

Effect of priming and storage containers on seed quality of barley (*Hordeum vulgare* L.)

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Abstract

The study was conducted on seeds of three two-rowed varieties viz. BH 885, DWRB 92 and DWRB 101 and three six-rowed rowed barley varieties viz. BH 946, BH 393, BH 902 at CCS HAU, Hisar, during 2020-21. Nine months naturally aged seeds were primed with GA₃ (50, 100 and 150 ppm), Ethanol (1, 3 and 5%) and ZnO nano-particles (50, 100 and 150 ppm). Primed seeds were stored in ordinary (Cloth bags) and moisture-proof (Polythene bags >700 gauge thickness) containers under ambient conditions. The results revealed that seed primed with ZnO 100 ppm recorded the lowest electrical conductivity (166.59 and 147.93 μ S/cm/seed) whereas seeds primed with ethanol 5% recorded maximum (181.26 and 162.59 μ S/cm/seed) in cloth and polythene bag, respectively. The highest electrical conductivity was recorded in BH 902 (201.90 and 182.03 μ S/cm/seed) in cloth and polythene bags, respectively while minimum in BH 393 (153.70 μ S/cm/seed) in cloth bag and in BH 885 (126.73 μ S/cm/seed) in polythene bag. Maximum germination (91.00 and 92.5%), seedling length (30.61 and 33.58 cm) seedling dry weight (306.67 and 282.33 mg), vigour index-I (2800 and 3118) and vigour index-II (23650 and 21048) were observed in primed seeds with ZnO 100 ppm while minimum germination (85.83 and 89.33%), seedling length (22.64 and 24.23 cm), seedling dry weight (181.97 and 189.44 mg), vigour index-I (1958 and 2170) and vigour index-II (15557 and 16923) were in ethanol 5% in cloth and polythene bag, respectively. Among varieties, DWRB 101 recorded highest germination percentage (93.17 and 94.10%) while BH 885 recorded minimum (79.57 and 82.43%) in cloth and polythene bag, respectively. Maximum seedling length (28.24 and 31.31cm) was recorded in BH 946 and minimum (26.02 and 29.11cm) was in BH 902. Maximum dry weight was observed in DWRB 92 (264.97mg and 254.73 mg) in cloth and polythene bag, respectively while minimum was observed in BH 946 (207.07 mg) in cloth bag and DWRB101 (180.53 mg) in polythene bag. The highest vigour index-I (2595) was found in the BH 946 in cloth bag followed by DWRB 92 (2938) in polythene bag and minimum was observed in BH 885 (2120 and 2402) in cloth and polythene bag, respectively. Maximum vigour index-II (23748 and 22662) was recorded in DWRB 92 in cloth and polythene bags, respectively and minimum was recorded in BH 885 (18232) in cloth bag and in DWRB 101 (16982) in polythene bag. It is concluded that Polythene bags (with thickness >700 gauge) are more suitable to maintain the seed quality of barley as compared to cloth bags. DWRB 101 and BH 946 performed better in all the seed quality parameters indicating highly vigorous cultivars which can be used for further breeding programmes. Seed quality of barley can be enhanced through priming with ZnO 100 ppm and GA₃ 100 ppm.

Keywords: Nano-particles, priming, storage container, two-rowed and six rowed barley



1. Introduction

Barley (*Hordeum vulgare* L.) is one of the major cereal and ranks fourth among grains with production of 156.12 million tonnes after maize, rice and wheat in India as well as in the world. Russia ranks first in barley production which contributes about 14 per cent of the world while India contributes 1.12 per cent in world barley production which was 1.75 million tonnes (Anonymous, 2019). Nutritionally, barley is an important source of carbohydrates (77.7%), protein (9.9%), fat (1.2 g), vitamins like niacin and pyridoxine and minerals like calcium, iron and manganese. The crop is also used as animal fodder, as a source of fermentable material for beer and certain distilled beverages and as a component of various health foods. Barley grains are commonly made into malt in a traditional and ancient method of preparation. In general, barley is mainly classified as six-rowed and two-rowed barleys based on arrangement of kernels. Seed is an important component and the quality seed plays a crucial role in agricultural production as well as in the national economy. Seed deterioration starts once the seed attains physiological maturity in the field. Seed deterioration will lead to some of physiological changes like drop of germinability, decrease in mean germination time and loss of vigour. Storage containers or packaging materials mostly influences the seed longevity during storage condition. The use of proper storage containers during storage is most important for maintaining seed quality until the next cropping season. The container properties greatly influence the interaction of seed with the surrounding environment. The rate of entry and exit of moisture content from the storage container will influence the seed longevity (Walters, 2007). Since, seed is hygroscopic in nature will absorb moisture when it is stored in humid storage conditions until it reaches the equilibrium moisture content. High temperature and moisture content increases the rate of seed deterioration (Roberts, 1972). To overcome all these factors, it is essential to store the seeds in moisture-proof containers such as polythene bags with or without desiccating agents to maintain the seed quality (Vijayalakshmi and Malabasari, 2018). The better barrier properties of the storage container will maintain the germination of seed for longer durations (Fu, 2018). Since seed is a living entity, deterioration is inevitable. It will be faster rate during storage conditions but the rate of

deterioration is slowed down by some seed enhancement techniques priming, coating, pelleting and hardening. Seed priming is one of the scientific techniques used for enhancing the quality of seed at post-harvest season. It is the process of controlled hydration of seeds to a level that allows pre-germination metabolic activity to continue while preventing actual radicle emergence (Vanangamudi, 2014). Seed priming has also been investigated as a pre-sowing or mid-storage treatment for seed batches that have lost vigour due to insufficient storage conditions (Pan and Basu, 1985; Singh *et al.*, 2001). Various studies have been carried out on seed priming and have shown positive results over non-primed seeds, though the methods are not widely used.

The behaviour of seed with different priming treatments depends on various physiological and biochemical factors. There is ample scope for investigating mechanism involved behind the beneficial and adverse effect impacts of seed priming on seed quality. Nanotechnology is a branch of science which deals with the synthesis and application of nanoparticles having size 1–100 nm (Roco, 2003). Now a days, nanotechnology is emerging as a promising approach to be incorporated in agriculture to improve productivity of different crops through seed treatment with nano-particles, their foliar spray on plants, nano-fertilizers for balanced crop nutrition, nano-herbicides for effective weed control, nano-insecticides for plant protection, early detection of plant diseases and nutrient deficiencies using diagnostics kits and nano-pheromones for effective monitoring of pests (Singh *et al.*, 2021). Zinc is essential for plant's enzyme system as it acts as cofactors, metal components and other regulatory factors of many enzymes (Prasad *et al.*, 2012) which comes in the fourth position after nitrogen, phosphorous and potassium. A very little information was available on priming and containers effects on seed quality of two rowed and six rowed of barley. Hence, present study was planned to assess the effect of containers and priming on natural aged seeds of barley.

2. Materials and Methods

The study was conducted on seeds of three two-rowed varieties *viz.* BH 885, DWRB 92 and DWRB 101 and three six-rowed rowed barley varieties *viz.* BH 946, BH 393, BH 902. The seeds were procured from the



Department of Genetics and Plant Breeding, CCS HAU, Hisar during 2020-21. Seed was stored in ordinary (cloth bags) and moisture-proof (polythene bags >700 gauge thickness) containers under ambient conditions. Nine months naturally aged seeds were primed with GA₃ (50, 100 and 150 ppm), ethanol (1, 3 and 5%) and ZnO nano-particles (50, 100 and 150 ppm) priming treatments at 25°C for 24 hours then dried to original moisture content at room temperature. The primed seeds were evaluated for seed quality parameters *viz.*, electrical conductivity, germination percentage, seedling length, seedling dry weight and vigour index-I and vigour index-II. Electrical conductivity was computed as per AOSA (1983). Fifty healthy and undamaged seeds from each treatment in three replications were soaked in 75 ml of distilled water in 100 ml beakers. Seeds were soaked entirely in distilled water and covered with parafilm to reduce evaporation. A control beaker one per replicate was also kept containing distilled water without seeds. After that, these samples were held at 25°C for 24 hrs. The electrical conductivity of the seed leachates was obtained through a direct reading of the conductivity meter and expressed in $\mu\text{S}/\text{cm}/\text{seed}$. For germination test hundred seeds from each variety with 3 replications were placed between sufficient moistened germination papers (BP) and kept at 20°C in seed germinator. The final count was taken on the 8th day and only normal seedlings were considered for per cent germination as per International Seed Testing Association (ISTA, 2019) rules. Ten normal seedlings were randomly selected from each replication of all six barley varieties at the time of final count of germination test and average seedling length was calculated and expressed in centimeters. After measuring the seedling length, these ten

seedlings from each replication were dried in a hot air oven for 48 hrs at $70\pm 1^\circ\text{C}$ and average seedling dry weight of each variety was calculated in milligrams. Seedling vigour indices were calculated according to the method given by Abdul-Baki and Anderson (1973):

Vigour index-I = Standard Germination (%) x Average seedling length (cm)

Vigour index-II = Standard Germination (%) x Average seedling dry weight

2.1 Synthesis of Zinc oxide nano-particles

Zinc oxide nano-particles were prepared as the procedure of Moghaddam *et al.* (2009), in the laboratory of Department of Seed Science and Technology, CCS HAU Hisar. The procedure involves, preparation of 0.45 M aqueous solution of Zinc nitrate $\text{Zn}(\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}$ and 0.9M aqueous NaOH in distilled water. After that, the beaker containing NaOH solution was heated at 55°C temperature. The $\text{Zn}(\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}$ solution was added drop wise slowly up to 40 minutes to the above solution. After this the beaker was sealed and kept for 2 hours. Then precipitated ZnO NPs was cleaned with deionized water and ethanol then dried in the air atmosphere at about 60 °C.

2.2 Characterization of Zinc oxide nano-particles

The characterization of synthesized ZnO NPs was done by FESEM (Field Emission Scanning Electron Microscope) and HRTEM (High Resolution Transmission Electron Microscope). As per the results of SEM and TEM, synthesized ZnO NPs had the characteristics with average particle size 35.25 nm with purity of 99.9% The particles were white in colour having spheroidal and ellipsoidal shape with inter -planar spacing of 0.85 nm.

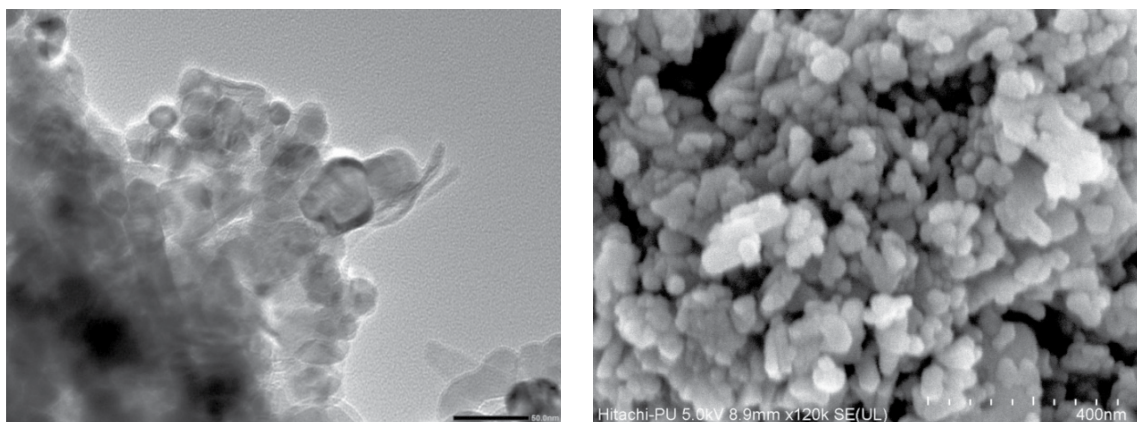


Fig. 1. High resolution transmission electron microscope (HRTEM) and Field emission scanning electron microscope (FESEM) image of ZnO NPs



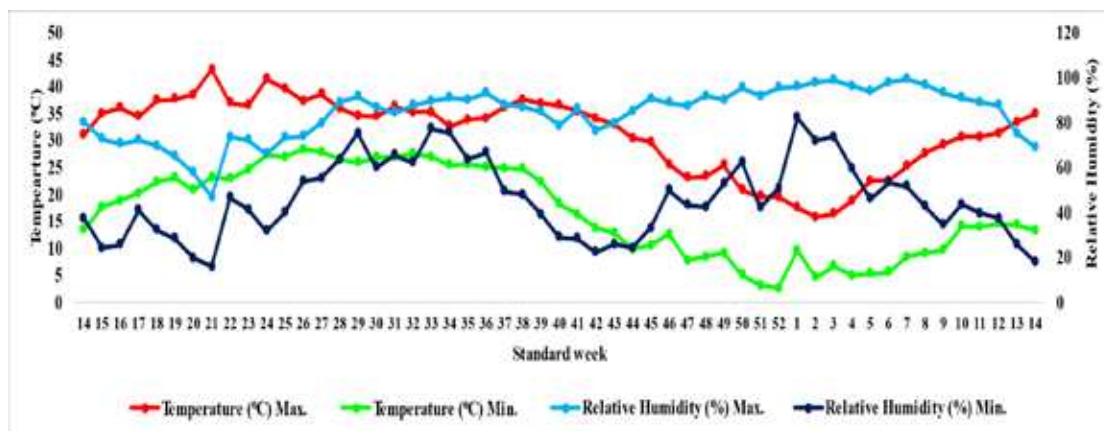


Fig. 2. Average weather data of Hisar during storage period (2020-21)

2.3 Statistical Analysis

The experiment was conducted in completely randomized design (CRD) and data obtained from the experiment were analyzed as per standard method suggested by Panse and Sukhatme (1985) and using the online statistical tool (OPSTAT) developed by Sheoran (2010).

3. Results and Discussion

The results revealed that seed primed with ZnO (100 ppm) recorded the lowest electrical conductivity (166.59 $\mu\text{S}/\text{cm}/\text{seed}$ and 147.93 $\mu\text{S}/\text{cm}/\text{seed}$), whereas seeds primed with ethanol 5% recorded maximum (181.26 $\mu\text{S}/\text{cm}/\text{seed}$ and 162.59 $\mu\text{S}/\text{cm}/\text{seed}$) in cloth and polythene bag, respectively. Significant difference was observed among the varieties also. The highest electrical conductivity was recorded in BH 902 (201.90 and 182.03 $\mu\text{S}/\text{cm}/\text{seed}$) in cloth and polythene bags, respectively while minimum was estimated in BH 393 (153.70 $\mu\text{S}/\text{cm}/\text{seed}$) in cloth bag and in BH 885 (126.73 $\mu\text{S}/\text{cm}/\text{seed}$) in polythene bag. Seeds primed with ZnO 100 ppm followed by GA_3 100 ppm recorded superiority for all seed quality parameters. Maximum germination (91.00 and 92.5%) was observed in primed seeds with ZnO 100 ppm while minimum (85.83 and 89.33%) was in ethanol 5% in cloth and polythene bag respectively. Among varieties, DWRB 101 recorded highest germination percentage (93.17 and 94.10%) while BH 885 recorded minimum (79.57 and 82.43%) in cloth and polythene bag, respectively. Polythene bag recorded significantly higher germination percentage (91.09%) as compared to cloth bag (87.77%).

Maximum seedling length (30.61 and 33.58 cm) was recorded in ZnO (100 ppm) which was at par with GA_3 100 ppm (30.94 and 32.97 cm) while the minimum (22.64

and 24.23 cm) in ethanol 5% in cloth and polythene bag, respectively. Among varieties, maximum seedling length (28.24 and 31.31 cm) was recorded in BH 946 while minimum (26.02 and 29.11 cm) was in BH 902. The highest seedling dry weight was also recorded in the ZnO 100 ppm (306.67 mg and 282.33) followed by GA_3 100 ppm (292.33 mg and 281.66) while ethanol 5% priming recorded the least seedling dry weight (181.97 and 189.44 mg) in cloth and polythene bag, respectively. Among the varieties, the highest dry weight was observed in DWRB 92 (264.97 and 254.73 mg) in cloth and polythene bag, respectively while minimum was observed in BH 946 (207.07 mg) in cloth bag and DWRB101 (180.53 mg) in polythene bag.

All the priming treatments significantly enhanced the vigour index-I except ethanol 5%. Maximum vigour index-I (2800 and 3118) was recorded in ZnO 100 ppm which was at par with 100 ppm GA_3 (2771 and 3058) while the minimum (1958 and 2170) was in ethanol 5% in cloth and polythene bag, respectively. The highest vigour index-I (2595) was found in the BH 946) in cloth bag followed by DWRB 92 (2938) in polythene bag and minimum was observed in BH 885 (2120 and 2402) in cloth and polythene bag, respectively.

All the priming treatments significantly enhanced the vigour index-II except ethanol 5%. Maximum vigour index-II (23650 and 21048) was recorded in ZnO 100 ppm while minimum (15557 and 16923) was in ethanol 5% in cloth and polythene bag, respectively. Among varieties, highest vigour index-II (23748 and 22662) was recorded in DWRB 92 in cloth and polythene bags, respectively



Table 1. Effect of storage container and priming treatments on electrical conductivity (μScm^{-1} seed⁻¹) of different varieties of barley

Treatments (T)	Cloth bag							Polythene bag						
	BH 946	BH 902	BH 393	BH 885	DWRB101	DWRB92	Mean	BH 946	BH 902	BH 393	BH 885	DWRB101	DWRB92	Mean
Control	180.53	206.57	158.17	165.57	169.63	196.2	179.45	173.27	186.7	140.1	130.9	156.77	176.97	160.79
GA₃ (50ppm)	173.68	201.71	154.31	159.71	164.78	190.34	174.09	166.41	181.84	136.24	125.04	151.91	171.11	155.43
GA₃ (100ppm)	170.68	195.71	149.31	156.71	159.78	186.34	169.76	163.41	175.84	131.24	122.04	146.91	167.11	151.09
GA₃ (150ppm)	178.68	204.71	155.31	163.71	168.78	193.34	177.42	171.41	184.84	137.24	129.04	155.91	174.11	158.76
Ethanol (1%)	177.68	203.71	154.31	162.71	166.78	192.34	176.26	170.41	183.84	136.24	128.04	153.91	173.11	157.59
Ethanol (3%)	175.68	201.71	153.31	161.71	165.78	193.34	175.26	168.41	181.84	135.24	127.04	152.91	174.11	156.59
Ethanol (5%)	183.68	207.71	159.31	168.71	170.78	197.34	181.26	176.41	187.84	141.24	134.04	157.91	178.11	162.59
ZnO (50 ppm)	173.68	199.71	152.31	158.71	163.78	190.34	173.09	166.41	179.84	134.24	124.04	150.91	171.11	154.43
ZnO (100 ppm)	166.68	193.71	146.31	152.71	156.78	183.34	166.59	159.41	173.84	128.24	118.04	143.91	164.11	147.93
ZnO (200 ppm)	178.68	203.71	154.31	163.71	165.78	193.34	176.59	171.41	183.84	136.24	129.04	152.91	174.11	157.93
Mean	175.97	201.9	153.7	161.4	165.27	191.63	174.97	168.7	182.03	135.63	126.73	152.4	172.4	156.31
CD(P = 0.5)	C = 0.821, V = 1.421, T = 1.835, CxV = 2.01, CxT = 2.595, VxT = NS, CxVxT = NS													

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Table 2. Effect of storage container and priming treatments on germination percentage (%) of different varieties of barley

Treatments	Cloth bag							Polythene bag						
	BH 946	BH 902	BH 393	BH 885	DWRB101	DWRB92	Mean	BH 946	BH 902	BH 393	BH 885	DWRB101	DWRB92	Mean
Control	90.67 (72.21)	83.67 (66.17)	90.67 (72.21)	78.67 (62.49)	91.67 (73.22)	84.67 (66.95)	86.67 (68.59)	91.33 (72.88)	91.33 (72.88)	97.33 (80.60)	80.00 (63.43)	92.67 (74.29)	93.33 (75.03)	91.00 (72.54)
GA₃ (50ppm)	91.33 (72.88)	85.33 (67.48)	92.33 (73.92)	79.33 (62.96)	92.33 (73.92)	85.33 (67.48)	87.67 (69.44)	93.33 (75.03)	93.33 (75.03)	90.33 (71.88)	82.67 (65.40)	93.33 (75.03)	93.33 (75.03)	91.06 (72.60)
GA₃ (100ppm)	92.33 (73.92)	87.33 (69.15)	94.33 (76.22)	80.33 (63.67)	93.33 (75.03)	86.33 (68.30)	89.00 (70.63)	94.33 (76.22)	95.33 (77.52)	91.33 (72.88)	84.33 (66.68)	95.33 (77.52)	94.33 (76.22)	92.50 (74.11)
GA₃ (150ppm)	90.33 (71.88)	82.33 (65.14)	89.33 (70.93)	78.33 (62.26)	90.33 (71.88)	83.33 (65.90)	85.67 (67.76)	92.33 (73.92)	93.33 (75.03)	88.33 (70.02)	82.33 (65.14)	94.33 (76.22)	92.33 (73.92)	90.50 (72.05)
Ethanol (1%)	91.33 (72.88)	85.33 (67.48)	91.33 (72.88)	79.33 (62.96)	93.33 (75.03)	85.33 (67.48)	87.67 (69.44)	92.33 (73.92)	93.33 (75.03)	88.33 (70.02)	82.33 (65.14)	94.33 (76.22)	92.33 (73.92)	90.50 (72.05)
Ethanol (3%)	92.33 (73.92)	87.33 (69.15)	92.33 (73.92)	80.33 (63.67)	95.33 (77.52)	86.33 (68.30)	89.00 (70.63)	93.33 (75.03)	94.33 (76.22)	90.33 (71.88)	83.33 (65.90)	96.33 (78.96)	93.33 (75.03)	91.83 (73.39)
Ethanol (5%)	90.33 (71.88)	82.33 (65.14)	89.33 (70.93)	78.33 (62.26)	91.33 (72.88)	83.33 (65.90)	85.83 (67.89)	90.67 (72.21)	90.67 (72.21)	89.33 (70.93)	80.33 (63.67)	91.67 (73.22)	93.33 (75.03)	89.33 (70.93)
ZnO (50ppm)	92.33 (73.92)	86.33 (68.30)	92.33 (73.92)	80.33 (63.67)	94.33 (76.22)	86.33 (68.30)	88.67 (70.33)	93.33 (75.03)	94.33 (76.22)	90.33 (71.88)	82.67 (65.40)	94.33 (76.22)	93.33 (75.03)	91.39 (72.94)
ZnO (100ppm)	94.33 (76.22)	89.33 (70.93)	94.33 (76.22)	82.33 (65.14)	97.33 (80.60)	88.33 (70.02)	91.00 (72.54)	94.33 (76.22)	95.33 (77.52)	91.33 (72.88)	84.33 (66.68)	95.33 (77.52)	94.33 (76.22)	92.50 (74.11)
ZnO (200ppm)	89.33 (70.93)	83.33 (65.90)	90.33 (71.88)	78.33 (62.26)	92.33 (73.92)	85.33 (67.48)	86.50 (68.44)	92.33 (73.92)	93.33 (75.03)	88.33 (70.02)	82.00 (64.90)	93.33 (75.03)	92.33 (73.92)	90.28 (71.83)
mean	91.47 (73.02)	85.27 (67.43)	91.67 (73.22)	79.57 (63.13)	93.17 (74.85)	85.47 (67.59)	87.77 (69.53)	92.77 (74.40)	93.47 (75.19)	90.53 (72.08)	82.43 (65.22)	94.10 (75.94)	93.23 (74.92)	91.09 (72.63)
C.D (P = 0.05)	C = 0.735, V = 1.273, T = 1.644, CxV = 1.8, CxT = NS, VxT = NS, CxVxT = NS													

Figures in parenthesis are angular transformed values





Table 3. Effect of storage container and priming treatments on seedling length (cm) of different varieties of barley

Treatments	Cloth bag							Polythene bag						
	BH 946	BH 902	BH 393	BH 885	DWRB101	DWRB92	Mean	BH 946	BH 902	BH 393	BH 885	DWRB101	DWRB92	Mean
Control	24.28	25.45	26.23	23.67	25.22	26.12	25.16	28.48	29.32	29.43	27.21	28.52	29.22	28.69
GA₃ (50 ppm)	28.8	25.77	30.49	27.53	27.07	29.84	28.25	30.18	30.55	31.25	29.35	30.88	31.63	30.64
GA ₃ (100 ppm)	33.51	28.17	34.75	29.63	29.43	30.15	30.94	31.52	32.35	34.85	30.93	32.63	35.52	32.97
GA ₃ (150 ppm)	25.01	25.73	27.25	26.21	27.77	28.55	26.75	29.83	28.72	30.5	28.91	29.67	30.08	29.62
Ethanol (1%)	29.76	26.02	28.22	26.56	26.42	27.87	27.48	28.28	30.65	30.05	29.68	29.14	31.57	29.9
Ethanol (3%)	30.4	27.07	27.5	27.8	28.64	28.85	28.38	32.17	33.12	32.72	30.69	32.82	33.14	32.44
Ethanol (5%)	22.49	20.57	25.11	19.39	23.77	24.5	22.64	22.85	20.95	28.2	24.65	22.01	26.72	24.23
ZnO (50 ppm)	29.3	26.87	27.5	27.57	28.8	28.87	28.15	31.56	30.25	32.1	29.03	30.4	31.79	30.86
ZnO (100 ppm)	33.4	27.73	31.87	29.8	30.64	30.23	30.61	33.07	32.57	33.54	31.89	34.78	35.65	33.58
ZnO (200 ppm)	25.48	26.82	26.73	26.53	27.29	27.9	26.79	29.58	29.34	30.53	28.8	29.34	28.72	29.39
Mean	28.24	26.02	28.56	26.47	27.5	28.29	27.51	29.75	29.78	31.32	29.11	30.02	31.4	30.23
CD (p = 0.05)	C = 0.845, V = 1.463, CxV = NS, T = 1.889, CxT = NS, VxT = NS, CxVxT = NS													

Table 4. Effect of storage container and priming treatments on seedling dry weight (mg) different varieties of barley

Treatments	Cloth bag							Polythene bag						
	BH 946	BH 902	BH 393	BH 885	DWRB101	DWRB92	Mean	BH 946	BH 902	BH 393	BH 885	DWRB101	DWRB92	Mean
Control	182.33	183.00	195.33	198.67	166.33	237.67	193.89	182.00	183.00	195.33	198.00	166.33	237.67	193.72
GA₃ (50 ppm)	207.67	218.67	204.33	218.33	219.67	263.67	222.06	197.33	199.00	213.33	212.67	179.33	253.67	209.22
GA₃ (100 ppm)	231.33	247.33	258.33	263.67	248.00	292.33	256.83	222.33	226.00	238.33	238.67	203.33	281.67	235.06
GA ₃ (150 ppm)	185.00	203.67	198.00	209.67	188.00	249.67	205.67	189.33	189.00	200.33	204.67	170.33	243.67	199.56
Ethanol 1%	211.33	223.67	218.67	227.33	205.33	262.67	224.83	197.33	199.00	201.33	212.67	178.33	253.67	207.06
Ethanol (3%)	221.33	243.67	239.67	287.33	245.33	282.67	253.33	203.67	199.00	213.33	234.45	196.00	270.67	219.52
Ethanol (5%)	169.33	169.67	187.33	184.50	153.33	227.67	181.97	181.00	179.00	189.33	194.00	163.67	229.67	189.44
ZnO (50 ppm)	224.33	210.67	228.67	224.67	225.67	270.33	230.72	179.33	223.00	217.33	193.67	172.33	251.67	206.22
ZnO (100 ppm)	241.67	244.67	256.33	260.67	252.67	306.67	260.44	221.00	191.00	235.67	236.00	201.33	282.33	227.89
ZnO (200 ppm)	196.33	190.33	216.00	214.33	203.33	256.33	212.78	186.33	187.00	198.33	203.67	172.33	242.67	198.39
Mean	207.07	213.53	220.27	228.92	210.77	264.97	224.25	195.97	197.50	210.27	212.84	180.33	254.73	208.61
CD (P = 0.05)	C = 1.226, V = 2.124, CxV = 3.004, T = 2.742, CxTv3.878, VxT = 6.717, CxVxT = 9.5													

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Table 5. Effect of storage container and priming treatments on vigour index-I of different varieties of barley

Treatments	Cloth bag							Polythene bag						
	BH 946	BH 902	BH 393	BH 885	DWRB101	DWRB92	Mean	BH 946	BH 902	BH 393	BH 885	DWRB101	DWRB92	Mean
Control	2202	2127	2380	1878	2312	2212	2185	2599	2675	2844	2177	2644	2723	2610
GA₃ (50 ppm)	2641	2208	2827	2195	2510	2558	2490	2828	2862	2834	2425	2893	2963	2801
GA₃ (100 ppm)	3105	2471	3289	2392	2758	2614	2771	2976	3095	3194	2610	3121	3352	3058
GA₃ (150 ppm)	2271	2128	2434	2064	2519	2390	2301	2766	2692	2705	2381	2810	2788	2690
Ethanol (1%)	2729	2231	2588	2118	2463	2389	2420	2622	2871	2666	2445	2760	2926	2715
Ethanol (3%)	2812	2373	2550	2244	2741	2501	2537	3013	3135	2966	2559	3172	3104	2992
Ethanol (5%)	2029	1704	2250	1530	2182	2053	1958	2076	1905	2530	1976	2025	2505	2170
ZnO (50 ppm)	2716	2330	2550	2226	2728	2503	2509	2956	2865	2911	2399	2879	2978	2831
ZnO (100ppm)	3153	2489	3017	2465	2993	2682	2800	3131	3116	3074	2686	3327	3374	3118
ZnO (200 ppm)	2287	2246	2425	2089	2530	2392	2328	2742	2750	2708	2361	2749	2663	2662
Mean	2595	2231	2631	2120	2574	2429	2430	2771	2797	2843	2402	2838	2938	2765
CD (p = 0.05)	C = 93.283, V = 161.57, CxV = NS, T = 208.585, CxT = NS, VxT = NS, CxVxT = NS													

Table 6. Effect of storage container and priming treatments on vigor index-II of different varieties of barley

Treatments	Cloth bag							Polythene bag						
	BH 946	BH 902	BH 393	BH 885	DWRB101	DWRB92	Mean	BH 946	BH 902	BH 393	BH 885	DWRB101	DWRB92	Mean
Control	16532	15249	17719	15661	16194	20112	16911	16615	16693	19016	15838	15415	22199	17629
GA₃ 50ppm	18952	18645	18869	17306	20268	22485	19421	18403	18558	19256	17582	16723	23661	19030
GA₃ 100ppm	21345	21585	24373	21166	23132	25229	22805	20969	21530	21753	20127	19370	26556	21717
GA₃ 150ppm	16697	16754	17689	16409	16968	20791	17551	17467	17625	17681	16850	16053	22484	18027
Ethanol 1%	19287	19071	19957	18020	19149	22399	19647	18206	18558	17770	17509	16812	23407	18710
Ethanol 3%	20445	21265	22114	23068	23374	24389	22442	19008	18757	19256	19537	18889	25266	20119
Ethanol 5%	15281	13954	16720	14438	13989	18957	15557	16411	16219	16899	15583	15006	21421	16923
ZnO 50ppm	20699	18173	21099	18033	21273	23324	20433	16723	21030	19617	16011	16256	23464	18850
ZnO 100ppm	22792	21842	24166	21447	24578	27074	23650	20844	18194	21531	19903	19189	26629	21048
ZnO 200ppm	17524	15846	19497	16774	18760	21859	18377	17190	17438	17505	16700	16070	22391	17882
Mean	18955	18238	20220	18232	19768	22662	19679	18183	18460	19028	17564	16978	23748	18994
C.D (p = 0.05)	C = 115.454, V = 199.973, CxV = 282.804, T = 254.163, CxT = 365.098, VxT = 632.369, CxVxT = 894.304													



and minimum was recorded in BH 885 (18232) in cloth bag and in DWRB 101 (16982) in polythene bag.

As per the results, ZnO (100 ppm) and GA₃ (100 ppm) were found the superior over the other treatments which enhanced the seed quality parameters. Priming treatments may cause the damages repaired in the cell membrane which prevents the expulsion of seed leachates out of the membrane. The increase in the germination may be due efficient production and utilization of germination metabolites and better genetic repair due to priming treatments. Although ethanol 1 and 3% enhanced the seed germination but ethanol 5% priming showed the negative effect on germination. The higher concentration of ethanol caused the toxicity in the seeds. The similar results were obtained in the previous studies. The variation among the varieties also found to be significant in both cloth and polythene bag stored seeds. The variety DWRB 92 recorded the maximum while BH 885 recorded minimum germination percentage. The response of different cultivars to the priming treatments were also noted by different authors (Heydecker and Coolbear, 1977; Bradford *et al.*, 1990; Rawat *et al.* (2018) in wheat. Several studies showed that Zn nano-particles increases the hormonal biosynthesis specially auxins and gibberellins which consequently activates the cell division and elongation and increase the degradation of food reserves that ultimately increases the vigour (El-Kereti *et al.*, 2014; Al-Harbi *et al.*, 2019).

4. Conclusion

It is concluded that Polythene bags (with thickness >700 gauge) are more suitable to maintain the seed quality of barley as compared to cloth bags. DWRB 101 and BH 946 performed better in all the seed quality parameters indicating highly vigorous cultivars which can be used for further breeding programmes. Seed quality of barley can be enhanced through priming with ZnO 100 ppm and GA₃ 100 ppm.

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Conflict of Interest

Authors declare that they have no conflict of interest.

Ethical Compliance Statement

NA

Author's Contribution

Siddu Appasaheb Kurubar: Execution of field/lab experiments and data collection

Axay Bhuker: Designing of the experiments, Analysis of data and interpretation and Preparation of the manuscript

Yogender Kumar: Contribution of experimental materials

5. References

1. A El-Kereti M, SA El-feky, MS Khater, YA Osman and A El-sherbini ES. 2013. ZnO nanofertilizer and He Ne laser irradiation for promoting growth and yield of sweet basil plant. *Recent Patents on Food, Nutrition and Agriculture* 5(3):169-181.
2. Abdul-Baki, AA and JD Anderson. 1973. Vigour determination in soybean by multiple criteria. *Crop Science* 13:630-633.
3. Al-Harbi HFA, E Abdelhalim, and NM Araf. 2019. Modulatory effect of zinc oxide nanoparticles on gamma radiation-induced genotoxicity in *Vicia faba* (Fabeaceae). *Genetics and Molecular Research* 18(1).
4. Anonymous. 2019. Food and Agriculture Organization of the United Nations, Rome, Italy.
5. AOSA. 1983. Seed vigour testing Hand book. Association of official seed analysts. Contribution No. 32:88.
6. Bradford KJ, JJ Steiner and SE Trawatha. 1990. Seed priming influence on germination and emergence of pepper seed lots. *Crop Science*, 30: 718-721.
7. Fu X, H Xiong, H Min, X Zhu, J He and H Mu. 2018. Effects of packaging materials on storage quality of peanut kernels. *Plos One*, 13(3):1-10. <https://doi.org/10.1371/journal.pone.0190377>.
8. Heydecker W and P Coolbear 1977. Seed treatments for improved performance-survey and attempted prognosis. *Seed Science and Technology* 5:353-425.
9. ISTA. 2019. Informational rules for seed testing. *International Seed Testing Association*. Zurich. Switzerland.
10. Moghaddam AB, T Nazari, J Badraghi and M Kazemzad. 2009. Synthesis of ZnO nanoparticles and electrodeposition of polypyrrole/ZnO nanocomposite



- film. *International Journal of Electrochemical Science* 4(2): 247-257.
11. Pan D and RN Basu. 1985. Mid-storage and pre-sowing seed treatments for lettuce and carrot. *Scientia Horticulturae* 25(1): 11-19.
12. Panse VG and PV Sukhatme. 1985. Statistical methods for agricultural workers, 4th Ed., ICAR, New Delhi.
13. Rawat PS, R Kumar, P Ram and P Pandey. 2018. Effect of nanoparticles on wheat seed germination and seedling growth. *International Journal of Agricultural and Biosystems Engineering* 12(1):13-16. <https://doi.org/10.5281/zenodo.1315657>.
14. Roberts EH. 1972. Cytological, genetic and metabolic changes associated with loss of viability In: E.H Roberts (ed.) Viability of seeds. Chapman and Hall limited, London: 253-306.
15. Roco M. 2003. Broader Societal Issues of Nanotechnology. *Journal of Nanoparticle Research* 5: 181-189.
16. Sheoran OP. 2010. Online statistical analysis (OPSTAT) software developed by Chaudhary Charan Singh Haryana Agricultural University, Hisar, India. <http://www.hau.ernet.in/opstat.html>.
17. Singh G, SS Gill and KK Sandhu. 2001. Storage of primed seeds of muskmelon (*Cucumis melo* L.). *Seed Research* 29(2): 235-237.
18. Singh N, A Bhuker and J Jeevanadam. 2021. Effects of metal nanoparticle-mediated treatment on seed quality parameters of different crops. *Naunyn-Schmiedeberg's Arch Pharmacology* 394(6):1067-1089. <https://doi.org/10.1007/s00210-021-02057-7>.
19. Singh P and AP. Singh. 2021. Nanomaterials in Soil Health Management and Crop Production: Potentials and Limitations. In: Kharissova O.V., Martínez L.M.T., Kharisov B.I. (eds) Handbook of Nanomaterials and Nanocomposites for Energy and Environmental Applications. Springer, Cham. https://doi.org/10.1007/978-3-030-11155-7_35-1.
20. Vanangamudi K. 2014. Seed Science and Technology, an illustrated text book. New India publishing agent, New Delhi: 371-372.
21. Vijayalakshmi N and TA Malabasari. 2018. Effect of Packaging Materials and Form on Storability of Summer Groundnut (*Arachis hypogaea* L.) CvG2-52. *International Journal of Current Microbiology and Applied Sciences* 7(11): 760-766.
22. Vijayalaxmi V, K Ramamoorthy and N Natarajan. 2013. Effect of nanoparticle (TiO₂) on naturally aged seeds of maize (*Zea mays* L.). 13th Nation. Seed Sem., Innovations in Seed Research and Development, UAS, Bangalore, June 2013: 8-10.
23. Walters C. 2007. Materials used for seed storage containers: response to Gómez-Campo. *Seed Science Research* 17(4): 233-242.

