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Effect of nanoparticles on storability of KRH-4 hybrid rice seeds

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ABSTRACT

The laboratory storage experiment on effect of nanoparticles on storability of KRH-4 hybrid rice seeds was carried out during 2017-18 in Department of Seed Science and Technology, UAS, Dharwad. The experiment was laid out in Complete Randomized Design with 10 treatments. The treatments consisted of T_1: Control, T_2: Zinc oxide 500 mg/kg, T_3: Zinc oxide 1000 mg/kg, T_4: Zinc oxide 1500 mg/kg, T_5: Silver 500 mg/kg, T_6: Silver 1000 mg/kg, T_7: Silver 1500 mg/kg, T_8: Titanium dioxide 500 mg/kg, T_9: Titanium dioxide 1000 mg/kg and T_{10}: Titanium dioxide 1500 mg/kg. The results of the experiment indicated that seed treatment with T_3: Zinc oxide 1000 mg/kg favored the seed quality attributes by keeping the slower rate of seed ageing and recorded the highest seed germination (79.75 %), seedling shoot length (9.10 cm), seedling root length (10.93 cm) seedling vigour index (1597), dehydrogenase activity (0.479 OD value) with lower seed moisture content (10.27 %) and electrical conductivity (0.248 dSm^{-1}) at the end of 12 months of storage period and thus indicated that utilization of Zinc oxide nanoparticles may be a feasible approach to increase the germination, vigour, storability.

Key words: nanoparticles, ZnO, Ag, TiO_2 and seed quality

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INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for nearly fifty per cent of the world's population. However, more than 90 per cent of rice is consumed in Asia, where it is the staple food for a majority of the population, including 560 million hungry people in the region. The success of seed production on commercial crop production primarily depends on genetic purity, timely availability and the affordability of hybrid seed costs to the farmers. Storage of seeds for the next season is one of such ways to ensure the timely availability of quality seeds to the farmers. Seeds undergo several biochemical processes of which certain process results in production of free radicals causing lipid peroxidation leading to rapid deterioration process during the course of storage period. Several strategies such as hydration and dehydration, halogenations and antioxidant treatments have been tested and proved beyond doubt that could prevent ageing process and extend the shelf life of seeds. These seed quality enhancement techniques are seems to be little cumbersome and are not being adopted routinely by the farmers due to practical difficulties. Under these circumstances, Nanotechnology, the science of working with smallest possible particles, raises hopes for the future to overcome the difficulties encountered in agriculture. Plenty of research works have been done in biological system to address wide range of field problems utilizing nanomaterials and nano-devices. [10] Elucidated various nanotechnological approaches in the field of agriculture including nano-polymer for seed hardening, nano-sensors, nano-barcodes and use of magnetic nanoparticles for aerial seeding. [15] and [16] further established the use of metal oxide nanoparticles in improving germination up to 30 per cent in aged seeds of black gram and tomato respectively which could be probably due to the quenching of reactive oxygen species (ROS) generated during seed storage. Applications of nanotechnology in improving seed germination, emergence and growth of seedlings [17], thwarting pest attack [9] are few of the multifarious beneficial interventions in the field of agriculture. Hence the present investigation was made to study the effect of ZnO, Ag and TiO_2 nanopartilcle on the storability of KRH-4 F_1 seeds.

MATERIAL AND METHODS
The laboratory storage experiment was carried out during 2017-18 in Department of Seed Science and Technology, UAS, Dharwad to know the influence of nanoparticles on the storability of KRH-4 hybrid seeds. The experiment was laid out in Complete Randomized Design with 10 treatments.

Seed treatment
The freshly harvested KRH-4 hybrid seeds were dry dressed with synthetic nanoparticles of ZnO, Ag and TiO_2 @ 500, 1000 and 1500 mg/kg using the screw capped air tight glass bottles at room temperature. The treatments consisted of T_1: Control, T_2: Zinc oxide 500 mg/kg, T_3: Zinc oxide 1000 mg/kg, T_4: Zinc oxide 1500 mg/kg, T_5: Silver 500 mg/kg, T_6: Silver 1000 mg/kg, T_7: Silver 1500 mg/kg, T_8:Titanium dioxide 500 mg/kg, T_9:Titanium dioxide 1000 mg/kg and T_{10}:Titanium dioxide 1500 mg/kg. The glass bottles containing the seeds and nanoparticles were manually shaken gently for 3 minutes at an interval of 15 minutes for 10 times as per the treatment details. Seeds shaken without the nanoparticles served as control. The treated seeds were packed in 700 gauze polythene bags and stored under ambient conditions. The seeds samples were drawn at monthly intervals for a period of 12 months to assess the various seed quality attributes.

Germination test [3]
The germination of the seeds was assessed with 100 seeds in 4 replications by between paper method. The normal seedlings were counted at the end of 14 days and mean was expressed in percentage. The seedlings obtained at the end of 14 days of the germination test were used to assess the other seed quality attributes (seedling shoot length and seedling root length).

Seedling Vigour index : [1]
The seedling vigour index was computed using the following formula and the mean was expressed as whole number.

Seedling Vigour index = Germination (%) × [Seedling shoot length (cm) + Seedling root length (cm)]

Moisture content [2]
Four replicates of five grams of seed material were taken for determining the moisture content using hot air oven. The powdered seed material was placed in a weighed moisture cup. After removing the lid, moisture cups were placed in hot air oven maintained at 130 ± 1 ^{o} C for 2 minutes and the contents were allowed to dry. Then it was cooled in desiccators for 30 min and weighed in an electronic balance along with metal cup and lid. The moisture content was worked out using the following formula and expressed as percentage.

Electrical conductivity of seed leachates [13]
Five grams of seeds from each treatment in four replications were weighed and soaked in 25 ml distilled water in a beaker and kept at 25 ± 1˚C temperature. After 24 hours of soaking the solution was decanted and the volume was made up to 25 ml by adding distilled water. The electrical conductivity of the leachate was measured in dSm^{-1}.

Dehydrogenase activity [6]
Twenty five representative seeds from each treatment were taken at bimonthly and preconditioned by soaking in water overnight at room temperature. Seeds were taken at random and dehusked seeds were steeped in 0.25 per cent solution of 2, 3, 5-triphenyl tetrazolium chloride and kept in dark for two hours at 40 ^{o} C for staining. The stained seeds were thoroughly washed with water and then soaked in 10 ml of 2 methoxy ethanol and kept overnight for extracting the red colour formazan. The intensity of red colour was measured using spectrophotometer (model SC-159) using blue filter at 470 nm wave length and methyl cellosolve was used as blank. The OD value obtained was reported as dehydrogenase activity.

RESULTS AND DISCUSSION
In the present investigation an attempt was made to cognizant of the influence of nanoparticles on seed quality and storability of KRH-4 hybrid rice. The dry seed treatment of nanoparticles significantly influenced the seed quality attributes and consistently maintained the viability of the seeds compared to the untreated control. Nanoparticles treated seeds significantly outperformed over control in terms of seed germination, seedling shoot length, seedling root length, vigour index and dehydrogenase activity even after 12 months of storage. Apparent variations were also noticed among the nanoparticles and their concentrations of seed treatment.

Among the tested nanoparticles the seed treatment with ZnO nanoparticles at the rate of 1000 mg/kg outperformed over all other nanoparticles including control and registered the higher seed quality attributes by allowing slower rate of seed ageing. T_3: Zinc oxide 1000 mg per kg registered the highest germination percentage (99.75 % initial and 79.75 % at the end of 12 months of storage), longest shoot length (12.93 cm and 9.10 cm at initial and 12 months after storage respectively), longest root length

(15.95 cm and 10.93 cm at initial and 12 months after storage respectively) and highest seedling vigour index (2880 at initial and 1597 at the end of 12 months of storage). The probable reason for maintenance of seed viability during storage period is the induction of oxidation-reduction reactions via the superoxide ion radicals during germination, resulting the quenching of free radicals in the germinating seeds. In turn, oxygen produced in such process could also be used for respiration, which further promotes germination by the nanoparticles [17]. Prasad *et al.* [12] also observed that ZnO nanoparticles at a concentration of 1000 ppm improved the germination, root growth, shoot growth, dry weight and pod yield in groundnut. The beneficial effect of the ZnO NPs in improving the germination could be ascribed to higher precursor activity of nanoscale zinc in auxin production. ZnO NPs could increase the level of IAA in roots (sprouts) thereby increasing growth rate of seedlings in *Cicer arietinum* [11].

However, with respect to the moisture content of seed and electrical conductivity of seed leachates, the untreated or control (T_1) seeds recorded the highest moisture content as well as electrical conductivity during the progress of the storage period, whereas, T_3: Zinc oxide 1000 mg per kg recorded the minimum seed moisture content at all the months of seed storage period. This could be ascribed to the higher rate of deterioration in the untreated seeds causing the loss of membrane integrity in the seeds and higher rate of production of free radicals as well as the reactive oxygen species owing to the seed respiration resulted in increase of seed moisture content. The electrical conductivity was found higher in case of treated seeds compared to untreated control for the first two months of storage which might be because of the presence of nanoparticles adhering to the seed coat of paddy seeds and where as with the increase in the storage period the electrical conductivity increased at higher rate in the untreated seeds which might be due to loss of membrane integrity and excess leaching of seed leachate from the untreated seeds compared to treated seeds. These results are in conformity with the findings of Awad [4] and Korishettar *et al.* [8].

Table 1. The effect of seed treatment with nanoparticles on seed germination during storage period of KRH-4 F_1 seeds

Treatments	Seed germination (%)												
	Months of storage period												
	Initial	1	2	3	4	5	6	7	8	9	10	11	12
T1	97.75 (81.38)	97.50 (80.92)	96.75 (79.67)	94.25 (76.11)	92.50 (74.10)	88.25 (69.95)	85.00 (67.19)	82.00 (64.87)	81.75 (64.69)	80.25 (63.59)	77.00 (61.32)	74.25 (59.48)	70.50 (57.08)
T2	98.25 (82.43)	98.00 (81.84)	97.75 (81.38)	96.25 (78.82)	94.50 (76.55)	90.50 (72.04)	87.75 (69.50)	84.00 6(6.40)	83.50 (66.01)	82.25 (65.06)	79.75 (63.23)	76.75 (61.15)	75.00 (59.99)
T3	99.75 (88.53)	99.50 (87.10)	98.75 (83.63)	96.75 (79.60)	95.25 (77.39)	92.50 (74.08)	90.25 (71.78)	87.25 (69.05)	86.75 (68.63)	87.00 (68.84)	83.25 (65.82)	81.50 (64.51)	79.75 (63.23)
T4	98.75 84.47)	98.75 (84.47)	98.00 (81.84)	95.75 (78.13)	94.25 (76.11)	89.50 (71.08)	87.00 (68.84)	83.50 (66.01)	83.00 (65.62)	81.75 (64.69)	79.00 (62.71)	77.00 (61.32)	73.75 (59.16)
T5	99.00 (85.06)	99.00 (85.06)	98.50 (83.03)	96.00 (78.43)	94.00 (75.79)	90.25 (71.78)	87.00 (68.84)	83.75 (66.21)	83.25 (65.82)	82.00 (64.87)	79.00 (62.71)	76.25 (60.81)	74.00 (59.33)
T6	99.50 (87.10)	99.50 (87.10)	98.00 (81.84)	96.50 (79.21)	95.25 (77.39)	91.75 (73.30)	90.00 (71.54)	86.75 (68.63)	86.25 (68.21)	86.50 (68.42)	83.00 (65.63)	81.50 (64.50)	78.00 (62.00)
T7	98.75 (84.47)	98.75 (84.47)	98.00 (81.84)	96.00 (78.43)	93.75 (75.50)	89.75 (71.30)	86.50 (68.42)	83.25 (65.82)	83.00 (65.63)	81.75 (64.69)	79.00 (62.71)	76.00 (60.64)	74.00 (59.32)
T8	98.25 (82.43)	98.25 (82.43)	98.25 (82.43)	95.75 (78.09)	93.50 (75.25)	89.75 (71.35)	87.50 (69.29)	84.00 (66.40)	84.00 (66.40)	82.50 (65.24)	78.75 (62.53)	76.00 (60.65)	74.25 (59.49)
T9	99.25 (85.66)	99.25 (85.66)	98.50 (83.03)	96.25 (78.82)	95.00 (77.05)	91.25 (72.78)	90.00 (71.54)	86.50 (68.45)	86.00 (68.02)	85.75 (67.80)	82.75 (65.44)	81.00 (64.14)	78.25 (62.18)
T10	99.00 (85.06)	99.00 (85.06)	98.25 (82.43)	95.50 (77.74)	93.75 (75.57)	89.00 (70.62)	86.75 (68.64)	83.50 (66.01)	83.00 (65.62)	81.50 (64.50)	78.50 (62.35)	76.00 (60.64)	74.00 (59.32)
Mean	98.83 (84.69)	98.76 (84.48)	98.08 (82.11)	95.90 (78.34)	94.18 (76.07)	90.25 (71.83)	87.78 (69.56)	84.45 (66.78)	84.05 (66.46)	83.13 (65.77)	80.00 (63.44)	77.63 (61.78)	75.15 (60.11)
S. Em. ±	0.34	0.35	0.25	0.27	0.49	0.51	0.39	0.43	0.37	0.29	0.37	0.39	0.53
C. D. (0.01)	1.30	1.36	0.99	1.04	1.90	1.99	1.52	1.67	1.42	1.11	1.42	1.52	2.07

*figures in the parenthesis indicate the arc sine transformed values

Legend;

T1: Control T2: ZnO 500 mg/kg T3: ZnO 1000 mg/kg; T4: ZnO 1500 mg/kg T5: Ag 500 mg/kg
T6: Ag1000 mg/kg T7: Ag 1500 mg/kg T8:TiO2 500 mg/k T9: TiO2 1000 mg/kg T10: TiO2 1500 mg/kg

The biochemical parameter dehydrogenase activity examined bimonthly during the course of seed storage period, decreased steadily with the advancement of the storage period irrespective of the treatments. The seed treatment with the nanoparticles showed positive role with the higher enzyme activity during the storage period compared to untreated seeds. Among the treated seeds, the seeds treated with Zinc oxide 1000 mg per kg recorded the higher dehydrogenase activity which might be because of the physiological and biochemical roles associated with the Zinc in the seed tissues. Zn is an important metal nutrient that acts as cofactor for most of the enzyme complexes associated with the respiration and food mobilization in the seeds. The increased availability of the micronutrient at nanoscale with increased chemical reactivity resulted in the increase in synthesis and activity of the enzymes as well as repair of damaged vital cell organelles [5] and counteraction of lipid peroxidation and minimization of free radical reactions during the course of seed ageing. The present investigations are in conformity with the findings of Savithramma *et al* [14]; Korishettar *et al.* [7] and Krishna and Natarajan [8].

Table 2. The effect of nanoparticles on seedling shoot length during storage period of KRH-4 F_1 seeds

Treatments	Seedling shoot length (cm)												
	Months of storage period												
	Initial	1	2	3	4	5	6	7	8	9	10	11	12
T_1	12.23	12.15	12.13	11.78	11.60	11.45	11.25	10.00	9.73	8.93	8.28	8.28	7.65
T_2	12.50	12.50	12.48	12.25	12.18	12.05	11.83	11.13	10.88	10.33	9.23	8.90	8.40
T_3	12.93	12.88	12.86	12.85	12.75	12.50	12.38	11.75	11.53	11.10	10.45	9.50	9.10
T_4	12.40	12.39	12.38	12.28	12.13	12.00	11.75	10.83	10.70	10.35	9.15	8.78	8.00
T_5	12.53	12.50	12.48	12.25	12.15	12.03	11.78	10.60	10.45	10.13	9.00	8.83	8.25
T_6	12.88	12.80	12.75	12.68	12.60	12.43	12.23	11.45	11.33	10.98	10.18	9.45	8.95
T_7	12.55	12.50	12.40	12.18	12.05	12.00	11.80	10.68	10.45	10.10	8.93	8.68	8.05
T_8	12.55	12.45	12.35	12.30	12.18	12.05	11.70	10.68	10.50	10.13	9.10	8.83	8.15
T_9	12.85	12.85	12.73	12.65	12.55	12.40	12.28	11.50	11.33	10.80	10.00	9.25	8.39
T_{10}	12.58	12.50	12.33	12.25	12.10	12.00	11.76	10.65	10.40	10.00	8.83	8.63	7.95
Mean	**12.60**	**12.55**	**12.49**	**12.35**	**12.23**	**12.09**	**11.87**	**10.93**	**10.73**	**10.28**	**9.31**	**8.91**	**8.29**
S. Em. ±	0.12	0.12	0.13	0.15	0.10	0.09	0.19	0.29	0.26	0.25	0.15	0.20	0.22
C. D. (0.01)	0.45	0.45	0.50	0.59	0.40	0.35	0.75	1.13	1.01	0.98	0.59	0.76	0.85

Table 3. The effect of nanoparticles on seedling root length during storage period of KRH-4 F_1 seeds

Treatments	Seedling root length (cm)												
	Months of storage period												
	Initial	1	2	3	4	5	6	7	8	9	10	11	12
T_1	15.05	14.85	14.73	14.53	14.18	13.93	13.43	13.25	13.00	12.58	11.40	10.18	9.40
T_2	15.58	15.50	15.48	15.23	15.00	14.85	14.60	14.50	14.00	13.38	12.75	11.75	10.35
T_3	15.95	15.78	15.65	15.50	15.30	15.25	15.08	15.00	14.75	14.25	13.50	12.60	10.93
T_4	15.45	15.43	15.40	15.23	15.00	14.93	14.50	14.38	14.00	13.25	12.68	11.63	10.20
T_5	15.50	15.45	15.43	15.10	14.90	14.78	14.43	14.28	13.93	13.15	12.55	11.38	10.25
T_6	15.75	15.70	15.60	15.43	15.28	15.08	15.00	14.90	14.65	14.13	13.43	12.25	10.63
T_7	15.45	15.40	15.35	15.15	14.88	14.73	14.50	14.25	13.95	13.05	12.43	11.28	10.00
T_8	15.48	15.43	15.39	15.19	14.96	14.75	14.38	14.20	13.85	13.03	12.65	11.15	9.93
T_9	15.78	15.63	15.55	15.40	15.23	15.05	14.93	14.80	14.33	14.00	13.00	12.00	10.50
T_{10}	15.43	15.40	15.30	15.10	14.80	14.68	14.33	14.18	13.78	13.00	12.38	10.85	9.70
Mean	**15.54**	**15.46**	**15.39**	**15.18**	**14.95**	**14.80**	**14.52**	**14.37**	**14.02**	**13.38**	**12.68**	**11.51**	**10.19**
S. Em. ±	0.10	0.09	0.10	0.13	0.14	0.17	0.21	0.22	0.23	0.20	0.31	0.34	0.30
C. D. (0.01)	0.39	0.33	0.38	0.49	0.53	0.68	0.82	0.84	0.91	0.77	1.21	1.33	1.17

Legend
T1: Control; T2: ZnO 500 mg/kg; T3: ZnO 1000 mg/kg; T4: ZnO 1500 mg/kg; T5: Ag 500 mg/kg T6: Ag1000 mg/kg T7: Ag 1500 mg/kg; T8:TiO2 500 mg/kg
T9: TiO2 1000 mg/kg; T10: TiO2 1500 mg/kg

Table 4. The effect of nanoparticles on seedling vigour index during storage period of KRH-4 F1 seeds

Treatments	Seedling vigour index												
	Months of storage period												
	Initial	1	2	3	4	5	6	7	8	9	10	11	12
T_1	2666	2633	2598	2479	2384	2239	2097	1906	1858	1725	1515	1370	1202
T_2	2751	2751	2732	2644	2568	2435	2319	2153	2077	1949	1752	1585	1405
T_3	2880	2851	2815	2743	2672	2567	2477	2334	2280	2205	1994	1801	1597
T_4	2750	2747	2722	2633	2557	2410	2284	2105	2050	1929	1724	1571	1342
T_5	2774	2767	2748	2626	2543	2419	2280	2083	2029	1909	1702	1540	1369
T_6	2848	2836	2778	2712	2655	2523	2450	2286	2240	2171	1959	1768	1527
T_7	2765	2755	2720	2623	2524	2399	2275	2075	2025	1892	1687	1516	1336
T_8	2753	2739	2725	2632	2537	2405	2282	2090	2045	1910	1713	1518	1342
T_9	2841	2826	2785	2700	2639	2505	2448	2274	2205	2127	1903	1721	1478
T_{10}	2772	2762	2714	2612	2522	2374	2263	2073	2007	1875	1664	1480	1306
Mean	**2780**	**2767**	**2734**	**2640**	**2560**	**2427**	**2317**	**2138**	**2082**	**1969**	**1761**	**1587**	**1390**
S. Em. ±	16.50	17.14	14.53	22.92	17.14	21.23	29.06	37.58	27.78	28.30	26.38	27.85	26.17
C. D. (0.01)	64.19	66.66	56.51	89.14	66.67	82.58	113.01	146.14	108.04	110.08	102.58	108.30	101.78

Table 5. The effect of nanoparticles on seed moisture content during storage period of KRH-4 F_1 seeds

Treatments	Seed moisture content (%)												
	Months of storage period												
	Initial	1	2	3	4	5	6	7	8	9	10	11	12
T_1	9.92	9.96	10.00	10.08	10.11	10.17	10.18	10.18	10.20	10.28	10.31	10.35	10.42
T_2	9.90	9.93	9.95	10.00	10.05	10.08	10.08	10.09	10.10	10.19	10.20	10.23	10.31
T_3	9.89	9.91	9.92	9.96	10.01	10.05	10.05	10.05	10.07	10.17	10.19	10.20	10.27
T_4	9.89	9.94	9.96	9.99	10.04	10.07	10.07	10.08	10.09	10.20	10.20	10.23	10.32
T_5	9.91	9.94	9.97	10.00	10.05	10.09	10.09	10.10	10.11	10.20	10.20	10.23	10.32
T_6	9.89	9.91	9.93	9.96	10.01	10.05	10.05	10.05	10.08	10.18	10.19	10.21	10.29
T_7	9.90	9.93	9.96	10.03	10.08	10.12	10.12	10.12	10.13	10.21	10.22	10.24	10.32
T_8	9.90	9.94	9.97	10.01	10.06	10.10	10.11	10.11	10.12	10.20	10.20	10.23	10.32
T_9	9.90	9.92	9.94	9.98	10.03	10.06	10.06	10.06	10.09	10.18	10.20	10.23	10.30
T_{10}	9.91	9.94	9.97	10.05	10.10	10.14	10.15	10.15	10.16	10.24	10.24	10.29	10.36
Mean	**9.90**	**9.93**	**9.96**	**10.01**	**10.05**	**10.09**	**10.10**	**10.10**	**10.11**	**10.20**	**10.22**	**10.24**	**10.32**
S. Em. ±	0.01	0.03	0.03	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.01
C. D. (0.01)	NS	NS	NS	NS	NS	0.08	0.08	0.09	0.09	0.07	0.06	0.05	0.05

Legend

T1: Control; T2: ZnO 500 mg/kg; T3: ZnO 1000 mg/kg; T4: ZnO 1500 mg/kg; T5: Ag 500 mg/kg; T6: Ag1000 mg/kg; T7: Ag 1500 mg/kg; T8:TiO2 500 mg/kg; T9: TiO2 1000 mg/kg T10: TiO2 1500 mg/kg; NS: Non-significant

Table 6. The effect of nanoparticles on electrical conductivity of seed leachates in KRH-4 F_1 seeds

Treatments	Electrical conductivity of seed leachates (dS m^{-1})												
	Months of storage period												
	Initial	1	2	3	4	5	6	7	8	9	10	11	
T_1	0.170	0.173	0.178	0.184	0.192	0.204	0.211	0.220	0.231	0.238	0.244	0.251	0.259
T_2	0.171	0.175	0.178	0.181	0.186	0.196	0.204	0.212	0.221	0.227	0.233	0.246	0.254
T_3	0.171	0.175	0.178	0.181	0.184	0.193	0.199	0.210	0.218	0.222	0.228	0.240	0.248
T_4	0.173	0.176	0.180	0.183	0.187	0.197	0.205	0.213	0.221	0.228	0.233	0.247	0.254
T_5	0.171	0.175	0.178	0.181	0.185	0.197	0.205	0.213	0.223	0.230	0.234	0.245	0.253
T_6	0.171	0.176	0.178	0.181	0.184	0.194	0.200	0.210	0.219	0.224	0.229	0.241	0.249
T_7	0.172	0.176	0.179	0.183	0.187	0.196	0.204	0.213	0.224	0.231	0.236	0.247	0.253
T_8	0.171	0.175	0.178	0.181	0.186	0.197	0.205	0.214	0.225	0.232	0.237	0.246	0.253
T_9	0.172	0.175	0.178	0.182	0.184	0.194	0.201	0.211	0.221	0.225	0.229	0.243	0.251
T_{10}	0.173	0.177	0.180	0.184	0.189	0.200	0.207	0.215	0.226	0.233	0.238	0.247	0.255
Mean	**0.171**	**0.175**	**0.178**	**0.182**	**0.186**	**0.197**	**0.204**	**0.213**	**0.223**	**0.229**	**0.234**	**0.245**	**0.253**
S. Em. ±	0.0006	0.0010	0.0006	0.0005	0.0005	0.0010	0.0010	0.0012	0.0014	0.0015	0.0014	0.0018	0.0013
C. D. (0.01)	NS	NS	NS	0.0021	0.0021	0.0039	0.0040	0.0047	0.0054	0.0059	0.0053	0.0071	0.0049

Table 7. The effect of nanoparticles on dehydrogenase activity during storage period of KRH-4 F_1 seeds

Treatments	Dehydrogenase activity (OD value)						
	Months of storage period						
	Initial	2	4	6	8	10	12
T_1 Control	0.582	0.574	0.562	0.553	0.546	0.436	0.391
T_2: Zinc oxide 500 mg/kg	0.593	0.586	0.577	0.568	0.563	0.477	0.442
T_3: Zinc oxide 1000 mg/kg	0.620	0.616	0.605	0.601	0.596	0.512	0.479
T_4: Zinc oxide 1500 mg/kg	0.594	0.587	0.575	0.567	0.561	0.476	0.440
T_5: Silver 500 mg/kg	0.592	0.587	0.575	0.566	0.559	0.473	0.439
T_6: Silver 1000 mg/kg	0.618	0.613	0.601	0.595	0.592	0.506	0.473
T_7: Silver 1500 mg/kg	0.595	0.587	0.574	0.565	0.558	0.473	0.437
T_8:Titanium dioxide 500 mg/kg	0.594	0.584	0.572	0.563	0.557	0.471	0.434
T_9:Titanium dioxide 1000 mg/kg	0.615	0.610	0.596	0.589	0.586	0.499	0.464
T_{10}:Titanium dioxide 1500 mg/kg	0.590	0.582	0.569	0.560	0.553	0.464	0.428
Mean	**0.599**	**0.593**	**0.581**	**0.573**	**0.567**	**0.479**	**0.443**
S. Em. ±	0.003	0.005	0.005	0.004	0.004	0.003	0.004
C. D. (0.01)	0.011	0.018	0.018	0.016	0.016	0.012	0.015

Legend
T1: Control; T2: ZnO 500 mg/kg; T3: ZnO 1000 mg/kg; T4: ZnO 1500 mg/kg; T5: Ag 500 mg/kg; T6: Ag1000 mg/kg, T7: Ag 1500 mg/kg; T8:TiO2 500 mg/kg
T9: TiO2 1000 mg/kg T10: TiO2 1500 mg/kg
NS: Non-significant

CONCLUSION

The present investigation revealed that dry seed treatment of KRH-4 F_1 paddy seeds with Zinc oxide nanoparticles at the rate of 1000 mg per kg favored the seed quality attributes and related biochemical parameters during the course of seed storage period. This outcome is valuable both for farmers as well as seed industries because nanoparticles utilization may be a feasible approach to increase the germination, vigour, storability and also to reduce consumption of chemicals substance in agriculture that would reduces environmental pollution.

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REFERENCES

1. Abdul-Baki, A. S. and Anderson, J. D., (1973), Vigour determination in soybean by multiple criteria. *Crop Sci.*, 13: 630-633.
2. Anonymous, (1999), International rules for seed testing. *Seed Sci. Technol.*, 27: 27-31.
3. Anonymous, (2014), International rules for seed testing. *Seed Sci. Technol.*, 44: 27-32
4. Awad, J., 2015, Green synthesis of silver nanoparticles using carob leaf extract and its antibacterial activity, *Int. J. Ind. Chem.,* 4: 29-32.
5. Burgass, R. W. and Powell, A. A., (1984), Evidence for repair processes in the invigoration of seeds by hydration. *Ann. Bot.*, 53: 753-757.
6. Kittock, D. L. and Law, A. G., (1968), Relationship of seedling vigour, respiration and tetrazolium chloride reduction by germination of wheat seeds. *Agron. J.,* 60: 286-288.
7. Korishettar, P., Vasudevan, S. N., Shakuntala, N. M., Doddagoudar, S. R., Hiregoudar, S. and Kisan, B., (2016), Seed polymer coating with Zn and Fe nanoparticles: An innovative seed quality enhancement technique in pigeonpea. *J. Appl. Nat. Sci.,* 8(1): 445-450.
8. Krishna, S. K. and Natarajan, N., (2016), Synthesis of inorganic nanoparticles for the enhancement of seed quality in groundnut cv.VRI-2. *Adv. Res. J. Crop Improv.* 7(1): 32-39.
9. Nair, R., Varghese, S. H., Nair, B. G., Maekawa, T., Yoshida, Y. and Sakthi Kumar, D., (2010), Nanoparticulate material delivery to plants. *J. Plant Sci.*, 179: 154–163
10. Natarajan, N. and Sivasubramanian, K., (2008), Nanotechnology application in seed management. *Nanotechnol. Appl. Agric.*, 43-52.
11. Pandey, A. G., Sharada, S., Sanjay, P. and Raghvendra, S. Y., (2010), Application of ZnO nanoparticles in influencing the growth rate of *Cicer arietinum*. *J. Exptl. Nanosci.*, 5(6): 488-497.
12. Prasad, T. N., Sudhakar, P., Sreenivasulu, Y., Latha, P., Munaswamy, V., Raja Reddy, K. T., Sajanlal, S. R. and Pradeep, T., (2012), Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut. *J. Plant Nutr.*, 35:905–927.

13. Presley, J. T., (1958), Relations of protoplast permeability of cotton seed viability and predeposition of disease. *Pant. Dis. Rep.*, 42: 582.
14. Savithramma, S., Ankanna. and Bhumi, G., (2012), Effect of Nanoparticles on Seed Germination and Seedling Growth of *Boswellia Ovalifoliolata* – an Endemic and Endangered Medicinal Tree Taxon. *Nano Vision*,.2 (1): 61-68.
15. Senthilkumar, S., (2011), Customizing nanoparticles for the maintenance of seed vigour and viability in Blackgram (*Vigna mungo*) cv. VBN 4. *M.Sc.(Agri.) Thesis*, Tamil Nadu Agric. Univ. Coimbatore (India).
16. Sridhar, C., (2012), Effect of nanoparticles for the maintenance of tomato seed vigour and viability. *M.Sc. (Agri.) Thesis*, TNAU, Coimbatore (India).
17. Zhang, L., Hong, F., Lu, S. and Liu, C., (2005), Effect of nano-TiO_2 on strength of naturally aged seeds and growth of spinach. *Biol. Trace Elem. Res.,* 106: 279–297.

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