Original Research Article

ImprovingProductionandQualityofStrawberry(*Fragaria*×*ananassa*Duch.)Cv.ChandlerwithPlantGrowth Regulators:AStudyinNorthern Punjab.

ABSTRACT

The use of plant growth regulators was researched to improve strawberry production and fruit Inthisstudy,weinvestigatedtheuseofplantgrowthregulatorstoimprovestrawberryproductionandfruit qualityinthecooler,northernPunjab regions,knownfortheirsuperioroutputandfruitquality by conducting randomizedblockexperimentusingstrawberry"Chandler", (*Fragaria*×*Ananassa*Duch.)Cv.Chandleruniformrunnerscultivatedinopenfieldswithpaddystrawmulch.After30and60daysofplanting,wefoliarsprayedtheplantswithNAA(60,90,120,and150mgl^{-1})andGA$_3$(60,90,120,and150mgl^{-1}). The experiment recordedplantgrowthcharacteristics,suchasnumberofleaves,stems,leafarea,petiolelength,andrunners,attheirhighestlevelswiththe applicationof120mgl^{-1}GA$_3$.Similarly,we foundtheoptimalnumberofstrawberriesproducedintermsofflowers,fruits,weight,marketability,andoverallfruityieldwiththesameapplication.Ontheotherhand,theapplicationof150mgl^{-1}NAAproducedstrawberrieswiththehighesttotalsolublesolids,ascorbicacid,reducingsugar,non-reducingsugar,andtotalsugarcontents.Nonetheless,wedidnotobserveanysignificanteffectoftheplantgrowthregulatortreatmentsonthenumberofdaysrequiredfor50.0%blooming,thefirmnessofthefruit,ortheaciditylevelofstrawberryfruits.Ourfindingsprovidealow-costproductionsystemthatcanimprovetheyieldandqualityofstrawberries,potentiallycontributingtopovertyalleviationamongfarmersinthe region.

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Keywords: Foliarspraying,fruitquality,Plantplantgrowthregulators,Povertypovertyalleviation.

INTRODUCTION

Strawberry,(*FragariaXananassa*Duch),Cv."Chandler",amemberoftheRosaceaefamily,isasignificant fruitcropthatispopularininternationalmarketsforitsattractiveredcolor,deliciousaroma,andhigh nutritionalcontent,includingvitamins(AandC),andminerals(FeandK).AccordingtotheNationalCenter forHomeFoodPreservation,strawberriesareoneofthe fruitsthatcontainenoughnaturalpectintomake agoodjellywithoutaddinganyadditionalpectin.Furthermore,theconsumptionofstrawberrieshasbeen linkedtothepreventionofvariousmalignanciesandheart-relateddiseases,aswellasreducing inflammationanddiseasesassociatedwithobesity(Arfin*etal*.,2016).Thedemandfor strawberriesinthe marketisgraduallyrising,promptinggrowerstocultivatethiscroptoincreasetheir income.

Strawberriescanbegrowneffectivelyinbothtemperateandsubtropicalclimatesinopenconditions, aswellasinprotectedenvironments(Kafkas, 2017).InIndia,mostofthestrawberry-growingregionsare devotedtothisfruitcrop,primarilybypoorormarginalfarmersinopenfieldsusingpaddystrawmulching. However,theproductivityofstrawberriesinthisregiondoesnotmatchthatfoundinotherpartsofthe nation.Therefore,thereisaneedforatechnicallyinnovative,cost-effective,andlong-lastingsolutionfor strawberrycultivation.Strawberriesgrowninopenfieldsrequireadditionalattentionandsensible managementtechniquestoachieveexcellentyields.Plantgrowthregulatorshavebeenfoundtohave immediatestimulatoryeffectsonplantresponses,includinggrowth,blooming,andfruiting.Strawberry plantrespondsfavorablytotheapplicationofgrowthregulators.Amongplantgrowthregulators, gibberellins(GA_3) andNaphthaleneaceticacid(NAA) haveundergoneextensive testingduetotheir low-costviabilityforapplicationinthepresentagriculturalsysteminseveralfruits(Bisht*etal.*,2018).The currentstudyaimedtoinvestigatetheeffectsofNAAandGA$_3$onstrawberrygrowth,yield,andqualityin the Punjabregion.

MATERIALSANDMETHODOLOGY

~~Thepresent~~This studywas~~conducted~~carried outduringthe2022growingseasonatLovelyProfessionalUniversity (LPU),Punjab,India,toinvestigatethe effectsofplantgrowthregulatorsonthe growth,yield,andquality ofstrawberry, ~~(~~*FragariaXananassa*Duch~~)~~Cv.Chandler.Theexperimentalsite hadasandyloamsoilwith apHof6.7.Beforeplanting,arecommendedamountoffarmyardmanure(15th^{-1})andchemicalfertilizers, includingurea,singlesuper phosphate (SSP),andmuriateofpotash(MOP) attheratesof 110,90,and90 kgha^{-1},respectively,wereapplied.Healthyanduniformrunnerplantletsfreeofpestsanddiseaseswere transplantedataspacingof2ftx1ft.Theplantgrowthregulators,Naphthaleneaceticacid(NAA)and gibberellins(GA_3),wereappliedtotheleavesofthe plantsataconcentrationof60,90,120,and150mgl^{-1},respectively,30and60daysafterplanting.Theexperimentaldesignwasarandomizedcompleteblock design(RCBD)withthreereplicationsofeachoftheninetreatments:T_1=60mgl^{-1}NAA,T_2=90mgl^{-1} NAA,T_3=120mgl^{-1}NAA, T_4=150mgl^{-1}NAA,T_5= 60mgl^{-1}GA_3,T_6=90mgl^{-1}GA_3, T_7=120mgl^{-1} GA_3,T_8=150mg^{-1}GA_3,andT_9=Nospray as~~(~~control~~)~~.Sixplantsfromeachtreatmentweretaggedand monitoredforgrowthanddevelopment.Leafareawasmeasuredusingaleafareameter(BiovisPSM-L2000)andexpressedincm^2.Tenberrieswererandomlyselectedfromeachtreatmentformeasurementof theirphysicochemicalcharacteristics,includingtotalsolublesolid(TSS)content,fruitfirmness,titratable acidity,sugarcontent,andascorbicacidlevels.Fruitsweighinglessthan15g,misshapen,ordiseasedwere consideredunmarketable.Thedatawereanalyzedusinganalysisofvariance(ANOVA),andsignificant differencesamongtreatmentswerecomparedusingtheLeastSignificantDifference(LSD)testat$p \leq 0.05$.

RESULTSANDDISCUSSION

1.Effectongrowthandfloweringofstrawberryplant

Theimpactoffoliarsprayingofplantgrowthregulatorsonthedevelopmentofstrawberryplantswas investigatedandanalyzed.Resultsshowedthatfoliarsprayingof120mgl^{-1}GA_3hadasignificanteffect onplantspread(28.72cm),leaflamina(122.25cm^2),petiolelength(11.80cm),aswellasontheproduction of strawberry runners (4.43), crowns (3.03),andleaves (29.33)(Table1). Thestudy foundthatexogenous administrationof plantgrowth regulatorsdidnotaffectthetimeittookfor strawberryplants toreach50% flowering.However,strawberryplantstreatedwith120mgl^{-1}GA_3showedtheearliestfloweringand producedsignificantlymoreflowersthancontrolplants(Table1).Theresultssuggestthatfoliarspraying of120mgl^{-1}GA_3isaneffective methodforenhancingthegrowthandyieldofstrawberryplants.

AccordingtoBishtetal.(2018),gibberellinshavetheabilitytostimulatecelldivisionandexpansion inepidermalandparenchymacells,particularlyinthemeristematictissueofleafprimordialinplantstreated withGA_3.Thisstimulationmayresultinagreaternumberofleaveswithbroaderleaflamina andpetioles oflongerlength.TheauthorsalsonotethathigherconcentrationsofGA$_3$canincreasetheseeffectseven further.PreviousresearchhasindicatedthatexogenousapplicationofGA$_3$ canleadtoahighernumberof leaveswithlargeleavesandpetiolesinstrawberries(MassetaniandNeri,2016).However,thestudyalso found thatvery high concentrationsof GA$_3$ can resultin slightly stunted growth instrawberry plants. This inhibitoryactionofGA$_3$athighconcentrationsinplantsisconsistentwiththefindingsofHeddenand Sponsel(2015).Thetrifoliateleavesofstrawberryarearrangedinarosetteatcrowns,andthelengthofthe petioledeterminestherelativeplantspread(MassetaniandNeri,2016).Vishal*etal*.(2016)investigated theeffectsofgibberellicacid(GA$_3$)onthegrowthanddevelopmentofstrawberryplants,specificallythe Sujathacultivar.TheresultsoftheirstudyshowedthatGA$_3$applicationledtoincreasedplantgrowth, numberofleaves,andcrownandrunnerformation,whichisconsistentwiththefindingsoftheprevious studies.ThestudyalsosuggestedthattheincreasednumberofleavesinGA$_3$-treatedplantsfacilitatedthe synthesisofmorephotosynthates,whichledtotheformationofagreaternumberofcrownsandrunners. Thisisimportantforstrawberryproductionasmorecrownsandrunners leadtoahigheryieldoffruits.

Table1.Effectofplantgrowthregulators(PGRs)onthegrowthandfloweringofstrawberry, (*Fragaria*× *ananassa*Duch.).Cvchandler.

Treatments	PlantSpread(cm)	Leaves Plant^{-1}	Leaf Area(cm^2)	Length ofPetiole(cm)	Crowns Plant^{-1}	Runners plant^{-1}	DaysTakento50% flowering	Flowers plant^{-1}
T_1	22.21	20.87	105.88	9.03	2.17	3.17	47.67	27.30
T_2	22.52	22.67	106.58	9.81	2.37	3.30	44.67	27.36
T_3	25.28	23.53	108.59	10.77	2.43	4.03	44.00	28.10
T_4	25.56	24.87	109.67	11.30	2.77	4.30	43.67	29.50
T_5	21.92	21.53	108.20	9.43	2.23	2.83	45.67	27.50
T_6	24.04	25.67	110.69	10.74	2.50	3.90	43.33	29.03
T_7	28.72	29.33	123.25	11.80	3.03	4.43	43.00	31.23
T_8	26.64	27.33	117.54	11.60	2.90	4.17	43.67	31.00
T_9	20.15	20.67	102.45	8.80	2.10	3.17	48.67	27.23
LSD$p\leq0.05$	3.99	5.23	11.68	1.39	0.53	0.78	NS	2.55

2.Effectonfruitingand yield ofstrawberry

Theeffectsofvariousplantgrowthregulator(PGR)treatmentsonthefruitingprocessofstrawberryplants (Table2).Amongthetreatments,foliarsprayingofGA$_3$ataconcentrationof120mgl^{-1}resultedinthe highestfruitproduction,weight(16.07g),andlength(4.88cm).Thesametreatmentalsoproducedthe maximumnumberoffruits(19.17)andmarketablefruits(16.70or86.90%perplant),aswellasthehighest totalmarketablefruityield(268.36gplant-1)andtotalfruityield(308.06gplant-1).Incontrast,thecontrol plantsexhibitedthelowestnumberof totalandmarketable fruitsandyield[Fig1(a)and(b)].GA$_3$playsaregulatoryroleinthemobilizationofmetabolitesfromfoliagetodevelopingfruits.Kumar*etal*.(2014)reportedthathighconcentrationsofGA$_3$canleadtofasterinitiationofflowering,whichcanbebeneficialforcropproduction.TheevidencealsosuggeststhatGA$_3$canhelpimprovefruitqualityinstrawberries,asitcanresultinahighernumber offlowers,fruits,andyield(Saima*etal*.,2014;Rajbhar*etal.*,2015).Thesefindingsareconsistentwithpreviousresearchthathasdemonstratedthe positiveeffectsofGA$_3$onplantgrowthanddevelopment.Overall,theapplicationofGA$_3$canbeaneffectivetoolforimprovingcropyieldandqualityinstrawberries.However,theoptimaldosageandapplicationtimingmayvarydependingontheplantspeciesandgrowingconditions.

Table2:Effectofplantgrowthregulators(PGRs)onthefruitingofstrawberry(*Fragaria×ananassa* Duch.)Cvchandler.

Treatments	Fruit weight (g)	Fruit length(cm)	Marketable fruitsplant^{-1}	Non-marketable Fruits Plant^{-1}	Totalf ruitsPlant^{-1}	Marketable Fruits(%)
T_1	12.88	4.49	13.39	4.00	16.77	79.00(63.00)
T_2	13.07	4.50	14.03	3.60	17.03	81.85(64.89)
T_3	13.59	4.62	15.30	3.00	17.70	86.13(68.15)
T_4	14.20	4.80	15.83	3.25	18.50	85.27(66.50)
T_5	12.20	4.34	13.90	3.60	16.90	81.80(65.05)
T_6	13.46	4.55	14.90	3.35	17.77	83.20(66.13)
T_7	16.07	4.88	16.70	3.10	19.17	86.90(68.99)
T_8	15.18	4.86	15.70	3.65	18.83	82.00(65.80)
T_9	12.14	4.18	13.03	4.20	16.70	78.12(61.87)
LSD $p \leq 0.05$	1.59	0.37	1.66	0.76	1.65	3.34

3.Effect onfruit qualityof strawberry

Theimpactoffoliarsprayingofplantgrowthregulatorsonthefirmnessandacidityofstrawberryfruits wasinsignificant.Nonetheless,themostnutritiousfruitswereproducedbythe plantstreatedwith150mg l^{-1}NAA,asevidencedbytheirhighestTSSandsugarcontent.Incontrast,thefruitfromtheunsprayed plantshadthelowestTSSandsugarlevels.Furthermore,plantstreatedwith150mgl^{-1}NAAproduced fruitswiththehighestascorbicacid~~(VitaminC)~~ content(Table3).

TheapplicationofGA$_3$cansignificantlyincreaseTSSandreducetitratableacidityinfruits. ExogenousapplicationofGA$_3$increasedthenumberofmarketablefruitsandfruityieldinstrawberries. Rathod*etal*.(2021) alsoreportedthatthe applicationofGA$_3$increasedthefruityieldinstrawberryplants. IthasbeensuggestedthatthepositiveeffectsofGA$_3$onfruityieldarerelatedtoitsabilitytoregulateauxin metabolism,whichcanindirectlyimpactfruitgrowthanddevelopment.Thakur*etal*.(2015)founda significantincreaseinTSSwiththesprayofGA$_3$.Rajbhar*etal*.(2015)alsofoundthatGA$_3$resultedin moreTSS(10.68ºBrix)instrawberryvar.Douglas.Additionally,theevidencesuggeststhatGA$_3$canalso impactotherfruitqualityparameters,suchasfruitlength,diameter,andweight..NAAapplicationin strawberryplantsmayhaveincreasedtheconcentrationofvolatilecompoundsandthehydrolysisofstarchy compounds,leadingtoanincreaseinTSSlevels.Palei*etal*.(2016) alsoobserveda similareffectonTSS when 50 ppmNAA wasadded tostrawberry fruits.Morethan60%oftheTSScontentismadeupoftotal sugars,andtheincreasedtotalandnon-reducingsugarcontentofstrawberryfruitsmaybeattributedto greaterenzymaticactivity,suchas-amylaseandinvertase,aftertheuseofNAA.NAAmaystimulatethe productionofprecursormetabolitesthatactivateascorbicacidproductioninplants,resultinginhigher ascorbicacidcontentinstrawberryfruits.Singh*etal.*(2017)reportedthattheapplicationof200ppmNAA (naphthaleneaceticacid)resulted in asimilar increaseinascorbicacidcontentin guava.

Table3:Effectofplantgrowthregulators(PGRs)onphysicochemicalpropertiesofstrawberry (*Fragaria*×*ananassa*duch).Cvchandler.

Treatments	FruitFirmness ($Kg cm^{-2}$)	TSS (Brix)	Acidity (%)	Abscorbic Acid (Mg 100 g^{-1})	Reducing Sugar (%)	Non-reducingsugar (%)	Total Sugar (%)
T_1	0.85	8.32	0.82	80.35	4.82	4.16	8.98
T_2	0.89	8.57	0.80	87.45	4.84	4.18	9.20
T_3	0.95	8.88	0.78	94.55	4.48	4.38	9.23
T_4	1.01	9.23	0.76	101.65	4.86	4.58	9.74
T_5	0.84	7.80	0.74	80.35	4.58	3.69	8.26
T_6	0.84	8.65	0.72	84.85	4.65	3.92	8.56
T_7	0.87	9.07	0.70	89.35	4.75	4.09	8.83
T_8	0.88	9.17	0.68	93.85	4.71	4.10	8.71
T_9	0.83	7.57	0.80	75.50	4.47	3.64	8.11
LSD$p \leq 0.05$	0.16	1.07	0.10	6.36	0.34	0.33	0.44

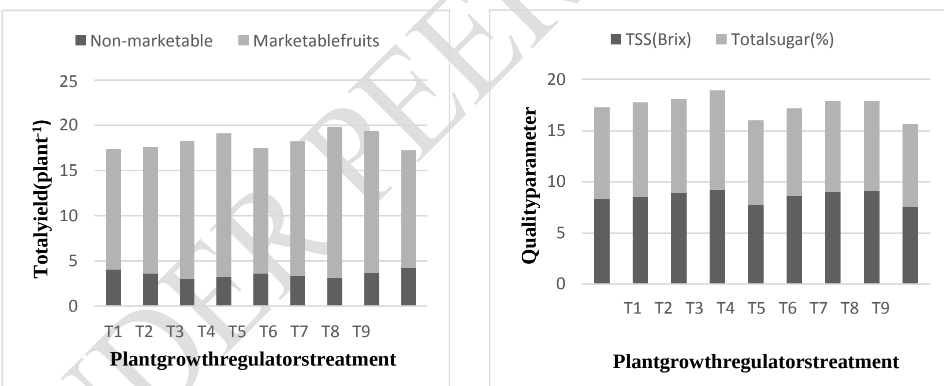

Fig:1Effectofplant growthregulatorsontotalyieldofplant.

CONCLUSION

Thefindingsofthisstudyarehighlysignificantinthepresenterawherethedemandforstrawberriesis increasingrapidly.Byutilizingthegoodcharacteristicsofmarket-availableplantgrowthregulatorsthatare relativelylessexpensive,thisstudyaimedtoincreasestrawberryoutput.Theresultsdemonstratethatthe applicationoffoliarspraysof120mgl^{-1}GA$_3$and150mgl^{-1}NAAatspecificgrowthstagescansignificantly enhancetheyieldandqualityofstrawberries.Thesefindingshaveenormouspotentialtocontributeto povertyalleviationamongfarmersbyboostingtheircropyieldandquality,leadingtohigherpricesand improvedlivelihoods.Futureresearchshouldfocusonoptimizingtheconcentrationandtimingofplant growthregulatorsforstrawberrycultivationindifferentregionstoensureconsistentandsustainableyields. ~~Thepresent~~This studyprovidesapromisingfoundationforthedevelopmentofnewstrategiestoincrease strawberryproductionandenhancefarmers'incomeintheyearstocomeandprovidealow-costproduction systemthatcanimprovetheyieldandqualityofstrawberries,potentiallycontributingtopovertyalleviation amongfarmersinthe region.

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