Vitality of Sorghum Seeds Effected by Storage Duration and Seeds Stimulation with Iron Nanoparticles

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Abstract. A laboratory experiment was carried out in the spring of 2021 at a Seed Technology Laboratory, Department of Field Crops, College of Agriculture, University of Anbar to study the effect of sorghum seeds storage duration (1, 3 and 5 years) and seeds stimulating with nano-iron fertilizer (0, 100, 200 and 300 mg L⁻¹) on the seed vitality and seedlings activity. Complete randomized design (CRD) was used with three replicates. The results showed that the seeds stored for one year and the seeds treated with a nano-iron at a 300 mg L⁻¹ as well as the interaction between them achieved the highest results in the percentage of germination at the first count, radicle length, plumule length and fresh and dry weight of seedling. It can be concluded that the increase of the storage duration negatively affects the vitality and activity of sorghum seedlings, and that the nano-iron element improved the vitality of seeds and seedling activity and can reduce the harmful effect of storage.

1. Introduction

Sorghum (Sorghum bicolor L.) is considered one of the most important cereal crops after wheat, rice, maize and barley in terms of cultivated area and production (7). Sorghum cultivation succeeds in most environments as result as own physiological and morphological characteristics. There are several problems when planting sorghum, including low field establishment that is affected by external and internal factors (27). Seedling establishment is one of the critical stages in field crop production, and it is directly related to the high quality of seeds, which is one of the basic requirements for successful field establishment (28), as the low seed viability and low embryo vigor contribute to reducing crop growth and productivity, the problem of low seed vitality and seedling activity is exacerbated when seeds are stored for long periods or under badstored conditions.

The long of the storage period of seeds is one of the problems that lead to a decrease in the vitality of the seeds and the percentage of their germination, as the seeds deterioration can't be stopped under normal storage conditions, through which the seeds may be exposed to environmental fluctuations and the consequent effects that harm the vitality of the seeds (6). There was a decrease in the vitality of wheat seeds by up to 2.5% after each year of storage, although the seeds were stored at a constant temperature (9), since the prolonged storage leads to the deterioration of the seeds, and that the most important reason of the deterioration is the increase in the activity of degrading enzymes such as amylase, phospholipase, protease and phytase, which lead to a decreasing in the vitality and vigor of seeds and field establishment (24). The effect of storage conditions is causing damage to the synthesis...
of DNA and rRNA and increasing the enzymes activity, respiration and membrane permeability, which is negatively reflected in the activity of the seeds (14).

Sorghum crop is affected by the deficiency of iron, which is involved in many functions in the plant, as it greatly affects the vitality of the seeds and the activity of the seedlings, as well as the ability of those seeds to resist storage conditions. The nano-fertilizer technology is better than conventional fertilizers to compensate for the lack of nutrients needed by the plant and it is an environmental friend technology as well as it is less cost and it is easily absorbed by the plant cell walls due to its biological and chemical properties (12). This study aimed to know the effect of sorghum seeds storage duration and seeds stimulating with nano-iron fertilizer on the seed vitality and seedlings activity.

2. Materials and Methods

A laboratory experiment was carried out in the spring of 2021 at a Seed Technology Laboratory, Department of Field Crops, College of Agriculture, University of Anbar. Two factors were studies; sorghum seeds storage duration (1, 3 and 5 years) and seeds stimulating with nano-iron fertilizer (0, 100, 200 and 300 mg L⁻¹). Complete randomized design (CRD) was used with three replicates. The stored seeds were soaked in the prepared concentrations for 12 hours, and then the seeds were aerobically dried. 36 boxes were prepared and the information was placed on each box. The boxes and the media (silica sand) were sterilized by washing with 5% of sodium hypochlorite, then washed it with distilled water several times and dried, then placed in the oven at a 130°C for 30 minutes before planting to eliminate fungi and insects. Twentyfive seeds of the Inqathcv. were sown in each box and placed in the growth chamber at 25 ±1°C with a relative humidity up to 95% (10).

2.1 Studied traits

2.1.1. Germination percentage at the first count (%): It was calculated after four days after placing the seeds in the growth chamber, the number of normal seedlings was calculated and then converted to a percentage according to the following equation:

\[
\text{Germination at the first count (\%)} = \frac{\text{No. of normal seedlings after 4 days}}{\text{No. of total seeds}} \times 100
\]

2.1.2. Radicle and plumule length (cm): It was calculated by taking ten normal seedlings, then the radicle and plumule were separated from their point of contact with the seed, and then the length of the radicle and plumule were measured separately by a ruler (4).

2.1.3. Seedling fresh weight and seedling dry weight (mg): It was calculated by taking ten normal seedlings and directly weighted, and then placed in perforated paper bags and dried in an electric oven at 80°C for 24 hours, then their weight was taken by using a sensitive scale (10).

The data were statistically analyzed for all the studied traits by using Gnestat program, and the least significant difference (L.S.D) test was used for comparison between means at the level of probability 0.05 (21).

3. Results and Discussion

3.1 Germination percentage at the first count (%)

The results in the table (1) showed that these seeds stored for 1 year was superior significantly and achieved the highest germination percentage at the first count (89.00%) compared to seeds stored for 5 years which achieved the lowest (80.17%). The reason for the superiority of the stored seeds for one year may be attributed to their high vitality and the lack of deterioration of some of their components. (5) reported that the age of the seeds is determined by their storage, and the storage time increases lead to a decrease in the percentage of seed germination, especially in sorghum seeds. These
results were confirmed by (18), (22) and (2) who indicated that seed viability decrease when the storage period is increased by the influence of temperature and moisture content factors. Also, the results indicate that the soaking of sorghum seeds with FeNPs at a300 mg L−1 was superior significantly and gave the highest germination percentage at the first count (91.11%) compared to the control treatment which gave the lowest (77.56%). The reason for the superiority of the seeds soaking with nano-iron may be attributed to the role of iron in improving the physiological processes which occur in the seed, improving its ability to germinate, reducing the germination period and increasing the activity of seedlings by increasing the efficiency of cell membranes, which improves the transfer of micro-nutrients to the cells and tissues of the plant as well as the activity of the enzymes responsible for germination that convert starch, proteins and nucleic acids into simple compounds that contribute to the activation of germination. This was confirmed by (25) who indicated that iron is a cofactor in the synthesis and activity of about 140 enzymes that catalyze biochemical reactions and increase the efficiency of biochemical transformation processes. Also, iron nanoparticles can easily enter through the cell wall and reach the plasma membrane, which leads to early positive effects when used (16). The interaction between two factors had a significant effect on this trait, the seeds stored for 1 year and soaked with FeNPs at a300 mg L−1 had the highest value (98.67%) while the seeds stored for 5 years and soaked with distilled water had the lowest value (74.00%).

| Storage duration (years) (S) | Germination percentage at the first count (%) Means | Radicle length (cm) Means | LSD 0.05 |
|-----------------------------|--------------------------------------------------|--------------------------|----------|
| 5                           | 74.00 78.67 82.67 85.33 80.17 9.500 7.067 8.300 6.833 8.556 | 5.467 5.833 6.333 6.833 | 0.583    |
| 3                           | 77.33 92.00 92.00 89.33 87.67 89.00 | 9.500 8.333 8.467 9.500 | 0.336    |
| 1                           | 81.33 89.33 86.67 98.67 89.00 6.833 8.433 8.467 | 9.500 8.556 | 0.291    |
| Means                       | 77.56 86.67 87.11 91.11 | 7.067 7.089 7.700 8.556 | 4.62     |
| LSD 0.05                    | S F SxF | S F SxF | S F SxF |

3.2 Radicle length (cm)
The results in table (1) revealed that the seeds stored for 1 year were superior significantly and gave the highest radicle length (8.808 cm) compared with seeds stored for 5 years which achieved the lowest (6.117 cm). The superiority of stored seeds for one year may be due to their high vitality and lack of deterioration, which led to their significant superiority over seeds stored for more than one year. This result was confirmed by (13) and (26) who indicated that the length of the storage duration affects on the length of the radicle negatively. Also, the results showed that the soaking of sorghum seeds with FeNPs at a300 mg L−1 was superior significantly and achieved the highest radicle length (8.556 cm) compared to other treatments. The reason of the superiority could be attributed to the role of iron in increasing the activity of enzymes and hormones that responsible for germination processes, seedling growth and development and promoting root elongation (3), (24), and (8) confirmed that the iron nanoparticles have a positive effect on physiological processes of the root and increase the effectiveness of the root plasma membrane (PMSI) thus increase the absorption of elements. The interaction between the two factors had a significant effect on this trait, the seeds stored for 1 year and soaked with FeNPs at a 300 mg L−1 had the highest value (9.500 cm), while the seeds stored for 5 years and soaked with distilled water had the lowest value.
3.3 Plumule length (cm)
The results in table (2) indicated that the seeds stored for 1 year was superior significantly and achieved the highest plumule length (11.70 cm) compared to the seeds stored for 5 years which achieved the lowest (6.96 cm). The superiority of the seeds stored for a shorter duration may be due to their high activity and lack of deterioration compared to the higher storage duration (Table 1 and 2). These results are in agreement with (13) and (6) who indicated that the length of the plumule decreases with the increase of the storage duration as a result of the deterioration and decomposition of some materials stored in the seeds. Also, the results reveal that the soaking of sorghum seeds with FeNPs at a 300 mg L\(^{-1}\) was superior significantly and achieved the highest plumule length (10.86 cm) compared to other treatments. The reason for an increase in plumule length when the soaking of seeds with FeNPs at a 300 mg L\(^{-1}\) may be due to a superior in the radicle length (Table 1). The interaction between two factors had a significant effect on this trait, the seeds stored for 1 year and soaked with FeNPs at a 300 mg L\(^{-1}\) had the highest value (13.23 cm) while the seeds stored for 5 years and soaked with distilled water had the lowest value.

3.4 Seedling fresh weight (mg)
The results in table (2) showed that the seeds stored for 1 year were superior significantly and achieved the highest seedling fresh weight (1.752 mg) compared to the seeds stored for 5 years which achieved the lowest (1.539 mg). The superiority of seeds stored for a shorter duration may be due to their high activity, which was reflected in an increase in the speed of their germination and growth, which increased the lengths of radicle and plumule (Tables 1 and 2), thus increase the fresh weight of seedlings. These results are in agreement with (26) who stated that the activation of sorghum seeds had a significant effect on the fresh weight of the seedling, especially under laboratory conditions, and the viability of the newly harvested seeds was better compared to the old seeds. Regarding the soaking treatments, the results indicated that the soaking of sorghum seeds with FeNPs at a 300 mg L\(^{-1}\) was superior significantly and gave the highest seedling fresh weight (1.447 mg) compared to other treatments. The reason of the superiority may be attributed to the positive effect of iron nanoparticles in improving the speed of germination (Table 1) due to the increase in the effectiveness of oxidizing enzymes as a result of stimulating the seeds with natural or synthetic solutions that enhanced the strength of the seeds and gave them a high germination percentage and seedlings homogeneity (20) (17). The interaction between two factors had a significant effect on this trait, the seeds stored for 1 year and soaked with FeNPs at a 300 mg L\(^{-1}\) had the highest value (2.350 mg), while the seeds stored for 5 years and soaked with distilled water had the lowest value (1.397 mg).

Table 2. Effect of storage duration and stimulation of seeds with nano-iron on plumule length and seedling fresh weight

| Storage duration (years) (S) | Plumule length (cm) | Seedling fresh weight (mg) |
|-----------------------------|---------------------|---------------------------|
|                             | Nano-iron mg L\(^{-1}\) (F) | Means | Nano-iron mg L\(^{-1}\) (F) | Means |
|                             | 0       | 100     | 200     | 300     | 0       | 100     | 200     | 300     |
| 5                            | 5.83    | 7.00    | 7.17    | 7.83    | 6.96    | 1.397   | 1.603   | 1.490   | 1.737   | 1.539   |
| 3                            | 8.67    | 9.88    | 10.33   | 11.50   | 10.10   | 1.457   | 1.560   | 1.633   | 1.477   | 1.634   |
| 1                            | 10.22   | 11.20   | 12.17   | 13.23   | 11.70   | 1.487   | 1.853   | 1.657   | 2.350   | 1.752   |
| Means                        | 8.24    | 9.36    | 9.89    | 10.86   | 1.447   | 1.672   | 1.593   | 1.854   |
| LSD 0.05                     | S       | F       | SxF     | S       | F       | SxF     | 0.817   | 0.707   | 1.415   | 0.285   | 0.330   | 0.571   |


3.5 Seedling dry weight (mg)

The results in table (3) revealed that these seeds stored for 1 year were superior significantly and gave the highest seedling dry weight (0.235 mg) which decreased with the increase of the storage duration to reach the lowest mean in the seeds stored for 5 years. The reason for an increase in seedling dry weight in the seeds stored for one year could be due to superior radicle length (Table 1), plumule length, and seedling fresh weight (Table 2). These results are in agreement with (26) and (6) who indicated that the seedling dry weight decreases with increasing storage duration. Regarding the soaking treatments, the results showed that the soaking of sorghum seeds with FeNPs at a 300 mg L\(^{-1}\) was superior significantly and gave the highest seedling dry weight (0.245 mg) compared to other treatments. The reason for an increase of seedling dry weight when the soaking of seeds with FeNPs at a 300 mg L\(^{-1}\) may be due to superior radicle length, plumule length, and seedling fresh weight (Table 1 and 2). These results are in agreement with (17) and (1) who showed that chelated iron nanoparticles increased the qualitative and quantitative characteristics of plants, as the vegetative growth and photosynthesis increased and the shoot dry weight increased. Also, these results are in agreement with (26) and (19) who indicated that the growth and quality of sorghum were affected by iron nano-fertilizers, which caused an increase in biomass and seedling dry weight. The interaction between two factors had a significant effect on this trait, these seeds stored for 1 year and soaked with FeNPs at a 300 mg L\(^{-1}\) had the highest value (0.283 mg) whereas the seeds stored for 5 years and soaked with distilled water had the lowest value.

Table 3. Effect of storage duration and stimulation of seeds with nano-iron on seedling dry weight

| Storage duration (years) | Nano-iron mg L\(^{-1}\) (F) | Means |
|--------------------------|-----------------------------|-------|
|                          | 0              | 100   | 200   | 300   |
| 5                        | 0.183          | 0.210 | 0.213 | 0.236 | 0.210 |
| 3                        | 0.213          | 0.216 | 0.206 | 0.216 | 0.213 |
| 1                        | 0.200          | 0.206 | 0.253 | 0.283 | 0.235 |
| Means                    | 0.198          | 0.210 | 0.224 | 0.245 |
| LSD 0.05                 |                |       |       |       | 0.0162 0.0187 0.0323 |

4. Conclusion

It can be concluded that increasing the storage duration negatively affects the vitality of seeds and activity of sorghum seedlings, and the iron nanoparticles proved their effectiveness in improving seed germination and seedling activity, especially at the higher concentration (300 mg L\(^{-1}\)), and this gives an indication that higher concentrations of the iron nanoparticles can improve more than the vitality and activity of the sorghum seeds. On the other hand, not all iron concentrations were able to prevent the deterioration of the seeds stored at different times, but they did reduce the deterioration of the seeds to a limited extent.

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