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EFFECT OF NANOPARTICLE SEED TREATMENTS ON LONGEVITY OF CHICKPEA (*CICER ARIETINUM* L.) SEEDS

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Abstract: The present study was carried out on chickpea variety Pusa 547 at Indian Agricultural Research Institute, New Delhi during 2020-21 with the objective to study the effect of nanoparticles on seed storage potential. The seeds were dry dressed and infused with each of nano and bulk forms of Zinc oxide, Titanium oxide, Silicon dioxide @ 50, 100, 250, 500 and 750ppm. Along with the two controls *i.e.,* untreated and treated with recommended PoP (Thiram treated @ 2g/Kg of seeds), seeds were stored in different packaging material *i.e.,* Polythene and cloth bags under ambient conditions up to 6 month, to study the storage efficacy. Results of storage studies illustrated that after 6 months of storage, highest value of germination percentage (80.67%), seedling vigour index-I (2781), seedling vigour index-II (38.16) and field emergence percentage (76.67%) were recorded in dry nano ZnO @ 250ppm treated seeds which were stored in polythene over both the controls. It was concluded that the seeds treated with dry nano ZnO @ 250ppm found to be most effective for the enhancement of longevity of chickpea seeds.

Keywords: Chickpea, germination, nanoparticles, storability, vigour, zinc oxide.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an annual winter grain legume, belonging to family Leguminosae, and having an extensive geographical distribution. Chickpea is known by different names in different places such as; gram, chana, garbanzo beans, bengal gram. It is a self-pollinated crop having chromosome number 2n= 16.

Chickpea is widely grown and consumed pulse crop around the world, particularly in Afro-Asian countries. It has a considerable amount of carbohydrates and proteins (12.4-31.5%), and it also contains dietary fibre (6%), lipids (6%), all the essential amino acids and minerals such as calcium, magnesium, phosphorous and especially potassium. It can be used to produce nutritious value-added products, which can then be used as nutritious food for low-income people in developing nations as well as patients with lifestyle diseases (6).

Stagnation in the crop yield has become one of the main concerns for the growing population in the last decade. The advancement of crop with any effective method is a crucial scientific task. A crop's production can be increased by either increasing the area under cultivation or improving the productivity per unit area. Because of limitation in the area, the yield per unit area must be raised to assure the nation's food security. On the other hand, in chickpea seed deterioration is a major issue caused by exposure to harsh environmental conditions as reported by Kasote *et al*. (9). Seed deterioration is inexorable, irreversible, and inevitable, and is primarily determined by the physical,

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physiological, and chemical composition of the seed (5). However, by imposing certain seed treatments before storage, the degree of deterioration could be slowed to a greater extent during storage. The use of nano-technological approaches is expected to minimise oxidative damage and quench reactive oxygen species, improving seed viability and vigour as reported by Sandeep *et al*. (15).

Nanoparticles have distinct physiological properties that enable them to penetrate plants and modify metabolic processes. The incorporation of nanoparticles into plants could have a substantial effect, and thus could be used for agricultural purposes to improve growth and yield (11). Metal oxide nanoparticles were found to have a positive effect on seed quality attributes (2).

Therefore, by keeping all the above aspects in view the present study was conducted to investigate the effects of seed treatments with three metal oxide nano-particles *viz*.; zinc oxide, titanium dioxide and silicon dioxide nano particles with different concentrations on storage potential of the chickpea crop.

MATERIALS AND METHODS

The present storage study was carried out during the year 2020-2021in laboratory of Division of Seed Science and Technology, ICAR-IARI, New Delhi.

Experimental Materials

Chick pea seeds of the variety Pusa 547 were treated with nano and bulk forms of Zinc oxide, Titanium dioxide, Silicon dioxide at the concentrations of 50, 100, 250, 500, and 750 mg kg-1 of seeds in both dry and wet formulations in Tamil Nadu Agricultural University in 1st October, 2020 and those treated seeds were received and used for the study along with two control *i.e.,* Untreated and treated with recommended (Thiram 2g/Kg) package of practices (PoP).

Treatment combinations (62)

Formulations: 2 (Dry and Wet)
Forms: 2 (Bulk and Nano)
Metal oxides: 3 (Zinc oxide, Titanium dioxide and Silicon dioxide)
Concentrations: 5 (50, 100, 250, 500 and 750 mg kg-1)
Controls: 2, untreated (control 1) and recommended PoP (control 2). The treatments details are given in Table 1.

The treated along with untreated seeds of chickpea were stored in two different packaging materials *viz.,* polythene bag and cloth bag under ambient room temperature. The seed samples were evaluated at different periods of storage *i.e*., 0, 3, 6 months for the following seed quality parameters *i.e,* germination percentage, seedling vigour index-I, seedling vigour index-II and field emergence percentage. The methods followed are explained below.

The germination test was conducted using between paper method as per ISTA (8). 50 seeds in three replications were placed on moist germination paper and then rolled towels were incubated at 20±1°C and 90 ± 2 % relative humidity. The final count was taken on 8th day and germination percentage was expressed based on normal seedlings.

The vigour indices were calculated using following formula (1):

SVI I= Germination (%) X Mean seedling length (cm)

SVI II= Germination (%) X Mean dry weight (g)

For evaluation of percent field emergence, seeds were sown in the field and the number of seedling emerged were recorded on fifteenth day after sowing and the mean seedling emergence was expressed in percentage.

STATISTICAL ANALYSIS

The data collected from the experiments were subjected to appropriate statistical analysis. Three factor analyses of the data were done and calculations of least significant difference (LSD) were performed. The correlation coefficient between different parameters was also worked out using SPSS 17 software. The values in percentage were converted to arc sine values using percentage transformation for the calculation of critical difference (C.D. at p=0.05).

Table 1: Details of formulations, forms, metal oxides and concentrations of nanoparticle treatments

T1= Untreated control	T22= Dry bulk ZnO @750ppm	T43= Wet nano TiO2 @50ppm
T2= Thiram treated @2g/kg	T23= Wet nano SiO2 @50ppm	T44= Wet nano TiO2 @100ppm
(Recommended PoP)	T24= Wet nano SiO2@100ppm	T45= Wet nano TiO2 @250ppm
T3= Wet nano ZnO @50ppm	T25= Wet nano SiO2 @250ppm;	T46= Wet nano TiO2 @500ppm
T4= Wet nano Zno @100ppm	T26= Wet nano SiO2 @500ppm	T47= Wet nano TiO2 @750ppm
T5= Wet nano ZnO @250ppm	T27= Wet nano SiO2 @750ppm	T48= Wet bulk TiO2 @50ppm
T6= Wet nano ZnO @500ppm	T28=Wet bulk SiO2 @50ppm	T49= Wet bulk TiO2 @100ppm
T7= Wet nano ZnO @750ppm	T29= Wet bulk SiO2 @100ppm	T50= Wet bulk TiO2 @250ppm
T8= Wet bulk ZnO @50ppm	T30= Wet bulk SiO2 @250ppm	T51=Wet bulk TiO2 @500ppm
T9= Wet bulk ZnO @100ppm	T31= Wet bulk SiO2 @500ppm	T52= Wet bulk TiO2 @750ppm
T10= Wet bulk ZnO @250ppm	T32 = Wet bulk SiO2 @750ppm	T53= Dry nano TiO2 @50ppm
T11= Wet bulk ZnO @500ppm	T33= Dry nano SiO2 @50ppm	T54= Dry nano TiO2 @100ppm
T12= Wet bulk ZnO @750ppm	T34= Dry nano SiO2 @100ppm	T55= Dry nano TiO2 @250ppm
T13= Dry nano ZnO @50ppm	T35= Dry nano SiO2 @250ppm	T56= Dry nano TiO2 @500ppm
T14= Dry nano ZnO @100ppm	T36= Dry nano SiO2 @500ppm	T57= Dry nano TiO2 @750ppm
T15= Dry nano ZnO @250ppm	T37= Dry nano SiO2 @750ppm	T58= Dry bulk TiO2 @50ppm
T16= Dry nano ZnO @500ppm	T38= Dry bulk SiO2 @50ppm	T59= Dry bulk TiO2 @100ppm
T17= Dry nano ZnO @750ppm	T39= Dry bulk SiO2 @100ppm	T60= Dry bulk TiO2 @250ppm
T18= Dry bulk ZnO @50ppm	T40= Dry bulk SiO2 @250ppm	T61= Dry bulk TiO2 @500ppm;
T19= Dry bulk ZnO @100ppm	T41= Dry bulk SiO2 @500ppm	T62= Dry bulk TiO2 @750ppm.
T10= Dry bulk ZnO @250ppm	T42= Dry bulk SiO2 @750ppm	

RESULTS AND DISCUSSION

The results obtained on effect of seed treatments with different NPs, packaging materials and periods of storage under this experiment are discussed hereunder.

Effect of nanoparticle seed treatments on germination (%) of chickpea seeds (Table 2)

The germination percentage at initial period (0 month) was found to be significantly higher (70.1%) than the germination percentage after 3 months (67.3%) and 6 months (58.4%) of storage in seeds treated with various nanoparticles. Significantly higher germination percentage after 6 months of storage under ambient conditions was noticed in seeds packed in polyethylene bags (65.9%) than the seeds and packed in cloth bags (64.6%). The NP seed treatment, T15 (Dry nano ZnO@250ppm) exhibited significantly higher values of germination percentage (88.0%) than untreated control (79.2%) and recommended PoP control (80.11%) after 6 month period of storage.

The germination is also affected by the packaging materials used and more so by conditions of storage. During the storage prevailing temperature and relative humidity conditions are most critical among all the factors. However, the initial status of the seed viability and moisture content would also play pivotal role in affecting the germination percentage during storage. The equilibrium moisture content of the seed would depend upon the materials in which the seed was packed and stored. The higher germination percentage in polyethylene bags could be linked to the lower gaseous exchanges and water vapors thereby help in maintaining the metabolic activity at low levels (13).

The retention of higher germination percentage in storage of chickpea seeds treated with zinc oxide (ZnO) nanoparticles could be due to inhibition of production of reactive oxygen species (ROS) and promotion of antioxidant enzyme activities (4).

Pawar *et al.* (14) reported significant enhancement of seed germination and growth parameters with lower concentrations iron oxide nanoparticles in chickpea.

Effect of nanoparticle seed treatments on seedling vigour index-I of chickpea seeds (Table 3)

The seedling vigour index -I at initial period (0 month) was found to be significantly higher (2009) than the seedling vigour index -I after 3 months (1899) and 6 months (1608) of storage

Table 2: Effect of different nanoparticle seed treatments, packaging materials and periods of storage on germination percentage of chickpea variety Pusa 547

Treatments (Trt)	Packaging material (PM)								
	Cloth (1)				Polythene (2)				
	Storage period (SP)			Mean	Storage period (SP)			Mean	G. Mean
	0 m	3 m	6 m		0 m	3 m	6 m		
T1	85.33 (67.53)*	80.67 (63.95)	68.67 (55.99)	78.22 (62.49)	85.33 (67.53)	82.67 (65.44)	72.67 (58.55)	80.22 (63.84)	79.22 (63.16)
T2	86.67 (68.66)	81.33 (64.44)	69.33 (56.42)	79.11 (63.17)	86.67 (68.66)	83.33 (65.95)	73.33 (58.95)	81.11 (64.52)	80.11 (63.85)
T3	52.67 (46.55)	48.67 (44.26)	41.33 (40.02)	47.56 (43.61)	52.67 (46.55)	50.67 (45.41)	44.00 (41.57)	49.11 (44.51)	48.33 (44.06)
T4	56.67 (48.86)	52.67 (46.55)	44.00 (41.57)	51.11 (45.66)	56.67 (48.86)	54.67 (47.70)	46.67 (43.11)	52.67 (46.56)	51.89 (46.11)
T5	61.33 (51.58)	58.67 (50.02)	50.00 (45.02)	56.67 (48.87)	61.33 (51.58)	60.00 (50.80)	52.67 (46.55)	58.00 (49.64)	57.33 (49.26)
T6	53.33 (46.94)	50.67 (45.41)	40.67 (36.93)	48.22 (43.99)	53.33 (46.94)	51.33 (45.79)	42.67 (40.80)	49.11 (44.51)	48.67 (44.25)
T7	50.00 (45.02)	46.67 (43.11)	36.67 (37.28)	44.44 (41.80)	50.00 (45.02)	48.00 (43.88)	38.67 (38.46)	45.56 (42.45)	45.00 (42.13)
T8	51.33 (45.79)	47.33 (43.49)	38.67 (38.46)	45.78 (42.58)	51.33 (45.79)	49.33 (44.64)	41.33 (40.03)	47.33 (43.48)	46.56 (43.03)
T9	53.33 (46.94)	49.33 (44.64)	40.67 (39.64)	47.78 (43.74)	53.33 (46.94)	51.33 (45.79)	43.33 (41.18)	49.33 (44.64)	48.56 (44.19)
T10	58.00 (49.63)	55.33 (48.09)	47.33 (43.49)	53.56 (47.07)	58.00 (49.63)	56.67 (48.86)	49.33 (44.64)	54.67 (47.71)	54.11 (47.39)
T11	54.00 (47.32)	50.67 (45.41)	41.33 (40.03)	48.67 (44.25)	54.00 (47.32)	52.00 (46.17)	43.33 (41.19)	49.78 (44.89)	49.22 (44.57)
T12	49.33 (44.64)	45.33 (42.34)	36.67 (37.28)	43.78 (41.42)	49.33 (44.64)	47.33 (43.49)	38.67 (38.47)	45.11 (42.20)	44.44 (41.81)
T13	85.33 (67.53)	81.33 (64.44)	72.00 (58.12)	79.56 (63.36)	85.33 (67.53)	83.33 (65.95)	75.33 (60.26)	81.33 (64.58)	80.44 (63.97)
T14	86.67 (68.63)	82.67 (65.46)	74.00 (59.38)	81.11 (64.49)	86.67 (68.63)	84.67 (66.99)	76.67 (61.15)	82.67 (65.59)	81.89 (65.04)
T15	92.00 (73.69)	89.33 (71.05)	80.67 (63.99)	87.33 (69.58)	92.00 (73.69)	90.67 (72.27)	83.33 (65.99)	88.67 (70.65)	88.00 (70.11)
T16	87.33 (69.24)	84.00 (66.48)	74.67 (59.81)	82.00 (65.18)	87.33 (69.24)	85.33 (67.56)	76.67 (61.15)	83.11 (65.98)	82.56 (65.58)
T17	86.67 (68.66)	82.00 (64.95)	72.67 (58.53)	80.44 (64.05)	86.67 (68.66)	84.00 (66.48)	74.67 (59.83)	81.78 (64.99)	81.11 (64.52)
T18	84.67 (66.99)	80.67 (63.95)	71.33 (57.68)	78.89 (62.87)	84.67 (66.99)	82.67 (65.44)	74.67 (59.84)	80.67 (64.09)	79.78 (63.48)
T19	85.33 (67.53)	81.33 (64.44)	72.67 (58.51)	79.78 (63.49)	85.33 (67.53)	83.33 (65.95)	75.33 (60.27)	81.33 (64.58)	80.56 (64.04)
T20	88.67 (70.38)	86.00 (68.09)	80.00 (63.49)	84.89 (67.32)	88.67 (70.38)	87.33 (69.20)	80.00 (63.49)	85.33 (67.69)	85.11 (67.50)
T21	87.33 (69.20)	84.00 (66.48)	74.67 (59.83)	82.00 (65.17)	87.33 (69.20)	85.33 (67.53)	76.67 (61.18)	83.11 (65.97)	82.56 (65.57)
T22	86.00 (68.09)	82.00 (64.95)	72.00 (58.09)	80.00 (63.71)	86.00 (68.09)	83.33 (65.95)	74.00 (59.38)	81.11 (64.48)	80.56 (64.09)
T23	48.00 (43.88)	42.00 (40.41)	32.67 (34.87)	40.89 (39.72)	48.00 (43.88)	44.67 (41.96)	35.33 (36.48)	42.67 (40.77)	41.78 (40.25)
T24	51.33 (45.79)	48.67 (44.26)	47.33 (43.49)	49.11 (44.51)	51.33 (45.79)	50.00 (45.02)	41.33 (40.02)	47.56 (43.61)	48.33 (44.06)

Table 2 Contd…

Treatments (Trt)	*Packaging material (PM)*								
	Cloth (1)				*Polythene (2)*				
	Storage period (SP)			*Mean*	*Storage period (SP)*			*Mean*	*G. Mean*
	0 m	*3 m*	*6 m*		*0 m*	*3 m*	*6 m*		
T25	56.67 (48.86)	53.33 (46.94)	43.33 (41.19)	51.11 (45.66)	56.67 (48.86)	54.00 (47.32)	45.33 (42.34)	52.00 (46.17)	51.56 (45.92)
T26	59.33 (50.41)	57.33 (49.25)	40.67 (39.64)	52.44 (46.43)	59.33 (50.41)	58.67 (50.02)	51.33 (45.79)	56.44 (48.74)	54.44 (47.58)
T27	54.67 (47.70)	50.67 (45.41)	41.33 (40.02)	48.89 (44.38)	54.67 (47.70)	52.67 (46.55)	43.33 (41.19)	50.22 (45.15)	49.56 (44.76)
T28	47.33 (43.49)	43.33 (41.19)	32.67 (34.87)	41.11 (39.85)	47.33 (43.49)	44.67 (41.96)	35.33 (36.48)	42.44 (40.64)	41.78 (40.25)
T29	50.00 (45.02)	46.67 (43.11)	36.67 (37.28)	44.44 (41.80)	50.00 (45.02)	48.00 (43.88)	39.33 (38.85)	45.78 (42.58)	45.11 (42.19)
T30	53.33 (46.94)	50.00 (45.02)	40.00 (39.25)	47.78 (43.74)	53.33 (46.94)	51.33 (45.79)	42.67 (40.80)	49.11 (44.51)	48.44 (44.12)
T31	58.67 (50.02)	56.00 (48.47)	47.33 (43.49)	54.00 (47.33)	58.67 (50.02)	57.33 (49.24)	49.33 (44.64)	55.11 (47.97)	54.56 (47.65)
T32	49.33 (44.64)	44.67 (41.96)	33.33 (35.28)	42.44 (40.63)	49.33 (44.64)	46.67 (43.11)	35.33 (36.48)	43.78 (41.41)	43.11 (41.02)
T33	85.33 (67.56)	81.33 (64.44)	70.67 (57.26)	79.11 (63.09)	85.33 (67.56)	82.67 (65.44)	73.33 (58.94)	80.44 (63.98)	79.78 (63.53)
T34	85.33 (67.53)	82.00 (64.95)	72.00 (58.09)	79.78 (63.52)	85.33 (67.53)	83.33 (65.95)	74.67 (59.83)	81.11 (64.43)	80.44 (63.98)
T35	86.00 (68.09)	83.33 (65.99)	72.67 (58.53)	80.67 (64.21)	86.00 (68.09)	84.00 (66.48)	75.33 (60.27)	81.78 (64.95)	81.22 (64.58)
T36	89.33 (70.99)	87.33 (69.27)	78.00 (62.60)	84.89 (67.62)	89.33 (70.99)	88.00 (69.81)	80.00 (63.91)	85.78 (68.24)	85.33 (67.93)
T37	88.67 (70.38)	86.00 (68.09)	75.33 (60.28)	83.33 (66.25)	88.67 (70.38)	86.67 (68.63)	77.33 (61.69)	84.22 (66.90)	83.78 (66.58)
T38	84.67 (66.99)	80.67 (63.95)	69.33 (56.41)	78.22 (62.45)	84.67 (66.99)	81.33 (64.44)	72.00 (58.09)	79.33 (63.17)	78.78 (62.81)
T39	84.00 (66.48)	80.67 (63.95)	70.67 (57.24)	78.44 (62.56)	84.00 (66.48)	82.00 (64.95)	73.33 (58.96)	79.78 (63.47)	79.11 (63.01)
T40	86.00 (68.09)	83.33 (65.95)	72.67 (58.51)	80.67 (64.18)	86.00 (68.09)	84.00 (66.48)	75.33 (60.27)	81.78 (64.95)	81.22 (64.57)
T41	88.00 (69.81)	85.33 (67.53)	76.67 (61.18)	83.33 (66.17)	88.00 (69.81)	86.67 (68.66)	78.67 (62.54)	84.44 (67.01)	83.89 (66.59)
T42	85.33 (67.53)	81.33 (64.46)	72.00 (58.09)	79.56 (63.36)	85.33 (67.53)	83.33 (65.95)	74.00 (59.38)	80.89 (64.29)	80.22 (63.82)
T43	52.67 (46.55)	49.33 (44.64)	39.33 (38.85)	47.11 (43.35)	52.67 (46.55)	50.67 (45.41)	42.67 (40.80)	48.67 (44.25)	47.89 (43.80)
T44	59.33 (50.41)	56.67 (48.86)	48.67 (44.26)	54.89 (47.84)	59.33 (50.41)	58.67 (50.02)	51.33 (45.79)	56.44 (48.74)	55.67 (48.29)
T45	56.67 (48.86)	53.33 (46.94)	43.33 (41.19)	51.11 (45.66)	56.67 (48.86)	54.00 (47.32)	46.00 (42.73)	52.22 (46.30)	51.67 (45.98)
T46	55.33 (48.09)	52.00 (46.17)	42.67 (40.80)	50.00 (45.02)	55.33 (48.09)	53.33 (46.94)	45.33 (42.34)	51.33 (45.79)	50.67 (45.40)
T47	48.67 (44.26)	44.00 (41.57)	34.00 (35.68)	42.22 (40.50)	48.67 (44.26)	45.33 (42.34)	36.00 (36.88)	43.33 (41.16)	42.78 (40.83)
T48	52.00 (46.17)	46.67 (43.11)	38.67 (38.46)	45.78 (42.58)	52.00 (46.17)	50.00 (45.02)	41.33 (40.03)	47.78 (43.74)	46.78 (43.16)
T49	56.00 (48.48)	53.33 (46.94)	44.67 (41.96)	51.33 (45.79)	56.00 (48.48)	54.67 (47.70)	47.33 (43.49)	52.67 (46.56)	52.00 (46.17)

Treatments (Trt)	Packaging material (PM)								
	Cloth (1)				Polythene (2)				
	Storage period (SP)			Mean	Storage period (SP)			Mean	G. Mean
	0 m	3 m	6 m		0 m	3 m	6 m		
T50	53.33 (46.94)	50.00 (45.02)	40.67 (39.64)	48.00 (43.87)	53.33 (46.94)	51.33 (45.79)	43.33 (41.19)	49.33 (44.64)	48.67 (44.26)
T51	50.00 (45.02)	47.33 (43.49)	37.33 (37.67)	44.89 (42.06)	50.00 (45.02)	48.67 (44.26)	40.67 (39.64)	46.44 (42.97)	45.67 (42.52)
T52	50.00 (45.02)	46.00 (42.73)	36.67 (37.28)	44.22 (41.67)	50.00 (45.02)	48.00 (43.88)	38.67 (38.46)	45.56 (42.45)	44.89 (42.06)
T53	85.33 (67.59)	83.33 (65.99)	73.33 (58.94)	80.67 (64.17)	85.33 (67.59)	84.67 (67.02)	76.67 (61.18)	82.22 (65.26)	81.44 (64.72)
T54	91.33 (73.02)	88.67 (70.38)	80.00 (63.49)	86.67 (68.96)	91.33 (73.02)	90.00 (71.66)	82.67 (65.44)	88.00 (70.04)	87.33 (69.50)
T55	87.33 (69.20)	84.00 (66.48)	74.67 (59.81)	82.00 (65.17)	87.33 (69.20)	85.33 (67.53)	77.33 (61.62)	83.33 (66.12)	82.67 (65.64)
T56	80.67 (63.95)	76.67 (61.18)	67.33 (55.17)	74.89 (60.10)	80.67 (63.95)	78.67 (62.54)	70.67 (57.25)	76.67 (61.25)	75.78 (60.68)
T57	78.67 (62.56)	74.67 (59.81)	64.67 (53.56)	72.67 (58.64)	78.67 (62.56)	76.00 (60.71)	66.67 (54.77)	73.78 (59.35)	73.22 (59.00)
T58	84.67 (66.99)	81.33 (64.44)	71.33 (57.68)	79.11 (63.04)	84.67 (66.99)	82.67 (65.44)	74.67 (59.81)	80.67 (64.08)	79.89 (63.56)
T59	88.00 (69.91)	85.33 (67.56)	76.67 (61.18)	83.33 (66.22)	88.00 (69.91)	86.67 (68.71)	79.33 (63.03)	84.67 (67.22)	84.00 (66.72)
T60	83.33 (65.99)	80.00 (63.49)	70.67 (57.26)	78.00 (62.25)	83.33 (65.99)	81.33 (64.48)	73.33 (58.94)	79.33 (63.14)	78.67 (62.69)
T61	79.33 (63.07)	75.33 (60.26)	65.33 (53.97)	73.33 (59.10)	79.33 (63.07)	76.67 (61.16)	68.67 (56.01)	74.89 (60.08)	74.11 (59.59)
T62	78.67 (62.54)	74.67 (59.81)	64.67 (53.56)	72.67 (58.64)	78.67 (62.54)	76.00 (60.71)	66.67 (54.77)	73.78 (59.34)	73.22 (58.99)
Mean	70.08 (57.81)	66.57 (55.41)	57.10 (49.36)	64.58 (54.19)	70.08 (57.81)	68.06 (56.41)	59.61 (50.92)	65.92 (55.05)	65.25 (54.62)
CD (p= 0.05)	PM= 0.18; SP= 0.22; Trt= 1.00; PM×SP= 0.31; PM×Trt= NS; SP×Trt= NS; PM×SP×Trt= NS.								

* Figures in parentheses are square root transformed values.

in seeds treated with various nanoparticles. Significantly higher seedling vigour index -I after 6 months of storage under ambient conditions was noticed in seeds packed in polyethylene bags (1934) than the seeds and packed in cloth bags (1864). The NP seed treatment, T15 (Dry nano ZnO@250ppm) exhibited significantly higher values of seedling vigour index -I (3084) than untreated control (2367) and recommended PoP control (2399) after 6 month period of storage.

At the end of the storage seedling vigour index –I was higher in polythene than in cloth, this could be due to that seeds are highly hygroscopic living things that absorb moisture from the environment. This increased moisture in the seed increases metabolic activity; this is the primary cause of Cloth bag seeds' rapid quality decline (3). Increased vigour index in treated seeds could be attributed to the NPs' favourable effects on repairing damaged vital cell organelles, production and activation of essential enzymes during germination, and reduction of lipid peroxidation and free radical reactions (7, 10).

Effect of nanoparticle seed treatments on seedling vigour index-II of chickpea seeds (Table 4)

The seedling vigour index -II at initial period (0 month) was found to be significantly higher (30.20) than the seedling vigour index -II after 3 months (27.9) and 6 months (24.27) of storage

Table 3: Effect of different nanoparticle seed treatments, packaging materials and periods of storage on seedling vigour index -I of chickpea variety Pusa 547

Treatments (Trt)	*Packaging material (PM)*								
	Cloth (1)				*Polythene (2)*				
	Storage period (SP)			*Mean*	*Storage period (SP)*			*Mean*	*G. Mean*
	0 m	*3 m*	*6 m*		*0 m*	*3 m*	*6 m*		
T1	2618	2396	1996	2337	2618	2461	2112	2397	2367
T2	2679	2417	2033	2376	2679	2436	2150	2422	2399
T3	1251	1096	901	1083	1251	1188	960	1133	1108
T4	1352	1222	996	1190	1352	1286	1055	1231	1211
T5	1540	1451	1217	1403	1540	1497	1282	1440	1421
T6	1307	1209	946	1154	1307	1244	993	1181	1168
T7	1221	1100	834	1051	1221	1157	879	1086	1069
T8	1182	1048	828	1019	1182	1122	888	1064	1042
T9	1246	1110	891	1082	1246	1185	950	1127	1105
T10	1418	1331	1111	1287	1418	1375	1158	1317	1302
T11	1288	1175	933	1132	1288	1228	979	1165	1149
T12	1124	995	776	965	1124	1065	819	1002	984
T13	2844	2612	2263	2573	2844	2752	2367	2654	2614
T14	2939	2732	2400	2690	2939	2849	2489	2759	2725
T15	3265	3117	2781	3054	3265	3202	2875	3114	3084
T16	2954	2762	2410	2709	2954	2864	2475	2764	2736
T17	2874	2629	2272	2592	2874	2761	2334	2656	2624
T18	2794	2566	2222	2527	2794	2703	2324	2607	2567
T19	2844	2641	2316	2600	2844	2756	2402	2667	2634
T20	3007	2870	2635	2837	3007	2944	2632	2861	2849
T21	2926	2738	2384	2683	2926	2833	2447	2735	2709
T22	2826	2613	2237	2558	2826	2723	2298	2615	2587
T23	1017	857	637	837	1017	934	690	880	859
T24	1117	1029	967	1038	1117	1072	843	1011	1024
T25	1272	1169	928	1123	1272	1195	971	1146	1135
T26	1376	1307	911	1198	1376	1340	1150	1289	1243
T27	1220	1104	880	1068	1220	1161	922	1101	1084
T28	921	809	580	770	921	855	628	801	786
T29	1055	957	726	912	1055	997	778	943	928
T30	1171	1075	840	1028	1171	1114	897	1060	1044
T31	1356	1272	1057	1228	1356	1314	1102	1257	1243
T32	1066	1024	704	931	1066	1020	746	944	938
T33	2702	2485	2096	2428	2702	2593	2175	2490	2459
T34	2766	2584	2220	2523	2766	2677	2302	2582	2552
T35	2853	2701	2318	2624	2853	2763	2402	2673	2648
T36	3041	2920	2650	2870	3041	2978	2645	2888	2879
T37	2822	2673	2324	2606	2822	2737	2385	2648	2627
T38	2596	2385	1987	2323	2596	2470	2065	2377	2350
T39	2601	2469	2113	2394	2601	2514	2192	2436	2415
T40	2740	2591	2223	2518	2740	2656	2306	2567	2543
T41	2858	2717	2411	2662	2858	2796	2474	2710	2686

Treatments (Trt)	Packaging material (PM)								
	Cloth (1)				Polythene (2)				
	Storage period (SP)			Mean	Storage period (SP)			Mean	G. Mean
	0 m	3 m	6 m		0 m	3 m	6 m		
T42	2690	2523	2184	2466	2690	2607	2244	2514	2490
T43	1101	1002	770	958	1101	1043	836	993	975
T44	1381	1296	1093	1257	1381	1354	1153	1296	1277
T45	1204	1106	877	1062	1204	1135	930	1090	1076
T46	1146	1041	820	1002	1146	1088	871	1035	1019
T47	983	875	645	834	983	924	683	863	849
T48	1060	923	737	907	1060	1004	788	951	929
T49	1201	1068	922	1064	1201	1161	977	1113	1088
T50	1105	1010	801	972	1105	1052	854	1004	988
T51	1027	938	710	892	1027	985	774	929	910
T52	1026	903	686	872	1026	968	724	906	889
T53	2716	2579	2218	2504	2716	2671	2319	2569	2537
T54	3181	3036	2706	2974	3181	3117	2797	3032	3003
T55	2923	2747	2404	2691	2923	2834	2491	2749	2720
T56	2577	2372	2031	2326	2577	2490	2130	2399	2363
T57	2418	2205	1851	2158	2418	2312	1908	2213	2185
T58	2664	2562	2131	2452	2664	2577	2231	2491	2472
T59	2822	2676	2400	2633	2822	2760	2463	2681	2657
T60	2554	2392	2079	2341	2554	2472	2157	2394	2368
T61	2422	2225	1877	2175	2422	2318	1973	2238	2206
T62	2315	2117	1763	2065	2315	2210	1818	2114	2090
Mean	2009	1864	1575	1816	2009	1934	1640	1861	1838
CD (p= 0.05)	PM= 10.67; SP= 13.07; Trt= 59.41; PM×SP= 0.73; PM×Trt= NS; SP×Trt= 102.9; PM×SP×Trt= NS.								

in seeds treated with various nanoparticles. Significantly higher seedling vigour index -II after 6 months of storage under ambient conditions was noticed in seeds packed in polyethylene bags (28.12) than the seeds and packed in cloth bags (26.79). The NP seed treatment, T15 (Dry nano ZnO@250ppm) exhibited significantly higher values of seedling vigour index -II (43.96) than untreated control (36.52) and recommended PoP control (36.47) after 6 month period of storage.

In comparison to the polythene bag, the cloth bag had a greater loss in seedling vigour. Cloth bag seeds absorbed moisture from the surrounding environment. The rate of deterioration in terms of development of abnormal seedlings and dead seeds, as well as seedlings with poor vigour due to increased respiratory activity and other physiological activities of the stored seeds with the increased moisture content (17). The increased chemical reactivity of Zn NPs as cofactors of enzymes involved in germination and seedling growth could explain their overall positive effects on seedling growth and dry weight of seedlings there by vigour index.

Effect of nanoparticle seed treatments on field emergence (%) of chickpea seeds (Table 5)

The field emergence percentage at initial period (0 month) was found to be significantly higher (73.22%) than the field emergence percentage after 3 months (68.86%) and 6 months (57.19%) of storage in seeds treated with various nanoparticles. Significantly higher field emergence percentage after 6 months of storage under ambient conditions was noticed in seeds packed in polyethylene bags (67.27%) than the

Table 4: Effect of different nanoparticle seed treatments, packaging materials and periods of storage on seedling vigour index- II of chickpea variety Pusa 547

Treatments (Trt)	*Packaging material (PM)*								
	Cloth (1)				*Polythene (2)*				
	Storage period (SP)			*Mean*	*Storage period (SP)*			*Mean*	*G. Mean*
	0 m	*3 m*	*6 m*		*0 m*	*3 m*	*6 m*		
T1	40.86	36.46	29.33	35.55	40.86	37.53	34.05	37.48	36.52
T2	40.90	36.28	29.29	35.49	40.90	37.34	34.14	37.46	36.47
T3	20.65	18.13	14.74	17.84	20.65	18.96	17.10	18.91	18.37
T4	21.65	19.23	15.41	18.76	21.65	20.07	18.07	19.93	19.35
T5	21.98	19.45	15.96	19.13	21.98	20.76	18.91	20.55	19.84
T6	20.38	18.60	14.42	17.80	20.38	18.95	17.33	18.89	18.35
T7	17.32	14.35	10.54	14.07	17.32	15.72	13.78	15.61	14.84
T8	18.12	15.75	12.24	15.37	18.12	16.53	14.58	16.41	15.89
T9	18.60	16.37	12.89	15.95	18.60	17.14	15.31	17.02	16.49
T10	21.55	19.03	15.73	18.77	21.55	20.33	18.47	20.11	19.44
T11	20.03	18.01	14.15	17.40	20.03	18.59	16.76	18.46	17.93
T12	17.23	14.06	10.72	14.00	17.23	15.63	13.50	15.46	14.73
T13	41.56	37.98	32.47	37.34	41.56	39.09	36.08	38.91	38.12
T14	41.60	38.26	33.16	37.67	41.60	39.37	36.61	39.19	38.43
T15	47.16	43.38	38.16	42.90	47.16	45.34	42.58	45.03	43.96
T16	40.09	37.30	32.18	36.52	40.09	38.06	35.51	37.89	37.21
T17	37.67	32.44	27.36	32.49	37.67	34.92	32.01	34.87	33.68
T18	41.43	37.88	32.34	37.22	41.43	38.96	35.97	38.79	38.00
T19	41.40	38.07	32.93	37.47	41.40	39.17	36.41	38.99	38.23
T20	43.29	40.73	35.43	39.82	43.29	41.55	40.69	41.84	40.83
T21	39.47	36.71	31.64	35.94	39.47	37.46	34.93	37.29	36.61
T22	37.94	32.98	27.58	32.83	37.94	35.17	32.23	35.11	33.97
T23	19.21	15.96	11.85	15.68	19.21	17.09	14.84	17.05	16.36
T24	20.52	18.61	17.38	18.84	20.52	19.25	17.24	19.00	18.92
T25	20.78	18.69	14.58	18.02	20.78	19.04	17.39	19.07	18.54
T26	26.06	24.35	16.76	22.39	26.06	25.03	22.92	24.67	23.53
T27	21.62	19.17	15.00	18.59	21.62	20.03	18.03	19.89	19.24
T28	16.43	14.17	10.11	13.57	16.43	14.70	12.87	14.66	14.12
T29	18.77	16.72	12.61	16.03	18.77	17.31	15.44	17.17	16.60
T30	20.66	18.55	14.27	17.83	20.66	19.16	17.25	19.02	18.42
T31	23.77	21.88	17.89	21.18	23.77	22.51	20.79	22.36	21.77
T32	21.58	18.77	13.51	17.95	21.58	19.71	17.11	19.47	18.71
T33	40.38	36.87	30.74	36.00	40.38	37.64	34.72	37.58	36.79
T34	41.16	38.15	32.41	37.24	41.16	38.94	36.18	38.76	38.00
T35	42.33	39.67	33.58	38.52	42.33	40.17	37.75	40.08	39.30
T36	44.93	42.62	36.07	41.21	44.93	43.15	41.08	43.05	42.13
T37	41.89	39.15	33.19	38.08	41.89	39.65	37.14	39.56	38.82
T38	37.77	34.62	28.51	33.63	37.77	34.82	31.99	34.86	34.25
T39	38.27	35.58	30.11	34.66	38.27	35.89	33.54	35.90	35.28
T40	41.63	38.91	32.91	37.82	41.63	39.48	36.78	39.30	38.56
T41	42.99	40.15	35.13	39.43	42.99	41.26	38.63	40.96	40.19
T42	39.90	36.38	31.15	35.81	39.90	37.70	34.98	37.53	36.67
T43	19.62	17.54	13.40	16.86	19.62	18.12	16.20	17.98	17.42
T44	21.15	19.37	16.03	18.85	21.15	20.18	18.34	19.89	19.37
T45	17.84	15.88	12.26	15.33	17.84	16.19	14.44	16.16	15.74
T46	18.09	16.07	12.49	15.55	18.09	16.59	14.55	16.41	15.98
T47	15.67	13.28	9.66	12.87	15.67	13.78	12.00	13.81	13.34
T48	16.58	14.07	11.09	13.91	16.58	15.18	13.47	15.08	14.50

Treatments (Trt)	Packaging material (PM)								
	Cloth (1)				Polythene (2)				
	Storage period (SP)			Mean	Storage period (SP)			Mean	G. Mean
	0 m	3 m	6 m		0 m	3 m	6 m		
T49	20.81	19.05	15.37	18.41	20.81	19.65	17.80	19.42	18.91
T50	18.52	16.51	12.82	15.95	18.52	17.06	15.23	16.93	16.44
T51	16.27	14.56	10.89	13.90	16.27	15.05	13.29	14.87	14.39
T52	15.54	13.37	10.00	12.97	15.54	14.06	12.27	13.96	13.46
T53	39.83	37.47	31.64	36.31	39.83	38.27	35.24	37.78	37.05
T54	45.64	43.03	36.98	41.88	45.64	43.85	39.56	43.02	42.45
T55	39.70	36.77	30.11	35.53	39.70	37.51	33.23	36.81	36.17
T56	36.42	33.23	26.59	32.08	36.42	34.26	29.93	33.54	32.81
T57	34.67	31.42	26.07	30.72	34.67	32.14	29.43	32.08	31.40
T58	37.47	35.82	27.86	33.72	37.47	35.35	30.63	34.48	34.10
T59	41.33	39.78	34.50	38.54	41.33	39.62	35.90	38.95	38.74
T60	36.58	33.78	28.80	33.05	36.58	34.48	31.89	34.32	33.69
T61	34.55	31.45	26.24	30.75	34.55	32.17	29.60	32.11	31.43
T62	34.67	31.42	26.04	30.71	34.67	32.13	29.14	31.98	31.34
Mean	30.20	27.49	22.67	26.79	30.20	28.30	25.87	28.12	27.45
CD (p= 0.05)	PM= 0.13; SP= 0.16; Trt= 0.73; PM×SP= 0.23; PM×Trt= NS; SP×Trt= 1.26; PM×SP×Trt= NS.								

seeds and packed in cloth bags (65.57%). The NP seed treatment, T15 (Dry nano ZnO@250ppm) exhibited significantly higher values of field emergence percentage (84.56%) than untreated control (71.67%) and recommended PoP control (72.22%) after 6 month period of storage.

It indicated that there were treatments which could prevent deterioration in field emergence which increased significantly with increased storage period, whereas the deterioration of seeds turned out to be more sensitive in cloth bags. Cloth bag seeds absorbed moisture from the surrounding environment. The increasing dead seeds rate was higher in cloth bag. Because it was due to absorption of high moisture and increased fungal activities (12).

The increased field emergence may be due to the enhanced cell activation in Zn NPs treated seeds leads to enhanced mitochondrial activity, which leads to the creation of higher-energy compounds and essential biomolecules that are available during the early stages of germination. In addition, zinc absorption triggered the cell cycle (16).

The conclusion drawn from the study was dry nano ZnO @ 250ppm found to be most effective treatment for enhancement storage potential in chickpea. In view of the above results we may deduce that the chickpea seeds treated with nanoparticles are therefore recommended to be stored at vacuum or low RH or low temperature condition to ensure good quality of seeds for better crop establishment.

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Table 5: Effect of different nanoparticle seed treatments, packaging materials and periods of storage on field emergence percentage of chickpea variety Pusa 547

Treatments (Trt)	*Packaging material (PM)*								
	Cloth (1)				*Polythene (2)*				
	Storage period (SP)			*Mean*	*Storage period (SP)*			*Mean*	*G. Mean*
	0 m	*3 m*	*6 m*		*0 m*	*3 m*	*6 m*		
T1	80.00 (63.54)*	72.00 (58.09)	58.67 (50.05)	70.22 (57.23)	80.00 (63.54)	76.00 (60.75)	63.33 (52.81)	73.11 (59.03)	71.67 (58.13)
T2	80.00 (63.49)	73.33 (58.99)	59.33 (50.42)	70.89 (57.63)	80.00 (63.49)	76.67 (61.18)	64.00 (53.19)	73.56 (59.28)	72.22 (58.46)
T3	59.33 (50.41)	52.00 (46.17)	40.67 (39.64)	50.67 (45.40)	59.33 (50.41)	55.33 (48.09)	44.00 (41.57)	52.89 (46.69)	51.78 (46.05)
T4	65.33 (53.96)	60.00 (50.81)	48.00 (43.88)	57.78 (49.55)	65.33 (53.96)	62.67 (52.38)	51.33 (45.79)	59.78 (50.71)	58.78 (50.13)
T5	68.00 (55.59)	65.33 (53.97)	53.33 (46.95)	62.22 (52.17)	68.00 (55.59)	66.67 (54.79)	54.67 (47.72)	63.11 (52.70)	62.67 (52.43)
T6	65.33 (53.96)	60.00 (50.81)	48.67 (44.26)	58.00 (49.68)	65.33 (53.96)	62.00 (51.99)	50.67 (45.41)	59.33 (50.45)	58.67 (50.06)
T7	62.00 (52.00)	57.33 (49.25)	45.33 (42.34)	54.89 (47.86)	62.00 (52.00)	60.00 (50.80)	48.00 (43.87)	56.67 (48.89)	55.78 (48.38)
T8	57.33 (49.25)	52.00 (46.17)	39.33 (38.86)	49.56 (44.76)	57.33 (49.25)	54.00 (47.32)	43.33 (41.18)	51.56 (45.91)	50.56 (45.34)
T9	63.33 (52.79)	58.00 (49.64)	46.67 (43.11)	56.00 (48.51)	63.33 (52.79)	60.00 (50.81)	49.33 (44.64)	57.56 (19.41)	56.78 (48.96)
T10	66.00 (54.38)	63.33 (52.76)	51.33 (45.79)	60.22 (50.97)	66.00 (54.38)	64.00 (53.16)	52.67 (46.55)	60.89 (51.36)	60.56 (51.17)
T11	63.33 (52.79)	60.00 (50.80)	46.67 (43.11)	56.67 (48.90)	63.33 (52.79)	60.00 (50.81)	48.67 (44.26)	57.33 (49.29)	57.00 (49.09)
T12	60.67 (51.23)	54.00 (47.32)	42.67 (40.78)	52.44 (46.44)	60.67 (51.23)	57.33 (49.25)	45.33 (42.34)	54.44 (47.60)	53.44 (47.02)
T13	82.67 (65.53)	75.33 (60.27)	63.33 (52.80)	73.78 (59.63)	82.67 (65.53)	78.00 (62.12)	67.33 (55.20)	76.00 (60.95)	74.89 (60.24)
T14	83.33 (66.05)	77.33 (61.67)	64.67 (53.57)	75.11 (60.43)	83.33 (66.05)	80.00 (63.52)	69.33 (56.40)	77.56 (61.99)	76.33 (61.21)
T15	90.67 (72.41)	86.00 (68.09)	75.33 (60.40)	84.00 (66.97)	90.67 (72.41)	88.00 (69.81)	76.67 (61.18)	85.11 (67.80)	84.56 (67.38)
T16	85.33 (67.66)	80.00 (63.59)	68.00 (55.64)	77.78 (62.30)	85.33 (67.66)	82.00 (65.07)	70.67 (57.27)	79.33 (63.33)	78.56 (62.82)
T17	83.33 (65.99)	77.33 (61.61)	66.67 (54.80)	75.78 (60.80)	83.33 (65.99)	81.33 (64.56)	69.33 (56.42)	78.00 (62.33)	76.89 (61.56)
T18	80.00 (63.52)	73.33 (58.96)	61.33 (51.60)	71.56 (58.03)	80.00 (63.52)	76.00 (60.71)	65.33 (53.98)	73.78 (59.41)	72.67 (58.72)
T19	83.33 (66.05)	78.67 (62.63)	66.00 (54.36)	76.00 (61.02)	83.33 (66.05)	80.67 (64.03)	69.33 (56.42)	77.78 (62.17)	76.89 (61.59)
T20	87.33 (69.20)	83.33 (65.99)	72.00 (58.11)	80.89 (64.43)	87.33 (69.20)	85.33 (67.66)	73.33 (58.94)	82.00 (65.27)	81.44 (64.85)
T21	84.00 (66.48)	80.00 (62.52)	68.00 (55.61)	77.33 (61.87)	84.00 (66.48)	82.67 (65.61)	70.67 (57.25)	79.11 (63.11)	78.22 (62.49)
T22	84.00 (66.56)	77.33 (61.67)	67.33 (55.21)	76.22 (61.15)	84.00 (66.56)	82.00 (65.02)	70.00 (56.83)	78.67 (62.80)	77.44 (61.97)
T23	59.33 (50.43)	52.00 (46.17)	40.00 (39.24)	50.44 (45.28)	59.33 (50.43)	55.33 (48.09)	42.67 (40.79)	52.44 (46.44)	51.44 (45.86)
T24	63.33 (52.79)	57.33 (49.25)	45.33 (42.34)	55.33 (48.13)	63.33 (52.79)	60.00 (50.81)	48.67 (44.26)	57.33 (49.29)	56.33 (48.71)
T25	65.33 (53.96)	60.00 (50.81)	47.33 (43.49)	57.56 (49.42)	65.33 (53.96)	62.00 (51.98)	50.67 (45.41)	59.33 (50.45)	58.44 (49.94)
T26	66.67 (54.77)	62.00 (51.97)	51.33 (45.79)	60.00 (50.84)	66.67 (54.77)	64.00 (53.19)	53.33 (46.94)	61.33 (49.03)	60.67 (51.24)

Table 5 Contd…

Treatments (Trt)	Packaging material (PM)								
	Cloth (1)				Polythene (2)				
	Storage period (SP)			Mean	Storage period (SP)			Mean	C. Mean
	0 m	3 m	6 m		0 m	3 m	6 m		
T27	63.33 (52.81)	58.00 (49.65)	45.33 (42.34)	55.56 (48.27)	63.33 (52.81)	60.00 (50.80)	47.33 (43.49)	56.89 (49.03)	56.22 (48.65)
T28	57.33 (49.26)	51.33 (45.79)	39.33 (38.85)	49.33 (44.63)	57.33 (49.26)	54.00 (47.32)	41.33 (40.02)	50.89 (45.53)	50.11 (45.08)
T29	62.67 (52.37)	56.00 (48.47)	44.67 (41.96)	54.44 (47.60)	62.67 (52.37)	59.33 (50.42)	47.33 (43.49)	56.44 (48.76)	55.44 (48.18)
T30	65.33 (53.98)	60.00 (50.81)	48.67 (44.26)	58.00 (49.68)	65.33 (53.98)	63.33 (52.76)	51.33 (45.79)	60.00 (50.85)	59.00 (50.26)
T31	60.67 (51.23)	54.00 (47.32)	43.33 (41.18)	52.67 (46.58)	60.67 (51.23)	56.67 (48.86)	45.33 (42.33)	54.22 (47.47)	53.44 (47.02)
T32	54.67 (47.71)	52.00 (46.17)	38.67 (38.45)	48.44 (44.11)	54.67 (47.71)	53.33 (46.94)	40.67 (39.61)	49.56 (44.75)	49.00 (44.43)
T33	80.00 (63.66)	73.33 (58.95)	61.33 (51.59)	71.56 (58.07)	80.00 (63.66)	76.00 (60.71)	63.33 (52.77)	73.11 (59.05)	72.33 (58.56)
T34	83.33 (65.99)	77.33 (61.62)	65.33 (54.09)	75.33 (60.57)	83.33 (65.99)	80.00 (63.59)	68.67 (56.04)	77.33 (61.87)	76.33 (61.22)
T35	85.33 (67.91)	79.33 (63.10)	67.33 (55.18)	77.33 (62.06)	85.33 (67.91)	82.00 (64.99)	70.67 (57.31)	79.33 (63.40)	78.33 (62.73)
T36	87.33 (69.24)	84.00 (66.48)	72.00 (58.09)	81.11 (64.60)	87.33 (69.24)	85.33 (67.59)	74.67 (59.89)	82.44 (65.57)	81.78 (65.09)
T37	84.00 (66.63)	79.33 (63.02)	66.00 (54.38)	76.44 (61.34)	84.00 (66.63)	81.33 (64.46)	68.67 (56.04)	78.00 (62.38)	77.22 (61.86)
T38	79.33 (63.16)	71.33 (57.68)	59.33 (50.46)	70.00 (57.10)	79.33 (63.16)	74.00 (59.38)	61.33 (51.61)	71.56 (58.05)	70.78 (57.58)
T39	81.33 (64.56)	75.33 (60.27)	62.67 (52.39)	73.11 (59.07)	81.33 (64.56)	77.33 (61.62)	65.33 (53.98)	74.67 (60.05)	73.89 (59.56)
T40	84.00 (66.48)	81.33 (64.54)	65.33 (53.97)	76.89 (61.66)	84.00 (66.48)	80.00 (63.54)	68.67 (56.01)	77.56 (62.01)	77.22 (61.84)
T41	85.33 (67.59)	79.33 (63.02)	70.00 (56.88)	78.22 (62.49)	85.33 (67.59)	83.33 (65.99)	72.67 (58.58)	80.44 (64.06)	79.33 (63.27)
T42	82.00 (65.20)	77.33 (61.63)	64.67 (53.60)	74.67 (60.14)	82.00 (65.20)	79.33 (63.02)	66.67 (54.79)	76.00 (61.00)	75.33 (60.57)
T43	60.00 (50.80)	53.33 (46.94)	41.33 (40.02)	51.56 (45.92)	60.00 (50.80)	56.00 (48.48)	44.67 (41.96)	53.56 (47.08)	52.56 (46.50)
T44	67.33 (55.18)	62.00 (51.99)	51.33 (45.79)	60.22 (50.99)	67.33 (55.18)	64.00 (53.17)	53.33 (46.95)	61.56 (51.77)	60.89 (51.38)
T45	64.00 (53.20)	60.00 (50.80)	48.67 (44.26)	57.56 (49.42)	64.00 (53.20)	62.00 (51.98)	51.33 (45.79)	59.11 (50.32)	58.33 (49.87)
T46	63.33 (52.82)	57.33 (49.25)	46.00 (42.72)	55.56 (48.26)	63.33 (52.82)	60.00 (50.80)	48.67 (44.25)	57.33 (49.29)	56.44 (48.78)
T47	61.33 (51.61)	54.00 (47.32)	42.67 (40.79)	52.67 (46.57)	61.33 (51.61)	57.33 (49.25)	44.67 (41.96)	54.44 (47.61)	53.56 (47.09)
T48	58.00 (49.65)	51.33 (45.79)	39.33 (38.85)	49.56 (44.76)	58.00 (49.65)	54.00 (47.32)	42.67 (40.80)	51.56 (45.92)	50.56 (45.34)
T49	67.33 (55.21)	60.00 (50.80)	49.33 (44.64)	58.89 (50.22)	67.33 (55.21)	62.00 (51.99)	51.33 (45.79)	60.22 (50.99)	59.56 (50.61)
T50	62.00 (51.98)	57.33 (49.25)	46.67 (43.10)	55.33 (48.11)	62.00 (51.98)	60.00 (50.80)	49.33 (44.64)	57.11 (49.14)	56.22 (48.63)
T51	62.67 (52.37)	57.33 (49.26)	46.00 (42.72)	55.33 (48.12)	62.67 (52.37)	60.00 (50.81)	48.67 (44.25)	57.11 (49.14)	56.22 (48.63)
T52	60.00 (50.80)	54.67 (47.70)	42.67 (40.78)	52.44 (46.43)	60.00 (50.80)	57.33 (49.25)	44.67 (41.94)	54.00 (47.33)	53.22 (46.88)
T53	83.33 (66.09)	77.33 (61.63)	65.33 (53.97)	75.33 (60.57)	83.33 (66.09)	80.00 (63.61)	68.67 (56.01)	77.33 (61.90)	76.33 (61.23)

Treatments (Trt)	*Packaging material (PM)*								
	Cloth (1)				*Polythene (2)*				
	Storage period (SP)			*Mean*	*Storage period (SP)*			*Mean*	*G. Mean*
	0 m	*3 m*	*6 m*		*0 m*	*3 m*	*6 m*		
T54	88.00 (70.13)	84.00 (66.63)	73.33 (58.99)	81.78 (65.25)	88.00 (70.13)	81.33 (64.48)	75.33 (60.31)	81.56 (64.97)	81.67 (65.11)
T55	85.33 (67.56)	80.00 (63.59)	69.33 (56.49)	78.22 (62.55)	85.33 (67.56)	86.00 (68.09)	72.00 (58.12)	81.11 (64.59)	79.67 (63.57)
T56	81.33 (64.56)	74.00 (59.38)	63.33 (52.78)	72.89 (58.91)	81.33 (64.56)	77.33 (61.67)	65.33 (53.99)	74.67 (60.07)	73.78 (59.49)
T57	80.00 (63.59)	73.33 (58.94)	62.67 (52.39)	72.00 (58.31)	80.00 (63.59)	77.33 (61.69)	64.67 (53.57)	74.00 (59.61)	73.00 (58.96)
T58	82.00 (65.02)	76.00 (60.75)	64.67 (53.57)	74.22 (59.78)	82.00 (65.02)	79.33 (63.07)	67.33 (55.21)	76.22 (61.10)	75.22 (60.44)
T59	85.33 (67.59)	81.33 (64.48)	70.00 (56.85)	78.89 (62.97)	85.33 (67.59)	83.33 (66.06)	72.67 (58.52)	80.44 (64.06)	79.67 (63.51)
T60	84.00 (66.48)	79.33 (63.10)	67.33 (55.21)	76.89 (61.60)	84.00 (66.48)	81.33 (64.48)	70.00 (56.83)	78.44 (62.60)	77.67 (62.10)
T61	79.33 (63.07)	72.00 (58.09)	61.33 (51.19)	70.89 (57.58)	79.33 (63.07)	75.33 (60.28)	63.33 (52.81)	72.67 (58.72)	71.78 (58.15)
T62	79.33 (63.16)	71.33 (57.66)	60.67 (51.19)	70.44 (57.34)	79.33 (63.16)	74.67 (59.83)	62.00 (51.98)	72.00 (58.32)	71.22 (57.83)
Mean	73.22 (59.41)	67.62 (55.69)	55.86 (48.49)	65.57 (54.53)	73.22 (59.41)	70.10 (57.30)	58.51 (50.06)	67.27 (55.59)	66.42 (55.06)
CD (p= 0.05)	PM= 0.32; SP= 0.39; Trt= 1.77; PM×SP= 0.55; PM×Trt= NS; SP×Trt= NS; PM×SP×Trt= NS.								

*Figures in parentheses are square root transformed values.

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