                                | NS                            | *                        | NS                               | NS                         | NS                                  |
| A × C               |                                | NS                            | *                        | NS                               | NS                         | NS                                  |
| B × C               |                                | NS                            | *                        | NS                               | NS                         | NS                                  |
| A × B × C           |                                | NS                            | *                        | NS                               | NS                         | NS                                  |

The increasing in final germination percentage of wheat seeds at the end of storage period by normal stored in gunny packages or metal containers conceivably recognized to maintenance of moisture content, which resulted in lower respiration rate, lower metabolic activity and maintenance of higher seeds vigour during storage. [4], [5], [6]. recognized these outcomes. On the other hand, [7] showed that at room temperature, seed stored in polythene bag had the highest germination percentage.

3- Effect of fumigation periods with phosphine:

Studied periods of fumigation wheat seeds with phosphine after beginning the storage (treating wheat seeds with phosphine at the rate of 3 tablets/m3 after 15, 30 and 45 days from the beginning the storage) had a significant effect on germination and seedlings parameters (final germination
percentage, abnormal seedlings percentage, rotten seeds percentage, sold seeds percentage, speed germination index, germination index, co-efficient of germination, mean germination time, germination energy percentage, plumule length, radical length, seedling vigor index and seedlings dry weight) at the end of storage period of wheat as shown from data presented in Tablets 2, 3 and 4. The lowest abnormal seedlings percentage, rotten and sold seeds percentages, speed germination index, co-efficient of germination and germination energy percentage were recorded in the samples of wheat seeds treated with phosphine at the rate of 3 tablets/m³ after 15 days from the beginning the storage, followed by treating with phosphine after 30 days from the beginning the storage and lastly treating with phosphine at the rate of 3 tablets/m³ after 45 days from beginning the storage at the end of storage period.

After 15 days from the beginning the storage, treating wheat seeds with phosphine produced the highest final germination percentage, germination index, mean germination time, plumule length, radical length, seedling vigor index and seedlings dry weight at the end of storage period, followed by treating wheat seeds with phosphine after 30 days from beginning the storage and then treating with phosphine after 45 days from the beginning the storage.

The reason that enhanced final germination percentage of wheat seeds at the end of storage period as a result of treating with phosphine after 15 days from beginning the storage probably ascribed to efficiency of phosphine in reduction damaged seeds and weight loss percentages as a result of its poison effect ([18], [19]), prevented the insects piercing and entering into grains, consequently increasing germination parameters. These results are in synchronization with those established by [8], [6], [9].

Table 4: Plumule and radical lengths, seedling vigor index (SVI) and seedlings dry weight of wheat as affected by storage methods, packages type and periods of fumigation with phosphine as well as their interactions at the end of storage period.

| Treatments | Characters | Plumule length (cm) | Radical length (cm) | Seedling vigor index (SVI) | Seedlings dry weight (g) |
|------------|------------|---------------------|---------------------|--------------------------|-------------------------|
| **A. Storage methods:** | | | | | |
| Open air   | 8.58       | 10.47               | 14.67               | 0.549                    |                         |
| Sunshade   | 8.94       | 10.83               | 15.48               | 0.571                    |                         |
| Stores     | 8.74       | 10.81               | 15.37               | 0.564                    |                         |
| L.S.D. (at 0.05) | 0.04 | 0.06                | 0.11                | 0.002                    |                         |
| **B. Packages type:** | | | | | |
| Normal (twisting plastic) | 8.45       | 10.55               | 15.04               | 0.555                    |                         |
| Gunny      | 8.91       | 10.67               | 15.66               | 0.561                    |                         |
| Polyethylene (nylon) | 8.53       | 10.60               | 13.88               | 0.531                    |                         |
| Metal      | 9.12       | 11.01               | 16.12               | 0.598                    |                         |
| L.S.D. (at 0.05) | 0.05 | 0.07                | 0.12                | 0.002                    |                         |
| **C. Periods of fumigation with phosphine from beginning the storage:** | | | | | |
| 15 days    | 9.06       | 10.86               | 16.09               | 0.646                    |                         |
| 30 days    | 8.76       | 10.70               | 15.25               | 0.557                    |                         |
| 45 days    | 8.44       | 10.55               | 14.17               | 0.480                    |                         |
| L.S.D. (at 0.05) | 0.04 | 0.06                | 0.11                | 0.002                    |                         |
| **D. Interactions (F. test):** | | | | | |
| A × B      | *          | *                   | *                   | *                        |                         |
| A × C      | *          | NS                  | NS                  | *                        |                         |
| B × C      | *          | *                   | *                   | *                        |                         |
| A × B × C  | *          | *                   | *                   | *                        |                         |

After 15 days from the beginning the storage period, treating wheat seeds with phosphine produced the highest final germination percentage, germination index, mean germination time, plumule length, radical length, seedling vigor index and seedlings dry weight at the end of storage period, followed by treating wheat seeds with phosphine after 30 days from beginning the storage and then treating with phosphine after 45 days from the beginning the storage.
4- Effect of the interactions
With regard to the interactions between the studied factors (storage periods, storage methods, packages type and periods of fumigation with phosphine), great deals of them were statistically significant in most cases. Thus, the author will discuss only the triple significant interaction among the studied factors as will mention in this time.

The interaction among storage methods, packages type and periods of fumigation with phosphine significantly affected final germination percentage, abnormal seedlings percentage, rotten seeds percentage, sold seeds percentage, germination index, plumule length, radical length, seedling vigor index and seedlings dry weight at the end of storage period of wheat as shown from data presented in Tablets 2, 3 and 4.

The highest percentage of final germination of wheat seeds at the end of storage period was obtained when stored wheat seeds under sunshade in gunny packages and treating with phosphine at the rate of 3 tablets/m³ after 15 days from the beginning the storage recorded, followed by stored wheat seeds under sunshade in metal packages and treating with phosphine after 15 days from beginning the storage (Table 5). Stored wheat seeds under sunshade in metal packages and treating with phosphine at the rate of 3 tablets/m³ after 15 days from beginning the storage recorded the highest plumule length, radical length, seedling vigor index and seedlings dry weight at the end of storage period, followed by stored wheat seeds under sunshade in metal packages and treating with phosphine after 30 then 45 days from the beginning the storage (Table 7).

Table 5: Final germination, abnormal seedlings, rotten and sold seeds percentages of wheat as affected by the interaction among storage methods, packages type and periods of fumigation with phosphine at the end of storage period.

| Characters | Final germination (%) | Abnormal seedlings (%) | Rotten grains (%) | Sold grains (%) |
|------------|-----------------------|------------------------|------------------|-----------------|
| Normal     | 15 days               | 76.25                  | 4.20             | 7.50            | 5.00            |
|            | 30 days               | 71.50                  | 8.01             | 9.50            | 7.00            |
|            | 45 days               | 64.75                  | 10.00            | 11.25           | 9.00            |
|            | 15 days               | 81.50                  | 4.20             | 3.50            | 5.00            |
| Gunny      | 30 days               | 81.00                  | 4.20             | 5.00            | 6.00            |
|            | 45 days               | 76.25                  | 6.00             | 9.75            | 10.00           |
|            | 15 days               | 79.50                  | 4.20             | 8.00            | 11.75           |
| Polyethylene | 30 days           | 78.50                  | 7.75             | 9.50            | 15.00           |
|            | 45 days               | 74.50                  | 9.50             | 11.50           | 19.75           |
|            | 15 days               | 81.25                  | 5.00             | 3.75            | 5.00            |
| Metal      | 30 days               | 80.50                  | 5.00             | 6.00            | 5.75            |
|            | 45 days               | 77.00                  | 8.00             | 9.50            | 9.50            |
|            | 15 days               | 76.25                  | 7.50             | 4.50            | 4.00            |
| Normal     | 30 days               | 74.25                  | 8.00             | 5.50            | 5.75            |
|            | 45 days               | 72.50                  | 9.00             | 6.25            | 6.00            |
|            | 15 days               | 84.25                  | 4.00             | 5.00            | 4.00            |
| Gunny      | 30 days               | 80.75                  | 4.00             | 6.75            | 7.00            |
|            | 45 days               | 76.50                  | 4.00             | 8.00            | 10.00           |
|            | 15 days               | 81.75                  | 7.00             | 8.00            | 9.75            |
| Sunshade   | 30 days               | 80.50                  | 8.00             | 9.75            | 12.00           |
| Polye-thylene | 45 days      | 76.00                  | 8.00             | 11.25           | 13.00           |
|            | 15 days               | 83.50                  | 6.00             | 4.00            | 3.50            |
| Metal      | 30 days               | 80.50                  | 7.00             | 5.25            | 7.00            |
| Stores       | 45 days | 15 days | 30 days | 45 days | 15 days | 30 days | 45 days | 15 days | 30 days | 45 days | 15 days | 30 days |
|--------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Normal       | 76.75   | 76.50   | 71.25   | 69.00   | 83.25   | 80.50   | 79.00   | 82.50   | 80.00   | 81.30   | 8.00    | 10.00   |
| Gunny        | 6.25    | 3.75    | 4.25    | 10.00   | 4.00    | 4.25    | 4.00    | 4.25    | 4.00    | 4.00    | 4.25    | 4.00    |
| Poly-ethylene| 10.00   | 7.00    | 6.25    | 10.00   | 8.00    | 5.25    | 8.50    | 8.00    | 7.75    | 8.00    | 8.50    | 8.00    |
| Metal        | 7.50    | 3.75    | 6.25    | 10.00   | 4.00    | 4.25    | 5.25    | 5.25    | 5.25    | 5.25    | 5.25    | 5.25    |
| L.S.D_{(at 0.05)} | 1.39    | 1.03    | 1.34    | 1.10    | 1.03    | 1.34    | 1.10    | 1.03    | 1.34    | 1.10    | 1.03    | 1.34    |
Table 6: Speed germination index (SGI), germination index (GI %), co-efficient of germination (CG), mean germination time and germination energy percentage (GE %) of wheat as affected by the interaction among storage methods, packages type and periods of fumigation with phosphine at the end of storage period.

| Treatments | Characters | Speed germination index (SGI) | Germination index (GI %) | Co-efficient of germination (CG) | Mean germination time (day) | Germination energy percentage (GE %) |
|------------|-----------|------------------------------|--------------------------|---------------------------------|----------------------------|-----------------------------------|
| Normal     | 15 days   | 18.70                        | 0.973                    | 18.35                           | 5.45                       | 74.00                             |
|            | 30 days   | 18.76                        | 0.960                    | 18.41                           | 5.43                       | 75.00                             |
|            | 45 days   | 18.96                        | 0.911                    | 18.66                           | 5.36                       | 79.00                             |
|            | 15 days   | 18.72                        | 0.997                    | 18.38                           | 5.44                       | 74.00                             |
| Gunny      | 30 days   | 18.70                        | 0.933                    | 18.35                           | 5.45                       | 74.00                             |
|            | 45 days   | 18.77                        | 0.991                    | 18.42                           | 5.43                       | 76.00                             |
|            | 15 days   | 19.02                        | 0.933                    | 18.73                           | 5.34                       | 80.00                             |
| Open air   | 30 days   | 19.02                        | 0.875                    | 18.73                           | 5.34                       | 80.00                             |
| Polyethylene | 45 days  | 19.05                        | 0.792                    | 18.76                           | 5.33                       | 81.00                             |
|            | 15 days   | 18.65                        | 0.994                    | 18.28                           | 5.47                       | 73.00                             |
| Metal      | 30 days   | 18.74                        | 0.985                    | 18.38                           | 5.44                       | 75.00                             |
|            | 45 days   | 18.89                        | 0.942                    | 18.55                           | 5.39                       | 78.00                             |
|            | 15 days   | 18.76                        | 1.000                    | 18.42                           | 5.43                       | 75.00                             |
| Normal     | 30 days   | 18.83                        | 0.985                    | 18.49                           | 5.41                       | 77.00                             |
|            | 45 days   | 19.00                        | 0.930                    | 18.69                           | 5.35                       | 80.00                             |
|            | 15 days   | 18.72                        | 1.031                    | 18.35                           | 5.45                       | 75.00                             |
| Sunshade   | 30 days   | 18.80                        | 0.988                    | 18.45                           | 5.42                       | 76.00                             |
| Gunny      | 45 days   | 19.05                        | 0.936                    | 18.76                           | 5.33                       | 81.00                             |
|            | 15 days   | 18.93                        | 0.933                    | 18.62                           | 5.37                       | 78.00                             |
| Polyethylene | 30 days | 19.05                        | 0.909                    | 18.76                           | 5.33                       | 81.00                             |
|            | 45 days   | 19.05                        | 0.887                    | 18.69                           | 5.35                       | 81.00                             |
|            | 15 days   | 18.70                        | 1.019                    | 18.35                           | 5.45                       | 74.00                             |
| Metal      | 30 days   | 18.85                        | 0.979                    | 18.52                           | 5.40                       | 77.00                             |
|            | 45 days   | 18.92                        | 0.933                    | 18.59                           | 5.38                       | 79.00                             |
|            | 15 days   | 18.81                        | 1.021                    | 18.48                           | 5.41                       | 76.00                             |
| Normal     | 30 days   | 18.85                        | 0.985                    | 18.52                           | 5.40                       | 77.00                             |
|            | 45 days   | 18.96                        | 0.939                    | 18.66                           | 5.36                       | 79.00                             |
|            | 15 days   | 18.76                        | 1.009                    | 18.41                           | 5.43                       | 75.00                             |
| Sunshade   | 30 days   | 18.76                        | 0.982                    | 18.42                           | 5.43                       | 75.00                             |
| Gunny      | 45 days   | 18.99                        | 0.930                    | 18.69                           | 5.35                       | 80.00                             |
|            | 15 days   | 18.92                        | 0.936                    | 18.59                           | 5.38                       | 79.00                             |
| Stores     | 30 days   | 19.00                        | 0.872                    | 18.69                           | 5.35                       | 80.00                             |
| Polyethylene | 45 days | 19.14                        | 0.844                    | 18.87                           | 5.30                       | 83.00                             |
|            | 15 days   | 18.65                        | 1.009                    | 18.28                           | 5.47                       | 73.00                             |
| Metal      | 30 days   | 18.72                        | 0.985                    | 18.35                           | 5.45                       | 75.00                             |
|            | 45 days   | 18.88                        | 0.966                    | 18.55                           | 5.39                       | 78.00                             |
| L.S.D.(at 0.05) | | | | | | NS |
|            | NS       | 0.017                        | NS                       | NS                              | NS                         | NS                                |
| Characters                  | Plumule length (cm) | Radical length (cm) | Seedling vigor index (SVI) | Seedlings dry weight (g) |
|-----------------------------|---------------------|---------------------|---------------------------|-------------------------|
| **Treatments**              | 15 days             | 30 days             | 45 days                   |                         |
| **Open air**                |                     |                     |                           |                         |
| Normal                      | 8.71                | 10.53               | 15.30                     | 0.632                   |
| 30 days                     | 8.02                | 10.22               | 14.32                     | 0.524                   |
| 45 days                     | 7.98                | 10.09               | 13.46                     | 0.482                   |
| 15 days                     | 9.16                | 10.77               | 16.14                     | 0.628                   |
| Gunny                       | 8.70                | 10.33               | 15.51                     | 0.493                   |
| 30 days                     | 8.22                | 10.15               | 14.01                     | 0.491                   |
| 45 days                     | 8.70                | 10.48               | 14.63                     | 0.615                   |
| Polyethylene                | 8.31                | 10.31               | 13.32                     | 0.521                   |
| 45 days                     | 8.07                | 10.07               | 11.74                     | 0.474                   |
| Metal                       | 9.18                | 11.13               | 16.19                     | 0.690                   |
| 30 days                     | 9.04                | 10.88               | 16.23                     | 0.608                   |
| 45 days                     | 8.90                | 10.74               | 15.23                     | 0.531                   |
| 15 days                     | 9.05                | 10.84               | 16.60                     | 0.633                   |
| Normal                      | 8.79                | 10.72               | 15.71                     | 0.541                   |
| 45 days                     | 8.05                | 10.54               | 14.27                     | 0.490                   |
| 15 days                     | 9.18                | 10.93               | 16.59                     | 0.653                   |
| Sunshade                    | 9.08                | 10.78               | 15.94                     | 0.544                   |
| Gunny                       | 8.90                | 10.68               | 14.88                     | 0.488                   |
| 45 days                     | 9.04                | 10.90               | 15.25                     | 0.625                   |
| Metal                       | 9.04                | 10.90               | 15.25                     | 0.625                   |
| Polyethylene                | 8.87                | 10.79               | 14.01                     | 0.572                   |
| 30 days                     | 8.51                | 10.67               | 13.23                     | 0.476                   |
| 45 days                     | 9.44                | 11.33               | 17.11                     | 0.692                   |
| Metal                       | 9.27                | 11.00               | 16.24                     | 0.616                   |
| 30 days                     | 9.12                | 10.90               | 15.90                     | 0.528                   |
| 45 days                     | 8.87                | 10.87               | 16.14                     | 0.643                   |
| Normal                      | 8.51                | 10.64               | 15.42                     | 0.591                   |
| 45 days                     | 8.08                | 10.49               | 14.12                     | 0.513                   |
| 15 days                     | 9.18                | 11.02               | 17.02                     | 0.642                   |
| Gunny                       | 9.01                | 10.79               | 15.99                     | 0.515                   |
| 30 days                     | 8.77                | 10.60               | 14.82                     | 0.429                   |
| 45 days                     | 8.88                | 10.86               | 15.05                     | 0.650                   |
| Stores                      |                     |                     |                           |                         |
| Polyethylene                | 8.44                | 10.78               | 14.27                     | 0.589                   |
| 30 days                     | 7.99                | 10.54               | 13.43                     | 0.478                   |
| 45 days                     | 9.36                | 11.11               | 17.07                     | 0.652                   |
| Metal                       | 9.08                | 11.04               | 16.10                     | 0.577                   |
| 30 days                     | 8.71                | 10.95               | 14.99                     | 0.484                   |
| L.S.D.(at 0.05)             | 0.14                | 0.22                | 0.37                      | 0.07                    |

4. Conclusion

This study recommended that stored wheat seeds under sunshade in metal packages and treating with phosphine at the rate of 3 tablets/m³ after 15 days from the beginning the storage to enhance storage
efficacy, seeds quality and germination and seedlings parameter of wheat under the environmental conditions of Dakahlia Governorate, Egypt.

References
[1] Abedi, T.; A. Alemzadeh and S.A. Kazemeini (2010). Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of wheat. Australian J. Crop Sci., 4: 384-389.
[2] Scariot, M.A.; L.L. Radünz ; R.G. Dionello ; I. Müller and P. Mara de Almeida (2017). Physiological performance of wheat seeds as a function of moisture content at harvest and storage system. Pesq. Agropec. Trop., Goiânia, 47(4): 456-464.
[3] Agrawal, P.K. (1985). Seed production technology for chickpea (Cicer arietinumL.) and lentil (Lens culinaris L.). Faba bean, kabuli chickpeas and lentils (Edited by Saxene, M.C., Varma). 271-279, Syria ICARDA.
[4] Chattha, S.H. ; L.A. Jamali ; K.A. Ibupoto and H.R. Mangio (2012). Effect of different packing materials and storage conditions on the viability of wheat seed (TD-1 variety). Sci., Tech. and Dev., 31 (1): 10-18.
[5] Nabila, S.M. ; A.K.M. Ruhul-Amin ; O. Islam ; N. Haque and A.K. Achakzai (2016). Effect of storage containers on the quality of wheat seed at ambient storage condition. American-Eurasian J. Agric. & Environ. Sci., 16(2): 402-409.
[6] Ramadan, Nany M.E. (2016). Methods of storage and their effect on seed of some filed crops. Ph D. Thesis, Fac. of Agric., Mansoura Univ., Egypt.
[7] Mutinda, Y.A. ; J.W. Muthomi ; J.M. Kimani ; G.N. Cheminigwwa and F.M. Olubayo (2017). Viability and dormancy of rice seeds after storage and pre-treatment with dry heat and chemical agents. J. of Agric. Sci., 9(7): 175-185.
[8] Badawi, M.A.; A.M. Salama; I.F.A. Mersal and N.E. Attia (2014). Effect of some seed treatments before storage on wheat seed quality. J. Plant Production, Mansoura Univ., 5(4):545-554.
[9] Badawi, M.A. ; S.E. Seadh ; W.A.E. Abido and R.M. Hasan (2017). Effect of storage treatments on wheat storage. Int. J. Adv. Res. Biol. Sci., 4(1): 78-91.
[10] International Seed Testing Association "ISTA" (1996). International Rules for Seed Testing. Seed Sci. & Tech., 30: 61-67.
[11] Karim, M.A.; N. Utsunomiya and S. Shigenaga (1992). Effect of sodium chloride on germination and growth of hexaploid triticale at early seedling stage. Japanese J. of Crop Sci., 61: 279 – 284.
[12] Copeland, L.O. (1976). Principles of Seed Science and Technology, Burgess Pub. Com., Minneapolis, Minnesota, pp: 164-165.
[13] Ellis, R.A. and E.H. Roberts (1981). The quantification of ageing and survival in orthodox seeds. Seed Sci. & Tech., 9: 373-409.
[14] Ruan S.; Q. Xue and K. Tylkowska (2002). The influence of priming on germination of rice (Oryza sativa L.) seeds and seedling emergence and performance in flooded soil. Seed Sci. & Tech., 30: 61-67.
[15] AbdulBaki, A.A. and J.D. Anderson (1973). Viability and leaching of sugars from germinating barley. Crops Sci., 10: 31 – 34.
[16] Gomez, K.A. and A.A. Gomez (1984). Statistical Procedures for Agricultural Research. 2nd Ed., Jhon Wiley and Sons Inc., New York, pp: 95-109.
[17] Snedecor, G. W. and W. G. Cochran (1980). Statistical Methods. 7th Ed. Iowa State University Press, Iowa, USA., p. 507.
[18] Chaudhry, M.Q. (2000). Phosphine resistance: a growing threat to an ideal fumigant. Pesticide Outlook, June 2000, 88 – 91.
[19] Collins, P.J. ; G.J. Daglish ; H. Pavic and R.A. Kopittke (2005). Response of mixed-age cultures of phosphine-resistant and susceptible strains of lesser grain borer, Rhizoperthadominica, to phosphine at a range of concentrations and exposure periods. J. of Stored Products Res., 41: 373–385.