



Effect of Zinc Oxide (ZnO) Nanoparticles on the Storability of Onion (*Allium cepa* L.) Seeds under Ambient Condition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Zinc oxide nanoparticles (ZnO-NPs) are considered a bio safe material for organisms. Earlier studies have demonstrated the potential of ZnO-NPs for stimulation of seed germination and plant growth as disease suppression and plant protection by virtue of their antimicrobial activity. Zinc oxide is an inorganic compound it appears in white powder. (ZnO) have a potential application as a bacteriostatic agent and can be used to control the spread and infection of variety of pathogens. These results could indicate that a low zincs concentration in seeds has an important physiological role during seed germination and early seedling growth. Zinc is a constituent of an enzyme influencing the secretion of indole acetic acid (IAA), which is a phytohormone (auxin) which

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significantly regulates plant growth by increasing the level of IAA, zinc gives a positive response in seed germination. The lab experiment was conducted on Onion seed storage using ZnO Nano-particles under ambient conditions for 3 months at Seed testing laboratory, Department of genetics and plant breeding, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, (U.P.). The present investigation was carried out, in different concentrations of ZnO Nano particle (10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140) ppm along with control (untreated) and stored in two types of packaging materials aluminium foil pouch (P1) and tin container (P2), and onion seed variety is Pusa round. The Lab experiment was conducted in factorial CRD with 4 Replications. The Observations recorded on the storage containers of the onion seedling on physiological and biochemical parameters. The results of lab experiment revealed that Aluminium foil pouch (P1) packaging material is better in germination percent, speed of germination, first count, root length, shoot length, seedling length, fresh weight, dry weight, vigour index, seed density, dehydrogenase activity, catalase activity and exhibited moisture percent and electrical conductivity as compared to tin container at end of 3 months storage. Seeds are treated with ZnO @50 ppm (T5) for 2 hours soaking in distilled water, exhibits the better results in seed quality parameters. As compared to control followed by ZnO @70ppm (T7) at the end of 3 months of storage. The study concluded that the seed germination and seedling length is increased in lower concentrations, however showed decreased in higher concentration.

Keywords: Zinc oxide; nanoparticle; onion; storage and packaging material.

1. INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family Liliaceae and is one of the most important monocotyledonous and cool season vegetable crops in India. Onion is one of the important vegetable crops belongs to the order Asparagales and family Amaryllidaceae. It has diploid chromosome number ($2n = 2x = 16$). Among the onion producing countries in the World, India ranks second in production. Onion has been the largest item of export accounting to 76.2 per cent in the total export of vegetables from India. K. Anadaraj *et al.* [1]. Onion (*Allium cepa* L.) is considered as one of the important vegetable crop among bulb crops. It occupies a major position in the world as it is cultivated in majority of the countries and has regular demand for its consumption. India is the country which stands first in the total area (12.25 lakh hectares) and occupies the second position in production (209.91 lakh mt) across the globe which occupies the place very next to the China, whereas the productivity of the onion in India is low (17.13 t/ha) when compared with the countries like China, Egypt, Netherland and Iran (Anon., 2016). Minimum requirement for long term storage seeds is prolonged seed viability. Majorly the initial quality of seeds, moisture level, relative humidity (RH %) and storage conditions have considerable influence on seed storability (Roberts, 1973).

The principal purpose of storing seeds of economic plants is to preserve planting stocks

from one season until the next. Storing the seeds of oil seed crop and vegetable crop is challenging because they easily get spoiled. In sunflower, seed germinability deteriorates quickly due to lipid peroxidation (Kibinza *et al.* 2006) during storage. Most of the vegetable seeds comes under recalcitrant seed category and it easily get spoiled with time.

Seed deterioration is common in vegetables especially onion, chilli, brinjal and it causes huge loss to the stored seeds. Many researchers worked on discovering new approaches to slow down the deterioration process of seeds to improve the storage life, maintain the vigour and viability during storage period.

Nowadays, various researchers have studied the effects of nanomaterials on plant germination and growth with the objective to promote its use for agricultural applications (Khot *et al.*, 2012).

It is proven that the seeds treated with zinc oxide nanoparticles at low concentration enhances cell division, mitotic index with minimum cell division abnormalities and also increased seed germination, promptness index, and seedling growth that indicate the lower concentration is not harmful to the cell division and early seedlings growth. The Objectives of this study were 1. To find out the effect of zinc oxide nanoparticle on physiological potential of onion (*Allium cepa* L.) seeds.

1. To evaluate the effect of zinc oxide nanoparticle on enzymatic activity during storage in onion (*Allium cepa* L.) seeds.
2. To study the effect of different storage containers and zinc oxide nanoparticle treated on onion (*Allium cepa* L.) seeds.

2. MATERIALS AND METHODS

The current study was conducted in a factorial CRD with four replications at Seed Testing Laboratory (Notified by Govt of Uttar Pradesh), Department of Genetics and Plant Breeding, Naini Agricultural Institute (NAI), Sam Higginbottom University of Agriculture, Technology & Sciences, Prayagraj (U.P.). To prepare nanoparticle solutions, the experiment was conducted at Biochemistry laboratory, Department of Biochemistry & Biochemical Engineering, Sam Higginbottom University of Agriculture, Technology & Sciences Prayagraj (U.P.) during 2022. All the tests were performed in controlled conditions keeping in mind all the safety precautions.

2.1 Experimental Details

-Source of Seed: The seeds of onion variety Pusa Round were obtained Department of Genetics and Plant breeding SHUATS in Prayagraj and used for the storage studies.

-Source of ZnO nanoparticles: Zinc oxide (ZnO) nanoparticles of particle size 20-30nm and purity of $\geq 99.9\%$ was purchased from Saveer Matrixnano Private Limited, Greater Noida, and Uttar Pradesh. Following are the different treatments and different concentration used for treating the seeds of onion (Pusa Round).

2.2 Seeds Soaking in the Solution

After recording the initial seed quality parameters, seeds of onion variety Pusa Round were soaked during 2 hours in nanoparticles solution as per the treatments (To (control) with non ZnO; T1:10 ZnO 10ppm; T2:30; T4:40; T5: 50; T6: 60; T7: 70; T8: 80; T9: 90; T10: 100; T11:110; T12: 120; T13: 130 and T14: 140 ppm of ZnO and then the seeds were dried overnight to safe moisture content and then they were packed in two types of containers viz, tin container and aluminium foil pouch and after they were stored under ambient condition at $25 \pm 3^\circ\text{C}$ temperature with 95% RH (Relative Humidity) in Seed Testing Laboratory (Notified

under Uttar Pradesh), Department of Genetics and Plant Breeding, SHUATS. Seed samples were taken every month during storage period of 3 months to evaluate the physiological parameters and the enzymatic activities of onion (*Allium cepa* L.)

2.3 Evaluation of Enzymatic Activities

The treatments were T0–Control, ZnO@10ppm(2hours), T2- ZnO@20ppm(2hours), T3- ZnO@30ppm(2hours), T4- ZnO@40ppm(2hours), T5- ZnO@50ppm(2hours), T6- ZnO@60ppm(2hours), T7- ZnO@70ppm(2hours), T8- ZnO@80ppm(2hours), T9- ZnO@90ppm(2hours), T10- ZnO@100ppm(2hours), T11- ZnO@110ppm(2hours), T12- ZnO@120ppm(2hours), T13- ZnO @ 130ppm(2hours), T14- ZnO @140ppm(2hours).

The onion seeds were treated with above different treatment agents in above different concentrations for a given duration. After treatment, seeds were used for storage condition in two different packaging material viz., aluminium foil pouch and tin container.

- **Dehydrogenase activity:** Dehydrogenase activity gradually decreased as a consequence of increased defects in the metabolism of seeds as the storage period gets progressed. During storage period among the treatments maximum dehydrogenase activity (0.315) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (0.311) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (0.228) and minimum dehydrogenase activity (0.257) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum dehydrogenase activity (0.288) and the minimum (0.284) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum dehydrogenase activity (0.328) was recorded in the combination T5P1 followed by (0.324) T7P1 while the minimum dehydrogenase activity was recorded in the combination of T14P2 (0.328) at the end of storage.

- **Catalase activity:** Catalase enzyme activity gradually decreased as a consequence of increased defects in the metabolism of seeds as

the storage period gets progressed. During storage period among the treatments maximum catalase enzyme activity (0.308) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (0.305) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (0.158) and minimum catalase enzyme activity (0.268) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum catalase enzyme activity (0.264) and the minimum (0.261) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum catalase enzyme activity (0.340) was recorded in the combination T5P1 followed by (0.326) T7P1 while the minimum catalase enzyme activity was recorded in the combination of T14P2 (0.280) at the end of storage

2.4 Statistical Analyses

2.4.1 Mean

The mean value of each character was worked out by dividing the total by the corresponding number of observations.

Mean = $\sum X/N$ Where, $\sum X$ = Sum of all the observations for each character in each replication.

N = Corresponding number of observations.

2.4.2 Standard error

The standard error is a statistical term that measures the accuracy with which a sample represents a population.

$$S.E.m. (diff.) = \sqrt{2MSE/r}$$

2.4.3 Critical difference

CD refers to a value indicating the least significant difference at values greater than which all the differences are significant is presented.

$$C.D. = \sqrt{2EMS/r} \times t_{edf} \text{ at } 5\%$$

Where,

r = Number of replications

EMS= Error mean sum of squares

t= Table value of t_{edf} at error degrees of freedom at 0.05 level of significance

3. RESULTS AND DISCUSSION

According to the findings, all the characteristics analyzed were influenced by the treatment and the difference between control (untreated seeds) and treated seeds in Table 1& was entirely relevant. The onion seeds were treated with above different treatment agents in above different concentrations for a given duration. After treatment, seeds were used for storage condition in two different packaging material viz., aluminium foil pouch and tin container. The silent found of the study are summarized below. After recording the initial seed quality parameters, seeds of onion variety Pusa Round were soaked in nanoparticle solution as per the treatment for 2 hours and then the seeds were dried over night to safe moisture content and then was packed in two types of containers viz, tin container and aluminium foil pouch and then stored under ambient condition with $25 \pm 3^{\circ}C$ temperature with 95% RH (Relative Humidity) in Seed Testing Laboratory (Notified under Uttar Pradesh), Department of Genetics and Plant Breeding, SHUATS. Seed samples were taken every month during storage period of 3 months to evaluate the physiological parameters and the enzymatic activities of onion (*Allium cepa* L.) Data were recorded for the following characters Viz., germination percent (%), speed of germination(days-1), root length(cm), shoot length(cm), seedling length(cm), fresh weight of Seedling(g), dry weight of Seedling(g), seedling growth rate, root: shoot ratio, seed metabolic efficiency(%), vigour index-I, vigour index-II, electrical conductivity, seed density, Dehydrogenase activity(OD g-1 mL-1), catalase enzyme activity($\mu\text{mol g-1fw min-1}$).

3.1 Germination Percent (%)

gradually decreased as a consequence of increased defects in the metabolism of seeds as the storage period gets progressed. During storage period among the treatments maximum germination (%) (56.75%) was recorded with Zinc Oxide nanoparticles at 50ppm (T5) followed by (55.75%) with Zinc Oxide nanoparticles 70ppm (T7) as compared to the (T0) control (48.87%) which was the minimum germination (%) (51.0%) was recorded at Zinc Oxide nanoparticles 140ppm (T14) it represented the lowest germination% in the treated onions. Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum germination percent (%) (54.46%) and the minimum (52.28%) was recorded by tin container (P2). In

the interaction effect of seed treatment and packaging materials (T x P) the maximum germination (%) with (59.50%) was recorded in the combination T5P1 followed by (58%) T7P1 while the minimum germination (%) was recorded in the combination of T14P2 (50.5%) at the end of storage. Similar results was found by Sudeshna Chakrabort (2012) the study revealed that the germination percent gradually decreased with increase in germination period of onion seeds under ambient storage condition.

3.2 Speed of Germination

The observations on speed of germination (days-1) were statistically analysed. During storage period among the treatments maximum Speed of Germination (days-1) (4.05) was recorded with Zinc Oxide nanoparticles at 50ppm (T5) followed by (3.98) with Zinc Oxide nanoparticles at 70ppm (T7) as compared to the (T0) control (3.49) and minimum Speed of Germination (days-1) (3.64) was recorded at Zinc Oxide nanoparticles at 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum Speed of Germination (days-1) (3.89) and the minimum (3.73) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum Speed of Germination (days-1) (4.25) was recorded in the combination T5P1 followed by (4.21) T7P1 while the minimum Speed of Germination (days-1) was recorded in the combination of T14P1 (3.61) at the end of storage. Similar results was found by S.V. Raskar et al. [2] conducted research on effect of zinc oxide nanoparticles on cytology and seed germination in onion, results pretraining to seed germination and early growth clearly indicate that zinc oxide at lower concentration (20ppm) promoted seed germination i.e. 96.5%, while untreated seeds showed 94.2%. Seed germination increased in lower concentrations, however showed a decrease in values at higher concentrations.

1. Germination percent (first count) gradually decreased as a consequence of increased defects in the metabolism of seeds as the storage period gets progressed. During storage period among the treatments maximum germination percent (first count) (28.37%) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (27.87%) with Zinc Oxide nanoparticles at 70ppm (T7) as compared to the (T0) control (24.43%) and minimum

germination percent (first count) (25.50%) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum germination percent (first count) (27.23%) and the minimum (26.14%) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum germination percent (first count) (29.75%) was recorded in the combination T5P1 followed by (29%) T7P1 while the minimum germination percent (first count) was recorded in the combination of T14P2 (25.05%) at the end of storage.

2. Moisture content gradually decreased as a consequence of increased defects in the metabolism of seeds as the storage period gets progressed. During storage period among the treatments maximum moisture content (7.45%) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (7.71%) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (8.20%) and minimum moisture content (8.01%) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum moisture content (7.87%) and the minimum (7.93%) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum moisture content (7.62%) was recorded in the combination T5P1 followed by (7.72%) T7P1 while the minimum moisture content was recorded in the combination of T14P1 (8.01%) at the end of storage. The observations on Root length (cm) were statistically analysed during storage period among the treatments maximum root length (cm) (3.87cm) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (3.62cm) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (2.98cm) and minimum root length (cm) (3.11cm) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum root length (cm) (3.45cm) and the minimum (3.28cm) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum

root length (cm) (4.46cm) was recorded in the combination T5P1 followed by (4.22cm) T7P1 while the minimum root length (cm) was recorded in the combination of T14P2 (8.01cm) at the end of storage. Similar results was found by Jayarambabu *et al.* (2014) the study revealed that the significant improvement in germination, root length and shoot length at lower concentration of ZnO NPs however, at higher concentration the growth started retarding

3. Shoot length maximum shoot length (5.55cm) was recorded with Zinc Oxide nanoparticles at 50ppm (T5) followed by (5.43cm) at 70ppm (T7) while control (T0) was (4.67 cm) minimum shoot length (4.72cm) was recorded at Zinc ONPs at 130ppm (T13). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum shoot length (cm) (5.23cm) and the minimum (4.96cm) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum shoot length (cm) (6.15cm) was recorded in the combination T5P1 followed by (5.90cm) T7P1 while the minimum shoot length (cm) was recorded in the combination of T13P1 (4.46cm) at the end of storage. Similar results was found by Jayarambabu *et al.* (2014) the study revealed that the significant improvement in germination, root length and shoot length at lower concentration of ZnO NPs however, at higher concentration the growth started retarding.
4. Seedling length (cm) gradually decreased as a consequence of increased defects in the metabolism of seeds as the storage period gets progressed. During storage period among the treatments maximum seedling length (cm) (9.42cm) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (9.19cm) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (7.65cm) and minimum seedling length (cm) (6.42cm) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum seedling length (cm) (8.68cm) and the minimum (8.06cm) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging

materials (T x P) the maximum seedling length (cm) (10.11cm) was recorded in the combination T5P1 followed by (10.6cm) T7P1 while the minimum seedling length (cm) was recorded in the combination of T14P2 (4.60cm) at the end of storage. Similar results were found by Jayarambabu *et al.* (2014).

During storage period among the treatments maximum fresh weight (g) (0.272g) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (0.267g) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (0.242g) and minimum fresh weight (g) (0.262g) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum fresh weight (g) (0.260g) and the minimum (0.259g) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum fresh weight (g) (0.280g) was recorded in the combination T5P1 followed by (0.273g) T7P1 while the minimum fresh weight (g) was recorded in the combination of T14P2 (0.258g) at the end of storage. Similar results was found by Pradeep Korishettar *et al.*, [3].

During storage period among the treatments maximum dry weight (g) (0.0357g) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (0.0357g) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (0.0340g) and minimum dry weight (0.0352g) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum dry weight (g) (0.0352g) and the minimum (0.0349g) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum dry weight (g) (0.0370g) was recorded in the combination T5P1 followed by (0.0363g) T7P1 while the minimum dry weight (g) was recorded in the combination of T13P2 (0.0349g) at the end of storage. Similar results was found by Pradeep Korishettar *et al.*, [3].

During storage period among the treatments maximum vigour index-I (525.07) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (515.07) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (374.67) and minimum vigour index-I (417.62) was recorded at Zinc Oxide

nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum vigour index-I (474.02) and the minimum (421.80) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum vigour index-I (629.66) was recorded in the combination T5P1 followed by (598.99) T7P1 while the minimum vigour index-I was recorded in the combination of T14P2 (232.55) at the end of storage. Similar results was found by K. Krishna Shyla and N. Natarajan [4].

During storage period among the treatments maximum vigour index-II (2.033) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (1.989) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (1.668) and minimum vigour index-II (1.875) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum vigour index-II (1.921) and the minimum (1.829) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum vigour index-II (2200) was recorded in the combination T5P1 followed by (2089) T7P1 while the minimum vigour index-II was recorded in the combination of T13P2 (1780) at the end of storage. Similar results was found by Pradeep Korishettar et al., [3], K. Krishna Shyla and N. Natarajan et al [4], Ahmed MMAA et al [5], Al-Aareji et al [6], Alamer K et al [7], Avinash C et al [8], Chaturvedi OP et al [9], Collins D et al [10], De Rosa MC et al [11], Handy RD et al [12], Kah M et al [13], Kamjab F et al [14], Khanm et al [15], Khan MR et al [16], Katoori Saisanthosh et al [17], Karimiyan A et al [18], Kaushik H et al [19], Kuldeep singh et al [20], Anandraj K et al [21], Lin D et al [22], Lakshmi SJ et al [23], Laware SL et al [24], Manjunatha SB et al [25], Mandal AK et al [26], Meenakshi G et al [27], Pandey AC et al [28], Moharana RL et al [29], Raja K et al [30], Senthikumar S et al [31], Sherin susan J et al [32].

Electrical conductivity gradually decreased as a consequence of increased defects in the metabolism of seeds as the storage period gets progressed. During storage period among the treatments maximum electrical conductivity (0.937) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (0.946) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (0.972) and

minimum electrical conductivity (0.955) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum electrical conductivity (1.921) and the minimum (1.829) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum electrical conductivity (0.930) was recorded in the combination T5P1 followed by (0.936) T7P1 while the minimum electrical conductivity was recorded in the combination of T14P2 (0.951) at the end of storage.

Seed density gradually decreased as a consequence of increased defects in the metabolism of seeds as the storage period gets progressed. During storage period among the treatments maximum seed density (0.990) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (0.982) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (0.800) and minimum seed density (0.832) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum seed density (0.867) and the minimum (0.866) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum seed density (1.064) was recorded in the combination T5P1 followed by (0.967) T7P1 while the minimum seed density was recorded in the combination of T14P2 (0.807) at the end of storage.

Dehydrogenase activity gradually decreased as a consequence of increased defects in the metabolism of seeds as the storage period gets progressed. During storage period among the treatments maximum dehydrogenase activity (0.315) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (0.311) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (0.228) and minimum dehydrogenase activity (0.257) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum dehydrogenase activity (0.288) and the minimum (0.284) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum dehydrogenase activity (0.328) was recorded in the combination T5P1 followed by (0.324) T7P1 while the minimum dehydrogenase activity was recorded in the combination of T14P2 (0.328) at the end of storage.

Table 1. Analysis of variance on impact of various packaging materials on onion seed quality after one month of ambient storage

SL No.	Parameters	Mean sum of square			
		Packaging materials (P) (df=1)	Treatment (T) (df=14)	Interaction (CXT) (df=14)	Error (df=90)
1	Germination percent(Final count)	143.008*	35.125*	11.473	18.175
2	Speed of germination	0.728*	0.179*	0.059	0.093
3	First count per cent	35.752*	8.781*	2.868	4.544
4	Moisture per cent	0.120	0.250*	0.189*	0.102
5	Root length	0.799	0.525	0.620	0.497
6	Shoot length	2.071*	0.615	0.716*	0.397
7	Seedling length	5.442	2.021	2.412	1.675
8	Fresh weight	0.0023	0.0011	0.0004	0.0012
9	Dry weight	0.00023	0.00016	0.00011	0.00008
10	Vigour index I	62.443*	16.819*	14.523*	5.683
11	Vigour index II	0.268*	0.743	0.329	0.535
12	Electrical conductivity	0.0001	0.0010*	0.0003	0.00018
13	Seed density	0.0001	0.026*	0.012	0.007
14	Dehydrogenase activity	0.005*	0.003*	0.002*	0.0003*
15	Catalase activity	0.0001	0.013*	0.004*	0.0004

Table 2. Analysis of variance on impact of various packaging materials on onion seed quality after two months of ambient storage

SL No.	Parameters	Mean sum of square			
		Packaging Materials(P) (df=1)	Treatment (T) (df=14)	Interaction (PXT) (df=14)	Error (df=90)
1	Germination percent	143.008*	35.125*	11.473	12.831
2	Speed of germination	0.730*	0.181*	0.058	0.066
3	First count per cent	35.752*	8.781*	2.868	3.208
4	Moisture per cent	0.124	0.260*	0.179	0.100
5	Root length	0.799	0.525	0.620	0.503
6	Shoot length	2.070	0.615	0.716*	0.396
7	Seedling length	5.443	2.021	2.412	1.678
8	Fresh weight	0.0024	0.0011	0.0084	0.0012
9	Dry weight	0.000023	0.000016	0.000011	0.000086
10	Vigour index I	57.877*	15.560*	13.482*	5.344
11	Vigour index II	0.0260*	0.720	0.317	0.462
12	Electrical conductivity	0.0001	0.0010*	0.0003	0.0002
13	Seed density	0.0001	0.026*	0.012	0.007
14.1	Dehydrogenase activity	0.003	0.005*	0.003*	0.001
14.2	Catalase activity	0.0001	0.013*	0.004*	0.001

Table 3. Analysis of variance on impact of various packaging materials on onion seed quality after threemonths of ambient storage

SL No.	Parameters	Mean sum of square			
		Packaging materials (P) (df=1)	Treatment (T) (df=14)	Interaction (CXT) (df =14)	Error (df=90)
1	Germination per cent (Final count)	143.008*	35.125*	11.473	12.831
2	Speed of germination	0.730*	0.180*	0.059	0.066
3	First count per cent	35.752*	8.781*	2.868	3.208
4	Moisture per cent	0.120	0.260*	0.180*	0.097
5	Root length	0.784	0.522	0.619	0.507
6	Shoot length	2.071*	0.615	0.716*	0.397
7	Seedling length	11.568*	4.142*	3.782*	1.681
8	Fresh weight	0.0011	0.0031	0.0029	0.0013
9	Dry weight	0.000022	0.000016	0.000012	0.000083
10	Vigour index I	81.799*	21.706*	15.479*	4.923
11	Vigour index II	0.252*	0.695	0.306	0.429
12	Electrical conductivity	0.0001	0.001*	0.0003*	0.0002
13	Seed density	0.0001	0.026*	0.012	0.007
14	Dehydrogenase activity	0.0001	0.004*	0.002	0.002
15	Catalase activity	0.0001	0.013*	0.004*	0.001

Table 4. Mean performance on impact of various packaging materials on onion seed quality after 3 months of ambient storage

	Germination percent	Speed of germination	First count percent	Moisture percent	Root length	Shoot length	Seedling length	Fresh weight	Dry weight	Vigour index I	Vigour index II	Electrical conductivity	Seed density	Dehydrogenase activity	Catalase activity
T0	48.875	3.49	24.43	8.20	2.98	4.67	7.65	0.242	0.0340	374.67	1.668	0.972	0.8	0.228	0.158
T1	53.5	3.82	26.75	7.84	3.4	5.08	8.48	0.260	0.0350	454.19	1.874	0.944	0.825	0.27	0.225
T2	53	3.78	26.5	8.02	3.5	5.18	8.68	0.261	0.0348	455.68	1.846	0.937	0.825	0.271	0.232
T3	55.5	3.96	27.75	8.04	3.75	5.30	8.92	0.265	0.0356	509.26	1.984	0.939	0.896	0.307	0.282
T4	50.75	3.62	25.37	8.03	3.38	5.07	8.45	0.259	0.0345	429.03	1.753	0.939	0.814	0.297	0.233
T5	56.75	4.05	28.37	7.45	3.87	5.55	9.42	0.272	0.0357	525.07	2.033	0.937	0.990	0.315	0.308
T6	54.25	3.87	27.12	7.78	3.5	5.05	8.55	0.258	0.0351	464.08	1.906	0.958	0.829	0.291	0.245
T7	55.75	3.98	27.87	7.71	3.62	5.43	9.19	0.267	0.0357	515.07	1.989	0.946	0.982	0.311	0.305
T8	52.75	3.76	26.37	8.00	3.28	4.97	8.25	0.260	0.0350	435.20	1.849	0.96	0.876	0.267	0.289
T9	53.5	3.82	26.75	7.84	3.25	5.58	8.83	0.259	0.0349	471.46	1.875	0.941	0.846	0.3	0.248
T10	55	3.92	27.5	8.03	3.32	5.00	8.33	0.261	0.0350	457.23	1.929	0.958	0.834	0.284	0.275
T11	54.5	3.89	27.25	7.96	3.38	5.07	8.45	0.260	0.0349	460.42	1.907	0.957	0.89	0.298	0.286
T12	53.5	3.82	26.75	7.76	3.11	5.09	8.12	0.259	0.0351	438.27	1.888	0.967	0.83	0.305	0.288
T13	52	3.71	26	7.89	3.03	4.72	7.75	0.262	0.0349	401.36	1.814	0.957	0.895	0.294	0.281
T14	51	3.64	25.5	8	3.11	4.78	6.42	0.259	0.0355	327.67	1.815	0.955	0.871	0.257	0.287
Mean	53.375	3.81	26.68	7.90	3.36	5.10	8.37	0.260	0.0351	447.91	1.875	0.951133	0.8668	0.286333	0.268
Sem.	1.266	0.09	0.63	0.11	0.25	0.22	0.45	0.012	0.0010	24.808	0.073	0.005	0.03	0.015	0.008
Sed.	1.791	0.12	0.89	0.15	0.35	0.31	0.64	0.018	0.0014	35.084	0.103	0.007	0.042	0.021	0.011
CD	3.564	0.25	1.78	0.30	NS	NS	1.29	NS	NS	69.819	NS	0.014	0.084	0.043	0.022
F-test	S	S	S	S	NS	NS	S	NS	NS	S	NS	S	S	S	S
P1	54.467	3.89	27.23	7.87	3.45	5.23	8.68	0.260	0.0352	474.02	1.921	0.95	0.867	0.288	0.264
P2	52.283	3.73	26.14	7.93	3.28	4.96	8.06	0.259	0.0349	421.80	1.829	0.952	0.866	0.284	0.261
Mean	53.375	3.81	26.68	7.90	3.36	5.10	8.37	0.260	0.0351	447.91	1.875	0.951	0.8665	0.286	0.262
Sem.	0.462	0.03	0.23	0.04	0.09	0.08	0.16	0.004	0.0037	9.059	0.026	0.002	0.011	0.006	0.003
Sed.	0.654	0.047	0.32	0.05	0.13	0.11	0.23	0.006	0.0052	12.811	0.037	0.002	0.015	0.008	0.004
CD	1.301	0.093	0.65	NS	NS	0.22	0.47	NS	NS	25.494	0.075	NS	NS	NS	NS
F-test	S	S	S	NS	NS	S	S	NS	NS	S	S	NS	NS	NS	NS

Table 5. Mean performance of interaction on impact of packaging materials on onion seed quality after 3 month of ambient storage

Interac tion	(TX P)	Germination percent	Speed of germination	First count percent	Moisture percent	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Fresh weight (gm)	Dry weight (gm)	Vigour index I	Vigour index II	Electrical conductivity (dSm/1)	Seed density (gm/cm ³)	Dehydrogenase activity (OD /g/ml)	Catalase activity µmol/g fw/ min
T0P1		49.5	3.54	24.75	8.24	2.75	4.43	7.1825	0.223	0.0342	355.45	1692	0.982	0.772	0.19	0.120
T0P2		48.25	3.45	24.12	8.17	3.23	4.91	8.13	0.260	0.0339	393.9	1644	0.961	0.827	0.266	0.194
T1P1		55	3.93	27.5	7.87	3.45	5.13	8.58	0.261	0.0351	472.125	1934	0.937	0.799	0.265	0.214
T1P2		52	3.71	26	7.72	3.35	5.03	8.38	0.260	0.0350	436.265	1815	0.949	0.849	0.273	0.236
T2P1		55	3.93	27.5	8.06	3.70	5.38	9.08	0.260	0.0347	492.61	1907	0.940	0.819	0.259	0.225
T2P2		51	3.64	25.5	7.98	3.30	4.98	8.28	0.261	0.0349	418.75	1784	0.933	0.829	0.282	0.239
T3P1		59	4.14	24.5	7.93	4.17	5.85	10.2	0.257	0.0361	579.02	2148	0.933	0.817	0.323	0.309
T3P2		51.5	3.68	25.75	8.10	3.05	4.73	7.88	0.264	0.0343	400.48	1768	0.948	0.914	0.277	0.234
T4P1		51.5	3.68	25.7	8.03	3.40	5.08	8.48	0.261	0.0345	437.16	1784	0.933	1.019	0.286	0.226
T4P2		50	3.57	25	8.05	3.38	5.06	8.43	0.258	0.0344	420.91	1722	0.942	0.809	0.306	0.24
T5P1		59.5	4.25	29.75	7.62	4.46	6.15	10.11	0.280	0.0370	629.665	2200	0.93	1.064	0.328	0.340
T5P2		54.5	3.89	27.25	7.63	3.03	4.71	7.73	0.260	0.0352	419.54	1919	0.940	0.944	0.294	0.234
T6P1		53	3.79	26.5	6.99	3.40	4.83	8.23	0.259	0.0350	435.59	1858	0.968	0.804	0.289	0.24
T6P2		55.5	3.96	27.7	7.93	3.60	5.28	8.88	0.258	0.0352	492.585	1955	0.947	0.852	0.292	0.249
T7P1		58	4.21	29	7.72	4.22	5.90	10.6	0.273	0.0363	598.995	2089	0.936	0.967	0.324	0.326
T7P2		53.5	3.82	26.7	7.82	3.58	5.26	8.83	0.258	0.0354	471.13	1890	0.954	0.824	0.289	0.300
T8P1		53	3.79	26.5	8.12	3.35	5.03	8.38	0.261	0.0349	442.96	1854	0.961	0.909	0.26	0.292
T8P2		52.5	3.75	26.2	7.90	3.23	4.91	8.13	0.259	0.0350	427.455	1844	0.958	0.842	0.274	0.286
T9P1		54	3.86	27	7.67	3.15	6.15	9.29	0.257	0.0349	499.835	1892	0.933	0.839	0.330	0.231
T9P2		53	3.79	26.5	8.02	3.35	5.03	8.38	0.264	0.0350	443.09	1857	0.948	0.852	0.299	0.264
T10P1		55.5	3.96	27.7	8.04	3.30	4.98	8.28	0.261	0.0345	456.875	1918	0.954	0.822	0.288	0.25
T10P2		54.5	3.89	27.2	8.02	3.35	5.03	8.38	0.260	0.0354	457.585	1940	0.961	0.844	0.278	0.300
T11P1		55.5	3.96	27.7	7.88	3.38	5.06	8.43	0.261	0.0349	467.05	1945	0.953	0.879	0.297	0.288
T11P2		53.5	3.82	26.7	8.04	3.40	5.08	8.48	0.259	0.0350	453.795	1869	0.959	0.899	0.299	0.284
T12P1		54	3.86	27	7.99	2.98	5.09	8.06	0.272	0.0351	437.05	1905	0.973	0.807	0.291	0.326
T12P2		53	3.79	26.5	7.92	3.25	4.93	8.18	0.257	0.0351	439.505	1870	0.959	0.852	0.318	0.289
T13P1		53	3.79	26.5	8.00	2.78	4.46	7.23	0.261	0.0349	383.195	1848	0.963	0.857	0.298	0.279
T13P2		51	3.64	25.5	7.79	3.30	4.98	8.28	0.262	0.0352	419.53	1780	0.951	0.932	0.288	0.282
T14P1		51.5	3.68	25.7	7.99	3.28	4.96	8.23	0.260	0.0358	422.79	1845	0.951	0.807	0.287	0.292
T14P2		50.5	3.61	25.5	8.01	2.95	4.61	4.6	0.258	0.0352	232.555	1785	0.958	0.934	0.226	0.280
Mean		53.375	3.81	26.514	7.91	3.37	5.10	8.37175	0.260	0.0351	447.91	1875	0.95	0.87	0.29	0.26
Sem.		1.791	0.128	0.895	0.156	0.356	0.315	0.648	0.018	0.0014	35.084	0.103	0.007	0.042	0.021	0.011
Sed.		2.533	0.181	1.266	0.22	0.503	0.446	0.917	0.025	0.0020	49.617	0.146	0.01	0.06	0.03	0.016
CD		NS	NS	NS	0.438	NS	0.887	1.825	NS	NS	98.738	NS	0.019	NS	NS	0.032
F-test		NS	NS	NS	S	NS	S	S	NS	NS	S	NS	S	NS	NS	S

Catalase enzyme activity gradually decreased as a consequence of increased defects in the metabolism of seeds as the storage period gets progressed. During storage period among the treatments maximum catalase enzyme activity (0.308) was recorded with Zinc Oxide nanoparticles @ 50ppm (T5) followed by (0.305) with Zinc Oxide nanoparticles @ 70ppm (T7) as compared to the (T0) control (0.158) and minimum catalase enzyme activity (0.268) was recorded at Zinc Oxide nanoparticles @ 140ppm (T14). Between packaging materials seeds stored in aluminium foil pouch (P1) recorded maximum catalase enzyme activity (0.264) and the minimum (0.261) was recorded by tin container (P2). In the interaction effect of seed treatment and packaging materials (T x P) the maximum catalase enzyme activity (0.340) was recorded in the combination T5P1 followed by (0.326) T7P1 while the minimum catalase enzyme activity was recorded in the combination of T14P2 (0.280) at the end of storage.

4. CONCLUSION

It is observed that zinc oxide performs better when treated at lower concentrations (10ppm, 20ppm, 30ppm, 40ppm, 50ppm, 60ppm, 70ppm) than control and results pertaining to seed germination and early seedling growth clearly indicate that zinc oxide at lower concentration promoted seed germination and seedling growth, but at higher concentration reduced seed germination and seedling growth. Highest concentration ZnO at 140ppm showed significantly low germination percentage and maximum percent seed germination observed in ZnO at 50ppm. However, high concentrations of zinc oxide have caused a range of toxicity on seed germination and seedling growth. There was no major difference in root and shoot ratio in all treatments however an increasing trend was seen from lower concentrations. Seeds stored in a aluminium foil pouch (P1) performs better results the reason is that helps in lower the seed deterioration due to low moisture levels. The lowest infection of fungi was recorded when the seeds were stored in aluminium foil pouch because of low moisture levels. Among the interactions, the combination (P1T5) recorded the best result and followed by (P1T7). The study concluded that the combination of aluminium foil pouch with ZnO at 50 ppm is the best combination that could be used to expand the storability of onion seeds under ambient condition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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