Effect of Zinc oxide (ZnO) nanoparticles on the storability of onion (*alliumcepa*L.)Seedsunder ambient condition

ABSTRACT

Zincoxidenanoparticles(ZnO-NPs)areconsideredabiosafematerialfororganisms.Earlierstudieshavedemonstratedthepotential ofZnO-NPsforstimulationofseedgerminationandplantgrowthasdiseasesuppressionandplantprotectionbyvirtueoftheirantimicrobialactivity.Zincoxideisaninorganiccompounditappearsinwhitepowder.(ZnO)haveapotentialapplicationasabacteriostaticagentandcanbeusedtocontrolthespreadandinfectionof varietyofpathogens.These resultscouldindicate thatalowzincs concentrationinseeds has an important physiological role during seed germination and early seedling growth.Zincisaconstituentofanenzymeinfluencingthesecretionofindoleaceticacid(IAA),whichisaphytohormone(auxin)whichsignificantlyregulatesplantgrowthbyincreasingthelevelofIAA,zincgivesapositiveresponseinseedgerminationThelabexperimentwasconductedonOnionseedstorageusingZnONano-particlesunderambientconditionsfor3monthsatSeedtestinglaboratory,Departmentofgeneticsandplantbreeding,SamHigginbottomUniversityofAgricultureTechnologyandSciences,Prayagraj,(U.P.).Thepresent investigation wascarried out, in different concentrationsofZnONano particle(10,20,30,40,50,60,70,80,90,100,110,120,130,140)ppmalongwithcontrol(untreated)andstoredintwotypesofpackagingmaterialsaluminiumfoilpouch(P1)andtincontainer(P2),andonionseedvarietyisPusaround.TheLabexperimentwasconductedinfactorialCRDwith4Replications. TheObservationsrecordedonthestoragecontainersoftheonionseedling on physiological and biochemical parameters. The results of lab experiment revealedthatAluminiumfoilpouch(P1)packagingmaterialisbetteringerminationpercent,speedofgermination,firstcount,rootlength,shootlength,seedlinglength,freshweight,dryweight,vigour index, seed density, dehydrogenaseactivity,catalaseactivity andexhibited moisturepercentandelectricalconductivityascomparedtotincontaineratendof3monthsstorage.SeedsaretreatedwithZnO@50ppm(T_5)for2hourssoakingindistilledwater,exhibitsthebetterresultsinseedqualityparameters.AscomparedtocontrolfollowedbyZnO@70ppm(T_7)attheendof3monthsofstorage.Thestudyconcludedthattheseedgerminationandseedlinglengthisincreasedinlowerconcentrations,howevershoweddecreasedinhigherconcentration.

Keywords*: zincoxide,Nanoparticle, Onion, Storage.Packaging material*

1. Introduction

Onion(*Alliumcepa*L.)belongstothefamilyLiliaceaeandisoneofthemostimportantmonocotyledonous and cool season vegetable crops inIndia. Onion is one of the important vegetable cropsbelongstotheorderAsparagalesandfamilyAmaryllidaceae. It has diploid chromosome number(2n=2x=16).Amongsttheonionproducingcountriesinthe World,Indiarankssecondinareaandproduction.Onion has been the largest item of export accountingto 76.2 per cent in the total export of vegetables fromIndia. K.Anadaraj*et al* (2017). Onion (*Allium cepa*L.) is considered as one of the important vegetablecrop among bulb crops. It occupies a major position intheworldasitiscultivatedinmajorityofthecountries and has regular demand for its consumption.India is the country which stands first in the total area(12.25 lakh hectares) and occupies the second positionin production (209.91 lakh mt) across the globe whichoccupies the place very next to the China, whereas theproductivity of the onion in India is low (17.13 t/ha)when compared with the countries like China, Egypt,NetherlandandIran(Anon.,2016).Minimumrequirement for long term storage seeds is prolongedseedviability.Majorlytheinitialqualityofseeds,moisture level, relative humidity (RH %) and storageconditionshaveconsiderableinfluenceonseedstorability(Roberts, 1973).

The principal purpose of storing seeds of economicplants is to preserve planting stocks from one seasonuntil the next. Storing the seeds of oil seed crop andvegetable crop is challenging because they easily getspoiled. In sunflower, seed germinability deterioratesquickly due to lipid peroxidation (Kibinza et al. 2006)during storage.Most of thevegetable seeds comesunderrecalcitrantseedcategoryanditeasilygetspoiledwithtime.

Seed deterioration is common in vegetables especiallyonion,chilli,brinjalanditcauseshugelosstothestored seeds. Many researchers worked on discoveringnewapproachestoslowdownthedeteriorationprocess of seeds to improve the storage life, maintainthevigourand viabilityduring storageperiod.

~~The recent advances in nanotechnology and its use inthe field of agriculture are astonishingly increasing;therefore, it is important to understand their role inplantlife.~~ It's a useless sentence

Nowadays,variousresearchershavestudiedtheeffectsofnanomaterialsonplantgerminationandgrowthwiththeobjective topromoteitsuseforagriculturalapplica-tions(Khot*etal.*,2012).Itisproventhattheseedstreatedwithzincoxidenanoparticlesatlower~~er~~concentrationenhancescelldivision~~al~~,mitoticindexwithminimumcelldivisionabnormalitiesandalsoincreasedseedgermination,promptnessindex,andseedlinggrowththatindicatethelowerconcentrationisnotharmfultothecelldivisionandearlyseedlingsgrowth.TheObjectives **of this study** were 1/~~:1.~~Tofindsouttheeffectofzincoxide nanoparticleonphysiologicalpotentialofonion(*Alliumcepa*L.) seeds. 2/To evaluate the effect of zinc oxide nanoparticle onenzymaticactivityduringstorage~~inonion(*Alliumcepa*L.)~~ seeds. 3/ To study the effect of different storage containersand zinc oxide nanoparticle ~~treated~~ on ~~onion (*Alliumcepa*L.)~~seeds.~~Inviewoftheabove,thepresentinvestigationwascarriedoutontopicentitled**"EffectofZincOxide(ZnO)nanoparticlesonthestorabilityofonion(*AlliumCepa*L.) Seeds under ambient condition."**~~

2.Materialsandmethods

Thecurrentstudy~~entitled**"EffectofZincoxide(ZnO)nanoparticlesonthestorabilityofonion(Allium cepa L.) Seeds under ambient condition"**~~wasconductedinafactorialCRDwithfourreplicationsatSeedTestingLaboratory(NotifiedbyGovt of Uttar Pradesh), Department of Genetics andPlantBreeding,NainiAgriculturalInstitute(NAI),SamHigginbottomUniversityofAgriculture,Technolo gy & Sciences, Prayagraj (U.P.). To preparenanoparticle solutions, the experiment was conductedatBiochemistrylaboratory,DepartmentofBiochemistry&BiochemicalEngineering,SamHigginbottom University of Agriculture, Technology& Sciences Prayagraj (U.P.) during 2022. All the testswereperformedincontrolledconditionskeepinginmind all the safetyprecautions.

1.1 2.1 ExperimentalDetails

3.1 - Source of Seed: The seeds of onion variety PusaRoundwereobtainedDepartmentofGeneticsandPlant breeding SHUATS in Prayagraj and used for thestoragestudies.

3.2 - Source of ZnO nanoparticles: Zinc oxide (ZnO)nanoparticlesofparticlesize20-30nmandpurityof ≥99.9%waspurchasedfromSaveerMatrixnanoPrivateLimited,GreaterNoida,andUttarPradesh.Following are the different treatments and differentconcentrationusedfortreatingtheseedsofonion(PusaRound).

2.2Seedssoakinginthesolution:

Afterrecordingtheinitialseedqualityparameters,seedsofonionvarietyPusarRoundweresoakedduring 2 hours innanoparticles solution as per the treatments (T0 (Control) with non ZnO; T1 : 10 ZnO 10ppm; T2 :30. T4; 40; T5: 50; T6: 60; T7: 70; T8: 80; T9: 90; T10: 100; T11:110; T12: 120; T13: 130 and T14: 140 ppm of ZnOfor 2 hoursandthentheseedsweredriedovernighttosafemoisture content, and then they were was packed in two types ofcontainers viz, tin container and aluminium foil pouchand, after they were then storedunderambient conditionat with 25±3˚Coc temperature with 95% RH (Relative Humidity) inSeedTestingLaboratory(NotifiedunderUttarPradesh), Department of Genetics and Plant Breeding,SHUATS.Seedsamplesweretakeneverymonthduringstorageperiodof3monthstoevaluatethephysiological parameters and the enzymatic activitiesofonion(*Alliumcepa*L.)

Table:1Detailsofthetreatmentswithitscode,concentrationandduration(hrs).Unnecessary, no new information

S.No	Treatments	ConcentrationofZnONanoparticles(ppm)	SoakingDuration (hours)
1	T0	Control(un-primed)	NoSoaking
2	T1	ZnOat10 ppm	For2hours
3	T2	ZnOat20 ppm	For2hours
4	T3	ZnOat30 ppm	For2hours
5	T4	ZnOat40 ppm	For2hours
6	T5	ZnOat50 ppm	For2hours
7	T6	ZnOat60 ppm	For2hours
8	T7	ZnOat70 ppm	For2hours
9	T8	ZnOat80 ppm	For2hours
10	T9	ZnOat90 ppm	For2hours
11	T10	ZnOat100ppm	For2hours
12	T11	ZnOat110ppm	For2hours
13	T12	ZnOat120ppm	For2hours
14	T13	ZnOat130ppm	For2hours
15	T14	ZnOat140ppm	For2hours

2-3 Evaluation of enzymatic activities……………………………………………….

- Dehydrogenase activity:

- Catalase activity:

2-4 Statistical analyses:

3.Resultsanddiscussion.

Accordingtothefindings,allthecharacteristicsanalyzedwere influenced by thetreatmentandthedifferencebetweencontrol(untreatedseeds)andtreated seeds ~~in~~(table 2)~~& was entirely relevant~~. Theonionseedsweretreatedwithabovedifferenttreatment agents in above different concentrations foragivenduration.Aftertreatment,seedswereusedforstorage condition in two different packaging materialviz.,aluminiumfoilpouchandtincontainer.Thesilent found of the study are summarized below. Afterrecording the initial seed quality parameters, seeds ofonion variety Pusa~~r~~Round were soaked in nanoparticlesolution as per the treatment for 2 hours and then theseeds were dried over night to safe moisture contentandthenwaspackedintwotypesofcontainersviz,tincontainerandaluminiumfoilpouchandthenstoredunderambientconditionwith25±3octemperaturewith95%RH(RelativeHumidity)inSeedTestingLaboratory(NotifiedunderUttarPradesh), Department of Genetics and Plant Breeding,SHUATS.Seedsamplesweretakeneverymonthduringstorageperiodof3monthstoevaluatethephysiological parameters and the enzymatic activitiesof onion (*Allium cepa* L.) Data were recorded for thefollowing characters Viz., germination percent (%),speed of germination(days-1), root length(cm), shootlength(cm),seedlinglength(cm),freshweightofSeedling(g),dryweightofSeedling(g),seedlinggrowthrate,root:shoot ratio,seedmetabolicefficiency(%),vigourindex-I,vigourindex-II,electrical conductivity, seed density, Dehydrogenaseactivity(ODg-1mL-1),catalaseenzymeactivity(µmolg-1fw min-1).

3-1 Germinationpercent(%)graduallydecreasedasaconsequenceofincreaseddefectsinthemetabolismofseedsasthestorage periodgetsprogressed.Duringstorageperiodamongthetreatmentsmaximumgermination ~~percent~~ (%) (56.75%)was recordedwithZincOxidenanoparticles~~@~~at 50ppm(T5)followedby(55.75%) with Zinc Oxide nanoparticles ~~@~~ 70ppm(T7)as comparedtothe(T0)control (48.87%)which was the minim ~~andminimum~~germination~~percent~~(%). (51.0%)wasrecordedatZincOxidenanoparticles@140ppm(T14)it represented the lowest germination% in the treated onions.Betweenpackagingmaterialsseedsstoredinaluminiumfoilpouch(P1)recordedmaximumgermination~~percent~~(%) with(54.46%)andtheminimum(52.28%)wasrecordedby tin container(P2).In theinteractioneffectofseedtreatmentandpackagingmaterials(TxP)themaximumgermination~~percent~~(%)(59.50%)wasrecordedinthecombinationT5P1followedby(58%)T7P1whiletheminimumgermination~~percent~~(%)wasrecordedinthecombinationofT14P2(50.5%)attheendofstorage.Similarresultswasfoundby**SudeshnaChakrabort(2012)**thestudyrevealed thatthegermination percentgraduallydecreasedwithincreaseingerminationperiodofonionseedsunderambientstoragecondition.

~~1.~~ 3.2 Speed of germination: TheobservationsonSpeedofGermination(days-1)werestatistically analysed.During storageperiodamongthetreatmentsmaximumSpeedofGermination (days-1) (4.05) was recorded with ZincOxidenanoparticles~~@~~at 50ppm(T5)followedby(3.98)withZincOxidenanoparticles~~@~~at 70ppm(T7)as compared to the (T0) control (3.49) and minimumSpeed of Germination (days-1) (3.64) was recorded atZinc Oxide nanoparticlesat~~@~~ 140ppm (T14). Betweenpackagingmaterialsseedsstoredin aluminiumfoilpouch (P1) recorded maximum Speed of Germination(days-1) (3.89) and the minimum (3.73) was recordedby tin container (P2). In the interaction effect of seedtreatmentandpackagingmaterials(TxP)themaximum Speed of Germination (days-1) (4.25) wasrecorded in the combination T5P1 followed by (4.21)T7P1whiletheminimumSpeedofGermination(days-1) was recorded in the combination of

T14P1(3.61) at the end of storage. Similar results was foundby **S.V. Raskar et al. (2014),** conducted research oneffectofzincoxidenanoparticlesoncytologyandseed germination in onion, results pretraining to seedgerminationandearlygrowthclearlyindicatethatzinc oxide at lower concentration (20ppm) promotedseed germination i.e. 96.5%, where aswhile untreated seedsshowed 94.2%.Seed germination increased in lowerconcentrations, however showed a decrease in values athigher concentrations.

2. Germinationpercent(firstcount)graduallydecreased as a consequence of increased defects in themetabolismofseedsasthestorageperiodgetsprogressed.Duringstorageperiodamongthetreatments maximum germination percent (first count)(28.37%) was recorded with Zinc Oxide nanoparticles@50ppm(T5) followedby(27.87%) withZinc Oxidenanoparticles@at 70ppm (T7) as comparedtothe(T0)control(24.43%)andminimumgermination percent (first count) (25.50%) was recorded at ZincOxidenanoparticles@140ppm(T14).Betweenpackagingmaterialsseedsstoredin aluminiumfoilpouch (P1) recorded maximum germination percent(first count) (27.23%) and the minimum (26.14%) wasrecorded by tin container (P2). In the interaction effectof seed treatment and packaging materials (T x P) themaximum germination percent (first count) (29.75%)was recorded in the combination T5P1 followed by(29%) T7P1 while the minimum germination percent(firstcount)wasrecordedinthecombinationofT14P2(25.05%) atthe end ofstorage.

3. 3-3 Moisturecontentgraduallydecreasedasaconsequence of increased defects in the metabolism ofseeds as the storage period gets progressed. Duringstorageperiodamongthetreatmentsmaximummoisturecontent(7.45%)wasrecordedwithZincOxidenanoparticles @50ppm(T5)followedby(7.71%) with Zinc Oxide nanoparticles @ 70ppm (T7)ascomparedtothe(T0)control(8.20%)andminimum moisture content (8.01%) was recorded atZinc Oxide nanoparticles @ 140ppm (T14). Betweenpackagingmaterialsseedsstoredin aluminiumfoilpouch(P1)recordedmaximummoisturecontent(7.87%) and the minimum (7.93%) was recorded bytin container(P2). In the interaction effect of seedtreatmentandpackagingmaterials(TxP)themaximum moisture content (7.62%) was recorded inthecombinationT5P1followedby(7.72%)T7P1while the minimum moisture content was recorded inthecombinationofT14P1(8.01%)attheendofstorage.

4. TheobservationsonRootlength(cm)werestatistically analysed during storage period among thetreatments maximum root length (cm) (3.87cm) wasrecordedwithZincOxidenanoparticles@50ppm(T5)followedby(3.62cm)withZincOxidenanoparticles @ 70ppm (T7) as compared to the (T0)control(2.98cm)andminimumrootlength(cm)(3.11cm)wasrecordedatZincOxidenanoparticles@140ppm(T14).Betweenpackagingmaterialsseedsstoredinaluminiumfoilpouch(P1)recordedmaximumrootlength(cm)(3.45cm) andtheminimum(3.28cm)wasrecordedbytincontainer(P2). In the interaction effect of seed treatment andpackaging materials (T x P) the maximum root length(cm) (4.46cm) was recorded in the combination T5P1followed by (4.22cm) T7P1 while the minimum rootlength(cm)wasrecordedinthecombinationofT14P2 (8.01cm) at the end of storage. Similar resultswas found by **Jayarambabu*et* *al.* (2014)** the studyrevealedthatthesignificantimprovementingermination,rootlengthandshootlengthatlowerconcentrationofZnONPshowever,athigherconcentrationthegrowthstartedretarding

5. 3-4 Shoot length: Theobservationsonshootlength(cm)werestatisticallyanalysedDuring

storageperiodamongthetreatmentsmaximumshootlength(cm)(5.55cm)wasrecordedwithZincOxidenanoparticles@at 50ppm(T5)followedby(5.43cm)a t withZincOxidenanoparticles@70ppm(T7)while ascomparedtothecontrol (T0)was (4.67cm) and minimum shoot length (cm)(4.72cm)wasrecordedatZincONPs Oxidenanoparticlesat @130ppm(T13).Betweenpackagingmaterialsseedsstoredinaluminiumfoilpouch(P1)recordedmaximumshootlength(cm)(5.23cm)andtheminimum(4.96cm)wasrecordedbytincontainer(P2).Intheinteractioneffectofseedtreatmentandpackagingmaterials(TxP)themaximumshootlength (cm) (6.15cm) was recorded in the combinationT5P1followedby(5.90cm)T7P1whiletheminimumshootlength(cm)wasrecordedinthecombinationofT13P1(4.46cm)attheendofstorage.Similarresultswasfoundby**Jayarambabu*etal.*(2014)**thestudyrevealed that the significant improvement ingermination,rootlengthandshootlengthatlowerconcentrationofZnONPshowever,athigherconcentrationthegrowthstarted retarding

6. 3-5 Seedlinglength(cm)graduallydecreasedasaconsequence ofincreaseddefects inthemetabolismof seedsasthestorageperiodgetsprogressed.Duringstorageperiodamongthetreatmentsmaximumseedlinglength(cm)(9.42cm)wasrecordedwithZincOxidenanoparticles@50ppm(T5)followedby(9.19cm) with Zinc Oxide nanoparticles @ 70ppm(T7)ascomparedtothe(T0)control(7.65cm)andminimumseedlinglength(cm)(6.42cm)wasrecordedatZincOxidenanoparticles@140ppm(T14).Betweenpackagingmaterialsseedsstoredinaluminiumfoilpouch(P1)recordedmaximumseedlinglength(cm)(8.68cm)andtheminimum(8.06cm)wasrecordedbytincontainer(P2).Intheinteractioneffectofseedtreatmentandpackagingmaterials(TxP)themaximumseedlinglength(cm)(10.11cm)wasrecordedinthecombinationT5P1followedby(10.6cm)T7P1whiletheminimumseedlinglength(cm)wasrecordedinthecombinationofT14P2(4.60cm)attheendofstorage.Similarresultswerefound by**Jayarambabu*etal.* (2014).**

7. Duringstorageperiodamongthetreatmentsmaximumfreshweight(g)(0.272g)wasrecordedwithZincOxidenanoparticles@50ppm(T5)followedby (0.267g)with Zinc Oxide nanoparticles@70ppm(T7)ascomparedtothe(T0)control(0.242g) and minimum fresh weight (g) (0.262g) wasrecordedatZincOxidenanoparticles@140ppm(T14). Between packaging materials seeds stored inaluminium foil pouch (P1) recorded maximum freshweight (g) (0.260g) and the minimum (0.259g) wasrecorded by tin container (P2). In the interaction effectof seed treatment and packaging materials (T x P) themaximum fresh weight (g) (0.280g) was recorded inthecombinationT5P1followedby(0.273g)T7P1while the minimum fresh weight (g) was recorded inthecombinationofT14P2(0.258g)attheendofstorage.Similarresultswasfoundby**PradeepKorishettar*etal.*, (2017)**

8. Duringstorageperiodamongthetreatmentsmaximum dry weight (g) (0.0357g) was recorded withZincOxidenanoparticles@50ppm(T5)followedby(0.0357g) with Zinc Oxide nanoparticles @ 70ppm(T7) as compared to the (T0) control (0.0340g) andminimum dry weight (0.0352g) was recorded at ZincOxidenanoparticles@140ppm(T14).Betweenpackagingmaterialsseedsstoredin aluminiumfoilpouch(P1)recordedmaximumdryweight(g)(0.0352g) and the minimum (0.0349g) was recordedby tin container (P2). In the interaction effect of seedtreatmentandpackagingmaterials(TxP)themaximum dry weight (g) (0.0370g) was recorded inthe combination T5P1 followed by (0.0363g) T7P1while the minimum dry weight (g) was recorded in thecombination of T13P2 (0.0349g) at the end of storage.Similar results was found by **PradeepKorishettar*etal.*, (2017)**

9. Duringstorageperiodamongthetreatmentsmaximum vigour index-I (525.07) was recorded withZinc Oxide nanoparticles @ 50ppm (T5) followed by(515.07)withZincOxidenanoparticles@70ppm(T7) as compared to the (T0) control (374.67) andminimumvigourindex-I(417.62)wasrecordedatZinc Oxide nanoparticles @ 140ppm

(T14). Betweenpackagingmaterialsseedsstoredin aluminiumfoilpouch(P1)recordedmaximumvigourindex-I(474.02) and the minimum (421.80) was recorded bytin container(P2). In the interaction effect of seedtreatmentandpackagingmaterials(TxP)themaximum vigour index-I (629.66) was recorded in thecombination T5P1 followed by (598.99) T7P1 whiletheminimumvigourindex-Iwasrecordedinthecombination of T14P2 (232.55) at the end of storage.SimilarresultswasfoundbyK.**KrishnaShylaand N.Natarajan(2015)**

~~10.~~ Duringstorageperiodamongthetreatmentsmaximum vigour index-II (2.033) was recorded withZinc Oxide nanoparticles @ 50ppm (T5) followed by(1.989) with Zinc Oxide nanoparticles @ 70ppm (T7)as compared to the (T0) control (1.668) and minimumvigour index-II (1.875) was recorded at Zinc Oxidenanoparticles@140ppm(T14).Betweenpackagingmaterials seeds stored in aluminium foil pouch (P1)recorded maximum vigour index-II (1.921) and theminimum (1.829) was recorded by tin container (P2).Intheinteractioneffectofseedtreatmentandpackagingmaterials(TxP)themaximumvigourindex-II (2200) was recorded in the combination T5P1followed by (2089) T7P1 while the minimum vigourindex-II was recorded in the combination of T13P2(1780) at the end of storage. Similar results was foundbyK.**KrishnaShylaandN.Natarajan(2015),PradeepKorishettar*etal*.,(2017)**

~~11.~~ Electrical conductivity gradually decreased as aconsequence of increased defects in the metabolism ofseeds as the storage period gets progressed. Duringstorageperiodamongthetreatmentsmaximumelectrical conductivity (0.937) was recorded with ZincOxidenanoparticles@50ppm(T5)followedby(0.946)with ZincOxidenanoparticles@70ppm (T7)ascomparedtothe(T0)control(0.972)andminimum electrical conductivity (0.955) was recordedatZincOxidenanoparticles@140ppm(T14).Betweenpackagingmaterialsseedsstoredinaluminiumfoilpouch(P1) recordedmaximumelectricalconductivity(1.921)andtheminimum(1.829)wasrecordedbytincontainer(P2).Intheinteractioneffectofseedtreatmentandpackagingmaterials (T x P) the maximum electrical conductivity(0.930)wasrecordedinthecombinationT5P1followedby(0.936)T7P1whiletheminimumelectricalconductivitywasrecordedinthecombinationofT14P2 (0.951)attheend ofstorage.

~~12.~~ Seeddensitygraduallydecreasedasaconsequence of increased defects in the metabolism ofseeds as the storage period gets progressed. Duringstorage period among the treatments maximum seeddensity(0.990)wasrecordedwithZincOxidenanoparticles @ 50ppm (T5) followed by (0.982) withZinc Oxide nanoparticles @ 70ppm (T7) as comparedto the (T0) control (0.800) and minimum seed density(0.832)wasrecordedatZincOxidenanoparticles@140ppm(T14).Betweenpackagingmaterialsseedsstoredin aluminiumfoilpouch(P1)recordedmaximumseeddensity(0.867)andtheminimum(0.866)wasrecordedbytincontainer(P2).Intheinteractioneffectofseedtreatmentandpackagingmaterials (T x P) the maximum seed density (1.064)was recorded in the combination T5P1 followed by(0.967) T7P1 while the minimum seed density wasrecorded in the combination of T14P2 (0.807) at theend ofstorage.

~~13.~~ Dehydrogenase activity gradually decreased as aconsequence of increased defects in the metabolism ofseeds as the storage period gets progressed. Duringstorageperiodamongthetreatmentsmaximumdehydrogenaseactivity(0.315)wasrecordedwithZinc Oxide nanoparticles @ 50ppm (T5) followed by(0.311) with Zinc Oxide nanoparticles @ 70ppm (T7)as compared to the (T0) control (0.228) and minimumdehydrogenase activity (0.257) was recorded at ZincOxidenanoparticles@140ppm(T14).Betweenpackagingmaterialsseedsstoredin aluminiumfoilpouch(P1)recordedmaximumdehydrogenaseactivity(0.288)andtheminimum(0.284)wasrecorded by tin container (P2). In the interaction effectof seed treatment and packaging materials (T x P) themaximumdehydrogenaseactivity(0.328)wasrecordedinthecombinationT5P1followedby(0.324)T7P1whilethemin imumdehydrogenaseactivity was recorded in the combination of T14P2(0.328)at the endofstorage.

~~14.~~ Catalase enzyme activity gradually decreased as aconsequence of increased defects in the metabolism ofseeds as the storage period gets progressed. Duringstorageperiodamongthetreatmentsmaximumcatalase enzyme activity (0.308) was recorded withZinc Oxide nanoparticles @ 50ppm (T5) followed by(0.305) with Zinc Oxide nanoparticles @ 70pp(T7) ascompared to the (T0) control (0.158) and minimumcatalase enzyme activity (0.268) was recorded at ZincOxidenanoparticles@140ppm(T14).Betweenpackagingmaterialsseedsstoredin aluminiumfoilpouch(P1)recordedmaximumcatalaseenzymeactivity(0.264)andtheminimum(0.261)wasrec ordedbytincontainer(P2).Intheinteractioneffectofseedtreatmentandpackagingmaterials(TxP)themaximum catalaseenzymeactivity(0.340)wasrecordedinthecombinationT5P1followedby(0.326)T7P1whilethemini mumcatalaseenzymeactivity was recorded in the combination of T14P2(0.280)at the endofstorage.

Table 2.**Analysisofvarianceonimpactofvariouspackagingmaterialsononionseedqualityafteronemonthofambient storage.**

SLNo.	Parameters	Meansumof square			
		Packagingmaterials(P)(df= 1)	Treatment(T)(df=14)	Interaction(CXT)(df=14)	Error(df=90)
1	Germination percent(Finalcount)	143.008*	35.125*	11.473	18.175
2	Speedofgermination	0.728*	0.179*	0.059	0.093
3	Firstcountpercent	35.752*	8.781*	2.868	4.544
4	Moisturepercent	0.120	0.250*	0.189*	0.102
5	Rootlength	0.799	0.525	0.620	0.497
6	Shootlength	2.071*	0.615	0.716*	0.397
7	Seedlinglength	5.442	2.021	2.412	1.675
8	Freshweight	0.0023	0.0011	0.0004	0.0012
9	Dryweight	0.00023	0.00016	0.00011	0.00008
10	VigourindexI	62.443*	16.819*	14.523*	5.683
11	VigourindexII	0.268*	0.743	0.329	0.535
12	Electricalconductivity	0.0001	0.0010*	0.0003	0.00018
13	Seed density	0.0001	0.026*	0.012	0.007
14	Dehydrogenaseactivity	0.005*	0.003*	0.002*	0.0003*
15	Catalaseactivity	0.0001	0.013*	0.004*	0.0004

Table 3.Analysis of varianceonimpactofvariouspackagingmaterialsononionseedqualityaftertwomonthsof ambient storage.

SLNo.	Parameters	Meansumof square			
		PackagingMaterials(P)(df=1	Treatment(T)(df=14)	Interaction(PXT)(df=14)	Error(df=90)
1	Germinationpercent	143.008*	35.125*	11.473	12.831
2	Speedofgermination	0.730*	0.181*	0.058	0.066
3	Firstcountpercent	35.752*	8.781*	2.868	3.208
4	Moisturepercent	0.124	0.260*	0.179	0.100
5	Rootlength	0.799	0.525	0.620	0.503
6	Shootlength	2.070	0.615	0.716*	0.396
7	Seedlinglength	5.443	2.021	2.412	1.678

8	Freshweight	0.0024	0.0011	0.0084	0.0012
9	Dryweight	0.000023	0.000016	0.000011	0.00086
10	VigourindexI	57.877*	15.560*	13.482*	5.344
11	VigourindexII	0.0260*	0.720	0.317	0.462
12	Electricalconductivity	0.0001	0.0010*	0.0003	0.0002
13	Seeddensity	0.0001	0.026*	0.012	0.007
14.1	Dehydrogenaseactivity	0.003	0.005*	0.003*	0.001
14.2	Catalaseactivity	0.0001	0.013*	0.004*	0.001

Table 4.**Analysisofvarianceonimpactofvariouspackagingmaterialsononionseedquality afterthreemonthsof ambient storage.**

SLN0.	Parameters	Meansumof square			
		Packaging materials (P) (df=1)	Treatment(T)(df=14)	Interaction(CXT)(df =14)	Error(df=90)
1	Germinationpercent(Final count)	143.008*	35.125*	11.473	12.831
2	Speedofgermination	0.730*	0.180*	0.059	0.066
3	Firstcountpercent	35.752*	8.781*	2.868	3.208
4	Moisturepercent	0.120	0.260*	0.180*	0.097
5	Rootlength	0.784	0.522	0.619	0.507
6	Shootlength	2.071*	0.615	0.716*	0.397
7	Seedlinglength	11.568*	4.142*	3.782*	1.681
8	Freshweight	0.0011	0.0031	0.0029	0.0013
9	Dryweight	0.000022	0.000016	0.000012	0.000083
10	VigourindexI	81.799*	21.706*	15.479*	4.923
11	VigourindexII	0.252*	0.695	0.306	0.429
12	Electricalconductivity	0.0001	0.001*	0.0003*	0.0002
13	Seed density	0.0001	0.026*	0.012	0.007
14	Dehydrogenaseactivity	0.0001	0.004*	0.002	0.002
15	Catalaseactivity	0.0001	0.013*	0.004*	0.001

Table5.Meanperformanceonimpact ofvariouspackagingmaterialsononionseed quality after3monthsofambientstorage

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

Table6.Meanperformanceof interactiononimpactofpacakagingmaterialsononion seedqualityafter3monthof ambientstorage

Interaction (TXP)	Germination per cent	Speed of germination	First count percent	Moisture per cent	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Fresh weight (gm)	Dry weight (gm)	Vigour indexI	Vigour indexII	Electrical conductivity (dSm/1)	Seed density (gm/cm³)	Dehydrogenase activity (OD/g/ml)	Catalase activity µmol/gfw/min
T0P1	49.5	3.54	24.75	8.24	2.75	4.43	7.1825	0.223	0.0342	355.45	1692	0.982	0.772	0.19	0.120
T0P2	48.25	3.45	24.12	8.17	3.23	4.91	8.13	0.260	0.0339	393.9	1644	0.961	0.827	0.266	0.194
T1P1	55	3.93	27.5	7.87	3.45	5.13	8.58	0.261	0.0351	472.125	1934	0.937	0.799	0.265	0.214
T1P2	52	3.71	26	7.72	3.35	5.03	8.38	0.260	0.0350	436.265	1815	0.949	0.849	0.273	0.236
T2P1	55	3.93	27.5	8.06	3.70	5.38	9.08	0.260	0.0347	492.61	1907	0.940	0.819	0.259	0.225
T2P2	51	3.64	25.5	7.98	3.30	4.98	8.28	0.261	0.0349	418.75	1784	0.933	0.829	0.282	0.239
T3P1	59	4.14	24.5	7.93	4.17	5.85	10.2	0.257	0.0361	579.02	2148	0.933	0.817	0.323	0.309
T3P2	51.5	3.68	25.75	8.10	3.05	4.73	7.88	0.264	0.0343	400.48	1768	0.948	0.914	0.277	0.234
T4P1	51.5	3.68	25.7	8.03	3.40	5.08	8.48	0.261	0.0345	437.16	1784	0.933	1.019	0.286	0.226
T4P2	50	3.57	25	8.05	3.38	5.06	8.43	0.258	0.0344	420.91	1722	0.942	0.809	0.306	0.24
T5P1	**59.5**	**4.25**	**29.75**	**7.62**	**4.46**	**6.15**	**10.11**	**0.280**	**0.0370**	**629.665**	**2200**	**0.93**	**1.064**	**0.328**	**0.340**
T5P2	54.5	3.89	27.25	7.63	3.03	4.71	7.73	0.260	0.0352	419.54	1919	0.940	0.944	0.294	0.234
T6P1	53	3.79	26.5	6.99	3.40	4.83	8.23	0.259	0.0350	435.59	1858	0.968	0.804	0.289	0.24
T6P2	55.5	3.96	27.7	7.93	3.60	5.28	8.88	0.258	0.0352	492.585	1955	0.947	0.852	0.292	0.249
T7P1	58	4.21	29	7.72	4.22	5.90	10.6	0.273	0.0363	598.995	2089	0.936	0.967	0.324	0.326
T7P2	53.5	3.82	26.7	7.82	3.58	5.26	8.83	0.258	0.0354	471.13	1890	0.954	0.824	0.289	0.300
T8P1	53	3.79	26.5	8.12	3.35	5.03	8.38	0.261	0.0349	442.96	1854	0.961	0.909	0.26	0.292
T8P2	52.5	3.75	26.2	7.90	3.23	4.91	8.13	0.259	0.0350	427.455	1844	0.958	0.842	0.274	0.286
T9P1	54	3.86	27	7.67	3.15	6.15	9.29	0.257	0.0349	499.835	1892	0.933	0.839	0.330	0.231
T9P2	53	3.79	26.5	8.02	3.35	5.03	8.38	0.264	0.0350	443.09	1857	0.948	0.852	0.299	0.264
T10P1	55.5	3.96	27.7	8.04	3.30	4.98	8.28	0.261	0.0345	456.875	1918	0.954	0.822	0.288	0.25
T10P2	54.5	3.89	27.2	8.02	3.35	5.03	8.38	0.260	0.0354	457.585	1940	0.961	0.844	0.278	0.300
T11P1	55.5	3.96	27.7	7.88	3.38	5.06	8.43	0.261	0.0349	467.05	1945	0.953	0.879	0.297	0.288
T11P2	53.5	3.82	26.7	8.04	3.40	5.08	8.48	0.259	0.0350	453.795	1869	0.959	0.899	0.299	0.284
T12P1	54	3.86	27	7.99	2.98	5.09	8.06	0.272	0.0351	437.05	1905	0.973	0.807	0.291	0.326
T12P2	53	3.79	26.5	7.92	3.25	4.93	8.18	0.257	0.0351	439.505	1870	0.959	0.852	0.318	0.289
T13P1	53	3.79	26.5	8.00	2.78	4.46	7.23	0.261	0.0349	383.195	1848	0.963	0.857	0.298	0.279
T13P2	51	3.64	25.5	7.79	3.30	4.98	8.28	0.262	0.0352	419.53	1780	0.951	0.932	0.288	0.282
T14P1	51.5	3.68	25.7	7.99	3.28	4.96	8.23	0.260	0.0358	422.79	1845	0.951	0.807	0.287	0.292
T14P2	50.5	3.61	25.5	8.01	2.95	4.61	4.6	0.258	0.0352	232.555	1785	0.958	0.934	0.226	0.280
Mean	53.375	3.81	26.514	7.91	3.37	5.10	8.37175	0.260	0.0351	447.91	1875	0.95	0.87	0.29	0.26
Sem.	1.791	0.128	0.895	0.156	0.356	0.315	0.648	0.018	0.0014	35.084	0.103	0.007	0.042	0.021	0.011
Sed.	2.533	0.181	1.266	0.22	0.503	0.446	0.917	0.025	0.0020	49.617	0.146	0.01	0.06	0.03	0.016
CD	NS	NS	NS	0.438	NS	0.887	1.825	NS	NS	98.738	NS	0.019	NS	NS	0.032
F-test	NS	NS	NS	S	NS	S	S	NS	NS	S	NS	S	NS	NS	S

CONCLUSION

It is observed that zinc oxide performs better when treated at lower concentrations (10ppm, 20ppm, 30ppm,40ppm, 50ppm,60ppm, 70ppm) than control andresultspertaining to seedgermination andearly seedlinggrowth clearly indicate that zinc oxide at lower concentration promoted seed germination and seedling growth,butathigherconcentrationreducedseedgerminationandseedlinggrowth.HighestconcentrationZnO~~@~~at 140ppm showed significantly low germination percentage and maximum percent seed germination observed inZnO~~@~~at 50ppm. However, high concentrations of zinc oxide havecaused ~~been observed on produce~~a range of toxicity onseed germination and seedling growth. There was no major difference in root and shoot ratio in all treatmentshowever an increasing trend was seen from lower concentrations. Seeds stored in ~~a~~aluminium foil pouch (P1)performs better results the reason is that helps in lower the seeddetoriation due to low moisture levels. Thelowest infection of fungi was recorded when the seeds were stored in aluminium foil pouch because of lowmoisture levels.Among theinteractions, the combination (P1T5) recorded the best result and followed by(P1T7). The study concluded that the combination of aluminium foil pouch with ZnO~~@~~at50 ppm is the bestcombinationthatcould be usedto expandthestorabilityofonionseedsunderambientcondition.

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