EFFECTOFNANOFERTILIZERON GROWTH,YIELDAND QUALITYOFBROCCOLI(*Brassicaoleracea*var.italica*)*

ABSTRACT

TheexperimentwasconductedintheHorticultureResearchFarm,DepartmentofHorticulture, NainiAgriculturalInstitute,SamHigginbottom,University ofAgriculture,Technologyand Sciences,Prayagraj(UP)duringOctober2021tofebruary 2022.Theexperimentwaslaidout inrandomizedblockdesign(R.B.D.)with10treatmentswith3replications. Fromthe observationsit wasfound that T_2 (Soilapplicationof50%recommendeddoseoffertilizersasconventional fertilizer+50%recommendeddoseofnanoNasfoliarapplicationnanoP&Kassoilapplication)wasfoundhad the best impact on the tobethebestrelatingtogrowthandyieldandqualityparameterslikeplantheight 65.27 cm, number ofleaves per plant 27.14, leaf length 55cm, leaf width 21.83cm,leaf area at harvesting stage725.00cm^2,daystoheadinitiation45.42days,daystoharvest55.67,head diameter21.16cm,headweight461.47gm,headyieldperplot2.77 Kg,headyieldper hectare16.95t,TSS9.76 Brix. Thehighestcost benefit ratio 3.55 was alsoobserved in T_2.

Keywords:Broccoli,Nanofertilizer, Brassicacea

INTRODUCTION

Broccoli(*Brassicaoleracea*L. var.italica)isacoolseason vegetableoffamily Brassicaceaecruciferous. Broccolicommonly knownasHariGobiinHindi.ItwasarareColecropinIndiabutnowitis gaining popularity.Intheworldmarketabout40percentismarketedasfreshandremaining60 percentasfrozen.Sincethetimeofthe RandomRoman Empire,broccolihasbeenconsideredauniquely valuable foodamongItalians.BroccoliwasbroughttoEnglandfromAntwerp inthemid-18th century by PeterScheemakers.BroccoliwasfirstintroducedtotheUnitedStates by Southern Italianimmigrants[1],butdidnotbecomewidely popular untilthe1920s. In IndiaTthe cultivationof broccoliwasinitiallyrestrictedtohillareasofJammuandKashmir,HimachalPradeshandUttar Pradesh but now is successfullygrown under NorthIndian plain conditions.Itis classified into two types:, headingandsprouting. ,sSprouting broccoliismorepopularinIndia.Broccoliisarich sourceofvitamins,minerals,proteinsetc.Ithasabout130timesmore higher content ofVitaminAcontentsthan cauliflowerand22timesmorethancabbage.Thenutritivevalueofbroccoliper100gismoisture 89.3g,energy141kg,carbohydrates6.64g,sugar1.7g,dietaryfibber2.6g,fat0.37g,protein 2.82g, calcium47mg,iron0.73mg,phosphorous 66mg,thiamine 0.071mg,riboflavin0.117mg, niacin0.639mg,vitC89.2mg [2].Broccolihasanticarcinogenicpropertiesandreduce therisk of prostatecancer byup to 45 percent.

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Theuseof excessof chemicalfertilizerforincreasingcropyieldcausesseriousenvironmental problems,(fore.g.eutrophicationof waters [3],lossof biodiversity,globalwarmingand stratospheric ozonedepletion),soilandplanthealthproblemsassomefertilizersalsocontains heavymetals, excess use ofwhich leadsfertilizer to enterthe food chain via absorption from soil. Thus,fertilizationoften leadstowater,soilandairpollution and.inithasbeenobservedthatthesoilfertility isdeclined.Unscientificapplicationsof conventionalchemicalfertilizers leadstodeteriorationof groundwater quality,increases thesalinityof thesoil, reduceprofitmargins, inducedeficiencyof other elements, interferewith metabolic processesand restrictyield and qualityof broccoli.

Nanofertilizersaresynthesizedormodifiedformoftraditionalfertilizers,fertilizersbulkmaterials orextractedfromdifferentvegetativeorreproductivepartsoftheplantby differentchemical, physical,mechanical or biological methodswith thehelpof nanotechnologyand are used to improvesoil fertility, productivityandquality ofagriculturalproduce.Nanofertilizersarebeing preparedby encapsulatingplantnutrientsintonanomaterials,employingthincoatingofnanomaterialsonplant nutrients,anddeliveringintheformofnano-sizedemulsions. Nanotechnologyreferstothe applicationofmoleculesandcompoundswhose sizedoesnotexceed100nm[4].This technique dependsonreducingtheparticletoasizeequaltoonebillionthofameter(10-9m)andthenusing thenewmaterial.Thenanofertilizerallowsincorporating nutrientsontoananodimensional adsorbent.Therefore,thisapproachleadstothecontrolledrelease of active ingredientsfor a long timeandpreventstheleachingofnutrientsintogroundwater,thusreducingtheamountoffertilizer used [5]. It isestimated that the amountof nanoformulations neededforplants is onlyequivalent to20%ofconventionalfertilizers[6].Nanotechnology isanewperspectiveofprecisionfarming, whichmaximizestheoutputfromcropswhileminimizingtheinputssuchasfertilizers,pesticides, fungicides and herbicides.
Plantnutrition is oneofthemostimportant factorsthatincreaseplantproduction.Usageofnano fertilizermightenhancetheproductionby increasingtheyield by targetspecificaction,with propernutrientuseefficiency [7]etc.andalsoapplicationofitwillnotharmthesoilhealthand alsominimizethepollutionhazard.Nanofertilizers,whichhavethegreaterroleinenhancingcrop productionthiswillreducethecostoffertilizerforcropproduction.However,very few scarce informationisreportedregardingtheeffectofNanofertilizers.Therefore,theaimofthisworkwas tostudy abouttheeffectofnanofertilizers ongrowth,yieldandqualityofBroccoli(*Brassica oleracea*var. italica)

2. MATERIALSAND METHODS

The experimentwasconductedatExperimentalResearchField,DepartmentofHorticulture, NainiAgriculturalInstitute,SamHigginbottomUniversity ofAgriculture,Technology&Sciences, Prayagraj(UP)during2021-2022 duringRabiseason inIndia.

TheexperimentmaterialconsistsofBroccoliF_1,HybridGreenMagic.Thesoiloftheexperiment fieldwasalkaline,sandyloamandpHof7.2.Theexperimentwaslaidoutinrandomizedblock designwiththreereplicationsconsisting of10treatments.Broccoliwasplantedinthefieldata spacing of0.45x0.60m inplotof1m x2m size. Theobservationwererecordedforleaflength (cm),leaf width(cm),plantheight(cm),daystakentoheadinitiation,Daysfor harvest,head weight(gm), headyield per plot (kg),headyield per hectare(tonnes), headdiameter(cm), TSS (total soluble solids), Vitamin Ccontent.

2.1 Statistical Analysis

Thedatawere analysedinrandomizedblockdesignasperprocedureofCochranandCox (1959).Interpretationofresultswasmadeonthebasisof"F" testandcriticaldifferenceat0.05 probabilitycalculated tocomparethe treatments.

2.2 Application Dosage of Fertilizer

(Recommended N: P: K dosage for Broccoli: 120:80:80 kg/ha).

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RDF of Nano Liquid formulation (NPK): 4 ml/lit.

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RDF of Nano Granular formulation(P&K): 15 - 20 Kg / acre.

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List1: **Treatment details:**

Treatment	Conventional fertilizer	Nanofertilizer	
		Foliarapplication	Soilapplication
T1	75%NPK	25%N	25%PK
T2	50%NPK	50%N	50%PK
T3	25%NPK	75%N	75%PK
T4	75%NPK	25%NPK	-
T5	50%NPK	50%NPK	-
T6	25%NPK	75%NPK	-
T7	100%NPK	-	-
T8	-	100%N	100%PK
T9	-	100%NPK	-
T10	-	-	-

3. RESULTSAND DISCUSSION

3.1Growth Attributes

The maximumplantheight(27.95)at20DAT(days after treatment) wasfound inT2andminimum(21.29cm)was found inT10(Absolute control).The maximumplantheight(55.00cm)at40DATwasfound in T2, followed byT5(54.76cm) and T1 (53.62cm) which arealso statisticallyat parvalue whilethe minimum(42.67cm)wasfound inT10.At60DAT,the highestplantheightwasfound inT2 (65.27cm), followed byT5 (64.40cm) whiletheminimum(48.67cm) was foundin T10.

ThemaximumNumberofleaves(10.8)at20DATwasfoundinT2,followed by T5(10.63)and T1(10.43)whicharealsostatistically atparvaluewhileminimumwasfoundinT10(Absolute control)whichwas7.31.ThemaximumNumber ofleaves(17.14)at40DATwasfoundinT2, followedby T5(16.11)whicharealsostatistically atparvaluewhiletheminimum(13.91)was foundinT10.At60DAT,themaximumnumber ofleaves(65.27)wasfoundinT2andthe minimum wasfoundin T10 (48.67).

Themaximumleafwidth(10.8cm)at20DATwasfoundinT2,followedby T5(10.63cm)and T1(10.43cm) which arealso statisticallyat parvaluewhile minimum(7.31cm) was found in T10.

Themaximumleafwidthat40DATwasfoundinT2(17.14cm),followed by T5(16.11cm)and theminimum(12.83cm)wasfoundinT10.ThemaximumLeafWidth(21.83)at60DATwas

foundin T2,followedbyT5(21.66cm)and the minimumleaf width (19.23cm) wasfoundinT10.

ThemaximumLeaflengthat20DATwasfoundinT2(18.16)followedby T5(18.06),and minimumleaf LengthwasfoundinT10(16.46).ThemaximumLeaflengthat40DATwasfound inT2(35.00)followedbyT5(34.81cm)andtheminimumwasfoundinT10(31.90cm).At60 DAT,themaximumleaflengthwasfoundinT2(55cm)followedby T5(52.1)andtheminimum leaf length (39.19cm)was found inT10.

TheMaximumLeafareaatharvestwasfoundinT2(725.00cm$^{2)}$andminimumleafareaatharvest (546.39 cm^2)was foundin T10 (Absolute control).

TheMinimumdaystoheadinitiation(45.42)wasfoundinT2followedbyT5(49.15days).While the maximumDaystoHeadinitiationwasfoundinT10 (59).The minimumDaystoHarvest (55.67) was found in T2.And maximum Days toHarvest (72.00) was found in T10.

Nano-fertilizerhelpsinbuildinglargercells,aswellasanincreaseinthenumberofcells,andthen an increaseinthegeneralgrowthof theplant,which isanindication of increasedvegetative growth.Inadditiontotheefficientabsorptionandpermeabilityofthenano-fertilizerintotheplant tissuesthroughthestomataholes,whoseionssizearesmallerthanthediameterofthestomataand cellwallholes.Inadditionofthefertilizerrecommendationanditseffectonproviding theplant withimportantnutrients,includingnitrogen,which isimportantinaminoacidsandproteins formation,celldivisionandelongation(Hakimetal.[9].Thepresenceofnitrogenintheavailable formleadstoearly growth,~~It~~itpromotesabsorptionofothernutrientsincluding potassiumand phosphorusandpromotestotalplantgrowth(Bloom,2015;Hemerly,2016).aswellaspotassium, whichisimportantintheformationofimportantenzymesforgrowth(Mirsaetal.[12]),andfinally phosphorous,whichisimportantintheformationofenergycompounds,thusincreasingvegetative growth.

Kanjanaetal.[13]~~has~~reportedthatnanofertilizersincreasedtheplantheightatsquareformation (45 DAS(days after sowing))andharveststage ofthecrop thannormalsourceof micronutrientsandcontrol.Also similarresultswere obtainedinthefindingsofSohairetal.[14], showedthatsignificantincrease inthe sympodialbrancheswasachievedwiththe applicationof ~~of~~ 50%RFD ofnanoNPK fertilizers. Significantincrease inthe heightof the plantandthe highestincrease ishasbeen achieved when the fertigation of the combination of nano NPK fertilizers (53.43 cm) and the traditionalfertilizer NPKof (44.33cm) comparedwiththecomparisontreatment,goodpotato productivity canbeachievedthroughtheadoptionoffertigationcombinedwithnanoN,PandK fertilizersand good irrigation management usingdrippingirrigation accordingto thestudy conductedby Hayyawietal.[15].Nofaletal.[16]foundthatplantfreshweight,leafarea,head freshweightandheadsizeoflettucesignificantlyincreasedbytheapplicationofnanoN,PandK fertilizers.Moreover,thehighestobtainedvalueswererecordedwithnanonitrogenattherateof 50%comparedtoothernanotreatmentsandNPKconventionalfertilizers(control).AbdelAziz etal. [17]found thatnanoNPKincreasedthegrowthof leavesinwheat,which wasobtainedby enhancedavailabilityofnutrientsbyeasypenetrationofnanoformulationofNPKthroughstomata of leaves viagas uptake.

Table 1. Effect of NanoFertilizer on growth traitsof Broccoli

Treatment no	Plant height (cm)	Numberof leaves per plant	Leafwidth (cm)	Leaflength (cm)	LeafArea at Harvest (cm^2)	Days for head initiation	Days for harvest
T1	62.97	26.01	21.03	52.00	700.14	45.42	55.67
T2	65.27	27.14	21.83	55.00	725.00	41.77	52.67
T3	58.80	25.59	20.70	47.45	630.98	48.44	60.67
T4	62.10	25.90	20.86	50.33	634.82	48.33	60.00
T5	64.40	26.11	21.66	52.10	702.00	43.75	53.00
T6	54.26	25.48	20.5	47.44	621.53	48.77	62.00
T7	53.91	25.33	20.26	46.17	600.01	49.15	62.33
T8	53.73	24.77	20.23	43.96	593.25	51.1	62.67
T9	50.53	24.63	19.26	43.35	560.28	52.33	63.00
T10	48.67	24.27	19.23	39.19	546.39	55	65.00
F-Test	S	S	S	S	S	S	S
S.Ed.	1.97	0.47	1.58	1.58	0.31	4.59	1.90
C.D. at 0.5	4.10	0.98	3.28	3.28	2.08	3.13	3.95
CV	5.06	2.72	4.88	4.88	4.78	4.59	4.70

Table 2. Effect of Nanofertilizer onyield and qualitytraitsof Broccoli

Treatment no	Yield traits				Qualitytraits	
	Head Diameter (cm)	Head weight (gm)	Head yield per plot(Kg)	Head yield tones/ha	TSS(0Brix)	Vitamin–C Content (mg/100gm)
T1	20.33	430.22	2.58	15.84	9.26	97.66
T2	21.16	461.47	2.77	16.95	9.76	102.66
T3	19.13	400.44	2.40	14.71	8.63	92.28
T4	19.9	421.98	2.53	15.5	8.84	92.51
T5	21.03	453.51	2.72	16.66	9.47	101.5
T6	18.56	392.99	2.36	14.45	8.06	86.44
T7	18.16	373.51	2.24	13.72	7.95	86.12
T8	17.6	350.24	2.10	12.81	7.82	78.68
T9	15.66	320.12	1.92	11.75	7.63	78.36
T10	14.16	210.55	1.26	7.68	7.6	76.04
F-Test	S	S	S	S	S	S
S.Ed.	0.44	8.07	0.04	0.29	0.29	1.72
C.D. at 0.5	0.91	16.74	0.10	0.62	0.60	3.57
CV	3.50	3.11	3.11	3.14	5.05	2.83

3.2 YieldAttributes

statically atparvalue and minimumheaddiameterwasfoundinT10(14.16).Themaximumhead weight(461.47gm)wasfoundinT2followedby T5(453.51)whichisstatically atpar valueand minimum head weight was found in T10 (210.55).

ThemaximumHeadYieldperplot(2.77kg)wasfoundinT2followedbyT5(2.72)andminimum Head yieldperplotwasfoundinT10(1.26kg)respectively.ThemaximumHeadYieldperhectare wasfoundinT2(16.95t)followedbyT5(16.6t),andminimumHeadyieldperhectarewasfound in T10(7.68 t).

Nanofertilizershavehighertransportanddeliveryofnutrientsthroughplasmodesmata,whichare nanosized(50–60nm)channelsbetweencells.ThehigherNUE(nutrient-use efficiency) andsignificantly lessernutrient lossesofnanofertilizersleadtohigherproductivity(6–17%)andnutritionalquality ofvegetable crops.Theadequate amountsof nitrogenenhance photosynthesis,celldivisionandcell enlargement.The h~~H~~igher the leafarea the higher willbe the photosyntheticsurface,higher the photosynthesis surfaceandhigherwillbethe photosyntheticaccumulationhenceresulting in higheryield(Shashidharaetal.)[18].The maximumdiameter,maximumleaf lengthand maximumleaf areaof the cultivar and the translocation ofthe photosynthesis products to the fruit (sink)whichishead(Singhetal.,[19].).Aswellaspotassium,whichisimportantintheformation ofimportantenzymesfor growth,andfinallyphosphorous,whichisimportantintheformationof energy compounds,thusincreasingrootsformationandincreasingvegetativegrowth.Thus,it reflects positivelyonyield.

AbdEl-Azeimetal.[20]observedthesuperiorityofyieldparametersfollowingfoliarapplication ofnanofertilizersattributedtoincreasedavailabilityofnutrientsbyfoliarapplicationduetoquick absorptionofNPKnano fertilizersbystomataltissues.Also,nutrientsuptakemayhaveincreased asaresultofincreasedphotosynthesisrate,freshanddry weightsofpotatoandconsequently improvedoverallgrowthparametersofpotatoplants.Mishraetal.[21]observed~~on~~in~~an~~experiments carriedintomatousingnanofertilizer,that the interactionbetweennanoparticle and fertilization ~~achieved~~resulted inincreasedconcentrationsof nitrogenandphosphorouselementsinthe fruits. ~~,~~tTherefore, thisreflectedpositively ontheincreaseingrowthandyield,andtheimprovementofoverall production andquality.InstudyconductedbyHelalyetal.[22]itwasfoundthatthehighrateofnanonitrogen (50%)significantlyincreasedthevegetativegrowthexpressedasplantfreshweight,leafareahead fresh weight, head size, firmness, totalyield andmarketableyield.

3.3 Quality Attribute

ThemaximumTSSBrix(9.76)wasfoundinT2followedby T5(9.47)andminimumTSSBrix wasfoundinT10(Absolutecontrol)whichwas7.6.ThemaximumVitaminCContent(mg/100g) wasfoundinT2(102.66)followedby T5(101.5)andminimumVitaminCContent(mg/100g) was found in T10(76.04)

TSSIncreaseddue toincreasedchlorophyllandphotosynthesis.Likewise,increasingfirmness couldbe associatedtosuperior accumulationof someosmolesandincrease potassium concentrationsincells.Abdeletal. [23]observedthepositiveeffectofnanofertilizersNPKon chemicalcompositionofplantyieldsuchastotalsolublesolids(T.S.S),dry matter,may be attributedtothepresenceofmacronutrientssuggesting thatnano-engineeredN,P,Kfertilizers appearedtoenhancetheuptakeanduseefficiencyofnutrientsbyplants.Nanofertilizershasa

mainroleinsugarsaccumulateinfruittissues leadingtoincreaseTSS. Theresultobservedin experimentcarriedoutbyAmanetal.[24]revealedthatspraytreatmentwithaconcentrationof 1.5mlL^{-1}nanoNPKwassuperiorinincreasingthechlorophyllcontent,TSS.Increasedpotassium fertilizationmarkedlyincreasedVitaminCcontent(Nagy [25]).AbdelAzizetal.observedthe positive effect of nanofertilizers NPK on chemical composition oflettuceplants such as ascorbic acid,sugars,phosphorusandpotassiumcontentmay beattributedto thepresenceofmacro nutrientssuggesting thatnano-engineeredN,P,Kfertilizersappearedtoenhancetheuptakeand use efficiencyof nutrients byplants.

Thestudy revealedthatamongthe10treatmentcombinations,T2~~was~~gave betteryield~~ingbetter~~.Thismight be due tothefactthattheconventionalfertilizersupplieddur ing basaldose fertilizer requirement supplied at early stageofthebroccoliplantdevelopment contributedtothevigorgrowthoftheplantinitially andtherequirementof thenutrientsat later stages ~~requirementof thenutrientswas~~were metwiththeapplicationof nano fertilizers. Withits highnutrient useefficiencynanofertilizerwasabletoenhancethegrowthat the laterstages ~~growth~~oftheplantdevelopment effectively.The nanostructuredformulationwithnanoNparticle havingsizevarying from20-50nmcaneasily penetrateintothestomatalporesandaugmentthenutrientabsorptionandstoredinplasmodesmata. Also,withthe soilapplicationofnanoP&Kfertilizerthenutrientsarereleasedintothesoilina controlledandgradualmanner,whichenhancebetternutrientsupplytotheplant,alsothemicrobial populationandenzymeactivityinthesoilmighthaveincreasedduetothe~~less~~reduced impactofthenano fertilizers to the soil.

4. CONCLUSION

Basedontheresultsof experiment,itcanbe concludedthatT2-Soilapplicationof 50%RDFas Traditionalfertilizer + 50% recommendeddoseof NanoNasfoliarapplication, P&Kassoil application was recordedthe best amongallcombinations of Traditional fertilizer NPK and Nano NPK in terms ofgrowth,yield attributeandqualityparameters

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